International Transport Forum

Zero Road Deaths and Serious Injuries

Leading a Paradigm Shift to a Safe System

Research Report

OECD

The International Transport Forum

The International Transport Forum is an intergovernmental organisation with 57 member countries. It acts as a think tank for transport policy and organises the Annual Summit of transport ministers. ITF is the only global body that covers all transport modes. The ITF is politically autonomous and administratively integrated with the OECD.

The ITF works for transport policies that improve peoples' lives. Our mission is to foster a deeper understanding of the role of transport in economic growth, environmental sustainability and social inclusion and to raise the public profile of transport policy.

The ITF organises global dialogue for better transport. We act as a platform for discussion and pre-negotiation of policy issues across all transport modes. We analyse trends, share knowledge and promote exchange among transport decision-makers and civil society. The ITF's Annual Summit is the world's largest gathering of transport ministers and the leading global platform for dialogue on transport policy.

The Members of the ITF are: Albania, Armenia, Argentina, Australia, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Canada, Chile, China (People's Republic of), Croatia, Czech Republic, Denmark, Estonia, Finland, France, Former Yugoslav Republic of Macedonia, Georgia, Germany, Greece, Hungary, Iceland, India, Ireland, Israel, Italy, Japan, Korea, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Mexico, Republic of Moldova, Montenegro, Morocco, the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Serbia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, the United Kingdom and the United States.

International Transport Forum
2, rue André Pascal
F-75775 Paris Cedex 16
contact@itf-oecd.org
www.itf-oecd.org

ITF Research Reports

Cite this publication as: ITF (2016), Zero Road Deaths and Serious Injuries: Leading a Paradigm Shift to a Safe System, OECD Publishing, Paris.

Foreword

The concept of a Safe System, in the context of road safety, originated in Sweden and the Netherlands in the 1980s and 1990s. At the time, scientists and policy makers began to question the prevailing view that the safety of road users was, in the last instance, their own responsibility and that the task of road safety policy was thus primarily to influence road users' behaviour so they would act safely at all times. Yet as the decades-long decreases in the number of road fatalities and severe injuries were levelling out, it became clear a predominant focus on education, information, regulation and enforcement was no longer delivering progress. A rethink was needed.

It was then that experts began to explore the notion of traffic as a Safe System. The approach to conceive complex systems in a way that takes into account the failings of humans had long been applied elsewhere, notably in occupational safety. For road transport, however, it was novel and even revolutionary, for it requires a fundamental change in mind-set. Adopting a Safe System starts with accepting the validity of a simple ethical imperative: No human being should be killed or seriously injured as the result of a road crash. Once this imperative is accepted, it is logically inescapable that a traffic system should be designed and used to this end – a notion that has been conceptualised in a number of countries and cities in bold policy frameworks under banners such as “Vision Zero” or “Towards Zero”.

This is a true paradigm shift, because it requires more than a mere political or administrative decision to simply switch to a Safe System. Building a Safe System is a holistic, long-term exercise which takes those who embark on it on a true journey, as the experience of pioneering countries and cities reviewed in this report shows. It requires mobilising broad support because a Safe System is based on shared responsibility for road safety performance. Not just road users, all involved in planning, building, maintaining, managing or using road traffic need to endorse a responsibility for road safety performance, and act on it.

The concept of a Safe System emerged in countries that have been most successful in reducing road trauma in past years and decades but now see progress is becoming more and more difficult to achieve. Yet it is highly relevant too for low- and middle-income countries and fast-growing cities that see increased numbers of road deaths and injuries in the wake of rapid motorisation. Among all public health issues, road trauma is unique in that strong economic growth correlates not with *less* public health issues but, often enough, with *more*. Safe System thinking offers countries and cities that face a road death and serious injury epidemic an opportunity to take a bold step forward by learning from the experience of pioneer countries.

These are the themes that are explored in depth in this report. It is written for political leaders, leaders of companies and public agencies, policy makers and academics in a position to influence change in a local, regional or national government, corporate or societal setting. Strong and sustained leadership to initiate and see through the shift to a Safe System is vital. Nothing will change without it. This report aims to provide these leaders with a starting point to chart their own journeys towards a Safe System armed with the theoretical background, practical tools, experiences and empirical evidence set out here, and to enable them to build on the ideas and actions pioneered by some countries to overcome challenges and address barriers on the way.

The report was prepared by a Working Group of more than 30 road safety experts representing 24 countries and organisations convened by the International Transport Forum (ITF) between September 2014 and August 2016. Building on the influential 2008 ITF report *Towards Zero: Ambitious Road Safety Targets and the Safe System Approach*, the Working Group drew upon the available published evidence and in particular material from the pioneering countries. While some evidence of the effectiveness of particular interventions exists and more is emerging, the evidence is still limited at the macro level, and the Working Group has endeavoured in particular to draw together the experiences of pioneering countries on this level to share in this report.

Better ways to protect lives and prevent injuries exist in a Safe System. The time to act boldly is now. Visionary, strong and sustained leadership is vital.

Table of contents

Figures

Tables

Executive summary

Background

Around 1.25 million people are killed on the world's roads every year, according to the World Health Organization. Between 20 and 50 million people are seriously injured. Traffic deaths and injuries have devastating effects on families everywhere. They cause enormous economic losses, estimated at around 2-5% of the Gross Domestic Product of countries. Clearly, such levels of road deaths and serious injuries are unacceptable both in terms of human suffering as well as societal and economic costs and not sustainable.

The United Nations, in their Sustainable Development Goals (SDGs), have set the target of reducing global road fatalities and serious injuries by 50% by 2020, compared to 2010 levels. Yet rapid motorisation in many low- and middle income countries points to the risk of further increases in the number of road fatalities and serious injuries in the coming years. Traffic in fast-growing cities in particular is becoming a major challenge. In countries with leading road safety improvement results, performance is plateauing or stalling.

The experience of countries achieving the lowest levels of death and injury provides useful lessons. A common feature of several well-performing countries – despite differences in terminology and operationalisation – is that they have adopted a long-term policy goal that no-one should be killed or seriously injured in a crash on their roads. This report shares the experience of countries who have introduced some form of "Vision Zero" (as it is commonly called in Sweden, one of the pioneers) with a view to providing a framework for the implementation of integrated road safety policies with the potential to bring road safety performance closer to the ultimate aspiration.

Findings

Drastically reducing road fatalities and serious injuries on a global scale will need more than increasing efforts in implementing traditional road safety measures. The UNs SDGs provide an opportunity for governments to fundamentally review their road safety policies and explore new approaches that deliver significantly better results.

Real progress will necessitate a fundamental paradigm shift in the way the road safety problem is viewed, as well as in the strategies used to address it. This paradigm shift involves a move from traditional road safety policies to an integrated view in which road traffic becomes a "Safe System" where serious outcomes from crashes are prevented in the first place.

Data from some pioneering countries shows that about 30% of serious crashes are caused by deliberate violations and risk-taking behaviour, while the majority result from simple errors of perception or judgement by otherwise compliant persons. An approach to road safety assuming that humans can be faultless road users throughout their lives is flawed. Significantly, it is also at odds with the safety approach taken in aviation, shipping, rail transport or occupational health in general, where safe behaviour is encouraged and guided through system design and builds changes that provide protection for the humans involved even where they err.

A Safe System is holistic and proactive in essence, managed so the elements of the road transport system combine and interact to guide users to act safely to prevent crashes and, when they occur, ensure that impact forces do not exceed the physical limits of the human body and result in serious injury or death. A Safe System moves beyond reactive approaches based on analysis of past crashes. Instead, it takes a proactive approach to guide safe behaviour while also assessing the risks inherent in a road network and identifying priority interventions that prevent serious trauma when crashes invariably occur. Most of all, a Safe System does not accept trade-offs between human lives and other priorities.

Four guiding principles are central to a Safe System: First, people make mistakes that can lead to road crashes. Second, the human body has a known, limited physical ability to tolerate crash forces before harm occurs. Third, while individuals have a responsibility to act with care and within traffic laws, a shared responsibility exists with those who design, build, manage and use roads and vehicles to prevent crashes resulting in serious injury or death and to provide post-crash care. Fourth, all parts of the system must be strengthened in combination to multiply their effects, and road users are still protected if one part fails.

A Safe System requires understanding and managing the complex and dynamic interaction between operating speeds, vehicles, road infrastructure and road user behaviour, in a holistic and integrated way, so that the sum of the individual parts of the system combine for a greater overall effect and if one part fails the other parts will still prevent serious harm from occurring.

There is no single pathway for the adoption, establishment and implementation of a Safe System. Moving to a Safe System is a learning-by-doing process best described as a journey which presents opportunities, hazards and challenges along the way. The experiences of the pioneering countries show that each follows its own journey, shaped by the cultural, temporal and local context, but guided by the four underlying principles.

Recommendations

Think safe roads, not safer roads

The conventional approach to road safety identifies next steps based on incremental improvement on current practice. A Safe System flips this approach on its head. By working backwards from the vision of eliminating road fatalities and serious injuries, a Safe System opens up new perspectives with respect to effective instruments that reduce the number of road crashes resulting in serious trauma.

Provide strong, sustained leadership for the paradigm shift to a Safe System

Nothing will change in road safety without strong and visionary leaders. On a political level, guiding a country or city through a paradigmatic policy shift requires building political and public support for the vision of zero road deaths and serious injuries. Leadership will also have to be sustained and focused on carrying the transformation across election cycles by ensuring a sound vision, adequate structures, strategic plans and effective processes are in place. On a stakeholder level, committed sectoral leaders and chief executives of companies and agencies are essential to create support for a Safe System within their purview by aligning their practices with a Safe System road safety environment.

Foster a sense of urgency to drive change

For a successful transition to a new paradigm in road safety it is critical for leaders to build a sense of urgency among stakeholders. In those countries that have adopted a Safe System, innovation occurred where political leaders strongly felt that the approach of the day could no longer deliver sufficient progress in reducing road deaths. Catalysts for such a perception of urgency that galvanised policy making and also public opinion have included political will, high-visibility traffic incidents, unfavourable ranking results or the failure to achieve existing road safety targets. Political leaders are advised to ensure this urgency permeates, and is sustained in, the responsible agencies.

Underpin aspirational goals with concrete operational targets

To counter criticism of a strategic vision like “zero road fatalities” as being unrealistic, it must be supported by concrete operational targets. These serve as milestone markers while managing the journey to a Safe System. The short-term targets must be backed by a package of interventions based on evidence for the results they can be expected to produce. Such detailed ex-ante assessment is successfully employed in Safe System pioneer countries and builds confidence when evidence of progress based on targets is reported publicly.

Establish shared responsibility for road safety

A Safe System requires individual road users and stakeholders to recognise their role and responsibility in making traffic safe. Road injury prevention involves different government departments and agencies interacting with civil society and the private sector. The organisational complexity involved is a challenge in itself and can lead to fragmentation. Based on the good governance principles of accountability, transparency, and inclusiveness, shared responsibility is the basis for integrated policies and complementary actions.

Apply a results-focussed way of working among road safety stakeholders

Effective road safety governance is an essential component of a successful Safe System policy. The management structure must fully support the achievement of results through implementation of Safe System interventions. It is important to find a way of working that supports the development of responsibility among stakeholders and contributes to road safety outcomes as an overarching process in society.

Leverage all parts of a Safe System for greater overall effect and so that if one part fails the other parts will still prevent serious harm

A Safe System deals with inherent risks and errors, but still guides and expects people to act responsibly and to comply with safety-related traffic rules. However, it is unrealistic to expect that a focus on education and enforcement of behavioural rules will achieve the needed step-change in improving road safety. Even compliant road users well versed in the rules make mistakes that lead to crashes. A Safe System seeks to create an environment that, above all, guides and encourages the user to act safely but recognises that human errors will occur. A Safe System holistically integrates the management of speed, vehicles and road and roadside infrastructure so that when a crash occurs, it provides protection to ensure impact forces do not cause serious harm. For a Safe System, all elements of the system must be strengthened to multiply the effect and ensure that even if one element fails, the other elements will provide sufficient protection. Post-crash care (prompt first aid, ambulatory response and emergency medical care) is also vital. An effective Safe System response includes initiatives designed to have immediate large-scale impact (e.g. speed limit changes, enhanced enforcement, education campaigns) together with measures that will bring sustained results over the medium to long term (e.g. stricter vehicle standards, safe system road and roadside infrastructure investments).

Use a Safe System to make city traffic safe for vulnerable road users

Growing cities with more inhabitants and more vehicles mean more people are at risk of becoming victims of urban road crashes. A disproportionately large share of casualties in cities consists of vulnerable road users such as pedestrians, cyclists, motorcyclists and particularly the elderly and the young. A number of leading cities are implementing a Safe System to reduce the number of victims on their streets. Careful management of speed where vulnerable users and vehicles can mix, or the separation of vulnerable users from faster-moving vehicle traffic offer opportunities for significant trauma reductions.

Build Safe System capacity in low and middle-income countries to improve road safety in rapidly motorising parts of the world

There is huge potential for low and middle-income countries to leapfrog potential spikes in road fatalities as the number of vehicles continues to grow dramatically, by drawing on lessons from the Safe System pioneers. Capacity-building measures are needed to help road safety agencies to develop stronger institutional capabilities, for instance through route or area-based demonstration programmes, where projects bring together all relevant agencies under a learning-by-doing approach.

Support data collection, analysis and research on road traffic as a Safe System

The concept of a Safe System in road transport is comparatively new. More analysis, evaluation and documentation is needed to improve and better share knowledge and to build capacity amongst stakeholders and system designers to implement a Safe System. The experience in a number of countries and cities has shown the positive impact of a Safe System but data is incomplete. It is important that countries collect and analyse data and research on all aspects of a Safe System to enable new insights and a better understanding. Matching hospital records with police crash records, adding location-specific, vehicle data and collecting injury and injury severity data in addition to data on deaths will provide a more complete picture and improve decision making.

Chapter 1. A Safe System–Promoting a world free of road traffic fatalities

Each year around 1.25 million people are killed and 50 million injured in road crashes worldwide. With the world's car fleet expected to double in little more than a decade, road injury is forecast to become the seventh leading cause of death by 2030. The UN Sustainable Development Goals now commit the international community to halve deaths and injuries caused by road crashes by 2020. To achieve this very ambitious target, countries around the world need to re-appraise their road safety strategies. The Safe System offers a fresh approach. Pioneered by countries like Sweden and the Netherlands, its starting point is the ethical maxim that road deaths and serious injuries are per se unacceptable and that road users have a right to expect that they should be safe.

Goals and targets to reduce the global road injury epidemic

According to the World Health Organization (WHO), each year around 1.25 million people are killed and 50 million injured in road crashes worldwide.[1] Every day, over 3 000 lives are lost and tens of thousands of people are injured or disabled. Low and middle-income countries account for over 90% of total road traffic deaths. As the world's motor vehicle fleet is expected to double in little more than a decade, road injury is forecast to become the seventh leading cause of death by 2030. Already, road crashes are the number one cause of death for people aged between 15 and 29. Vulnerable road users – children, pedestrians, motorcyclists, cyclists and older people – suffer 50% of all road fatalities.

Most striking of all is that the growing epidemic of road death and injury is both predictable and preventable. Over the past fifteen years, high-income countries have reduced the level of road fatalities even as motor vehicle use has increased. This is mainly the result of the systematic application of evidence-based measures, with proven effectiveness, promoting safer road users, safer roads, safer vehicles and safer speeds.

However, great differences exist in the risk of sustaining road injury across the world. Middle and low-income countries are experiencing average fatality rates per 100 000 people of 20.1 and 18.3 respectively, whereas the average figure for high-income countries is 8.7. Alongside terrible grief and suffering, road crashes also cause huge economic losses to victims, their families, and societies as a whole, costing countries between 2 and 5% of their Gross Domestic Product. These are avoidable losses that represent a significant restraint on a country's economic and social development.

From 1 January 2016 the United Nations and its Member States committed to an unprecedented effort to promote road safety. A global target was adopted to halve deaths and injuries caused by road crashes by 2020. This new target is included in the UN's framework of Sustainable Development Goals (SDGs) in which road safety appears in the objectives for both health and cities (see Box 1.1). This reflects the contribution that the UN expects road injury prevention to make towards a paradigm shift in favour of healthy lifestyles and sustainable urban development. The SDGs are universal in scope, and therefore apply to all UN Member States. The highly ambitious target for reductions in both road crash fatalities and injuries poses a significant challenge to all governments to reinvigorate their national road safety policies and plans.

Box 1.1. **Road Safety in the UN Global Goals for Sustainable Development**

Goal 3. "Ensure healthy lives and promote well-being for all at all ages."

Goal 3.6. "By 2020, halve the number of global deaths and injuries from road traffic accidents."

Goal 11. "Make cities and human settlements inclusive, safe, resilient and sustainable."

Goal 11.2: "By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all. Improving road safety – notably by expanding public transport – with special attention to the needs of those in vulnerable situations: women, children, persons with disabilities and older persons."

Source: https://sustainabledevelopment.un.org

The new targets were endorsed in the Brasilia Declaration[2] at the Second Global High-level Conference on Road Safety on 18-19 November 2015 and also in a resolution on "Improving Global Road Safety"[3] adopted by the UN General Assembly on 15 April 2016. The UN member states have therefore given their strongest-ever mandate for action on road safety. The new targets also give fresh impetus to the UN Decade of Action for Road Safety, proclaimed by the General Assembly in 2010.[4]

The launch of the UN Decade of Action represented a major breakthrough for international recognition of road injury as a major public health and development challenge. Despite the fact that road crashes kill more people than malaria or tuberculosis, road safety had not been included in the SDG's precursor, the Millennium Development Goals, that set the agenda of international development from 2000 to 2015. This omission has been corrected with the inclusion of road safety in the SDGs. The new casualty reduction target is considerably stronger than the existing goal of the Decade of Action which is "to stabilise and then reduce the forecast level of road traffic fatalities" worldwide by 2020.[5] Significantly, the aim to halve road deaths and injuries by 2020 is closely aligned with some other existing targets, such as those set by the Association of South East Asian Nations (ASEAN) and the European Union (EU)[6] and thus provides further support to such regional road safety initiatives.

At the mid-point of the UN Decade of Action some progress has been made, with the overall growth in road traffic deaths now halted. According to the WHO's *Global Status Report on Road Safety 2015*, the total number of road traffic fatalities has remained constant at around 1.25 million since 2007. Since 2013, the WHO reports that 84 countries have experienced a rise in road fatalities and 80 have achieved a reduction. The plateau in road traffic deaths is occurring despite a 3% rise in population and a 16% rise in motorisation worldwide. This suggests that the UN Decade of Action has encouraged wider adoption of road injury prevention policies, and that these have begun to have some positive impact.

The *2016 Annual Road Safety Report* released by the International Transport Forum's International Traffic Accident Data and Analysis Group (IRTAD) also shows encouraging progress from 32 countries that have achieved an overall 42% decline in road fatalities between 2000 and 2014 (ITF, 2016). However these, mostly high-income, countries account for only 6% of global road deaths. There are also some worrying trends among the IRTAD countries: in 2015 the long-running trend of declining numbers of road fatalities has been reversed in some of the most successful countries**.**

The adoption of the UN SDG target implies a substantial scaling up of the global effort in road injury prevention. Measured against a 2010 baseline, achieving the UN target will require improvements in rates of fatalities per 100 000 population as follows (SLoCat, 2014):

- High-income countries: from 8.7 deaths per 100 000 population in 2010 to 4 by 2020
- Middle-income countries: from 20.1 deaths per 100 000 population in 2010 to 7 by 2020
- Low-income countries: from 18.3 deaths per 100 000 population in 2010 to 12 by 2020.

To achieve improvements on this scale before the end of the Decade of Action is very ambitious and challenging. The adoption of the SDGs will encourage countries around the world to re-appraise their existing road safety strategies and align their efforts towards the achievement of the UN's new casualty reduction target. The time is right, therefore, for a fresh approach to road injury prevention.

Leadership at a political level will now be essential to ensure that government agencies and officials are equipped with a deep understanding of innovative approaches that can deliver the needed reductions in fatalities and the skills to lead arguments for policy change, adequate resourcing for priority measures, and provision of political support for highly important measures and legislation which may initially prove to be unpopular with their colleagues and the community.

Ambitious road safety targets and the Safe System approach

In 2008, the ITF published *Towards Zero Ambitious, Road Safety Targets and the Safe System Approach* (ITF/OECD, 2008). This report highlighted the need for a fundamental shift in road safety policies based on the axiom that any level of serious trauma arising from the road transport system was unacceptable.

The *Towards Zero* report included nine main recommendations (see Box 1.2) and argued that the long-term vision of eliminating road deaths and serious injuries "needs to be complemented with robust interim target for planning terms up to a decade or so".

Box 1.2. **Main recommendations from Towards Zero: Ambitious Road Safety Targets and the Safe System Approach (2008)**

1. Adopt a highly ambitious vision for road safety
2. Set interim targets to move systematically towards the vision
3. Develop a Safe System approach, essential for achieving ambitious targets
4. Exploit proven interventions for early gains
5. Conduct sufficient data collection and analysis to understand crash risks and current performance
6. Strengthen the road safety management system
7. Accelerate knowledge transfer
8. Invest in road safety
9. Foster commitment at the highest level of government

The *Towards Zero* report was subsequently endorsed by the First Global Ministerial Conference on Road Safety held in Moscow in 2009.[7] This ministerial conference supported the launch of the UN Decade of Action and inspired a "Global Plan for the UN Decade of Act for Road Safety".[8] This Global Plan, prepared by the UN Road Safety Collaboration, closely followed the recommendations of the *Towards Zero* report. The Global Plan is based on a five-pillar Safe System framework of policy action. It provides an integrated, multi-sectoral package of recommended measures related to road safety management, safer roads, safer vehicles, safer road users, and post-crash response. Implementation of the Global Plan has been supported by the Second Global High-Level Conference on Road Safety and the UN General Assembly.

Thus, the Safe System approach is today at the centre stage of road safety policy making at the global, regional and national levels. Its starting point is an ethically inspired perspective, namely that there is no acceptable level of road deaths and serious injuries, and that road users respecting the rules of their road networks have a right to expect that they should be safe. A Safe System encourages a "forgiving" strategy for road injury prevention, which accepts that while human error on the road is inevitable, death and serious injury as result of a crash is not. It recognises the shared responsibility of system designers and road users to ensure that crash energy remain at all times below levels that will cause fatal or serious injury, and promotes a holistic, multi-sectoral approach which can reframe the way in which road safety is perceived and managed. The overall aim is to apply an integrated "fail safe" strategy which challenges the public and policy makers alike to imagine a world ultimately free of traffic fatalities.

Sweden and the Netherlands were the countries that originally pioneered the Safe System approach. Sweden's "Vision Zero" strategy was adopted by Parliament in 1997. The decision stated that "the transport system's design, function and use should be aligned so that no one is killed or seriously injured". This imperative, combined with the recognition of the reciprocal rights and responsibilities of road users and managers, have become the cornerstones of Sweden's application of a Safe System. In the Netherlands, a similar policy was developed in the 1990s by the Dutch Institute for Road Safety Research (SWOV) in an effort to promote "inherently safe road traffic". This vision was named "Sustainable Safety".

Variations of a Safe System have subsequently been adopted by, among others, Australia, Luxembourg, New Zealand, the United Kingdom, and at a regional level also by the European Commission (European Commission, 2011). Some major cities are doing the same. In New York City, Mayor Bill de Blasio has adopted "Vision Zero", stating that "no level of fatality on city streets is inevitable or acceptable" and hence the City of New York would "no longer regard traffic crashes as mere 'accidents', but rather as preventable incidents that can be systematically addressed".[9] Private-sector companies are also using their own versions of a Safe System, for example, applying it to fleet management policies, or, in the case of car manufacturers, as their design philosophy. Similarly, the new international standard for road traffic safety management systems, the International Organization for Standardization's ISO 39001 standard, uses Safe System principles to guide organisational safety objectives, targets and the planning requirements.

In the context of the new SDGs and the UN Decade of Action, the key recommendations of the 2008 *Towards Zero* report seem highly prescient. Indeed in the UN General Assembly Resolution A/RES/70/260 adopted in April 2016, member states embraced Safe System principles of "shared responsibility to move towards a world free from road traffic fatalities and serious injuries". The challenge now is to accelerate the implementation of the Global Plan by harnessing the added impetus provided by the SDGs and encouraging all UN member states to achieve the greatest possible reduction in the number of road casualties. In this phase of commitment and renewal in international road safety work, wider application of the Safe System concept can play a leading role.

Why a Safe System?

The countries with the world's most successful road safety performances apply policies and plans inspired by the Safe System concept. What are the features of Safe System thinking and policy that have given it global prominence and a dominant role in road safety policy of the best-performing countries?

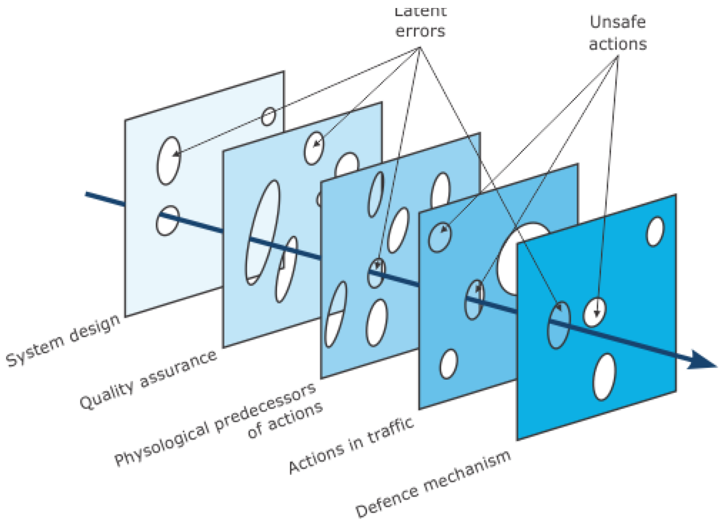
First and foremost, a Safe System helps to overcome the risk of a behavioural bias in road injury prevention. A major weakness of early road safety policies in high-income countries in the 1950s and 1960s was the assumption that the primary goal was to correct human errors in road crashes rather than an acknowledgment of the causes of crashes related to the inherent risks in the road infrastructure. These early road safety efforts often relied excessively on driver education measures.

A significant shift away from this unsuccessful approach was pioneered by William Haddon, the first administrator of the US National Highway Traffic Safety Administration (NHTSA). The pioneering injury-prevention matrix developed by Haddon in 1970 encouraged evaluation of all the factors that contribute to road injury and provided a methodology to assess the effectiveness of a full range of potential counter measures.

Haddon also highlighted the importance of human biomechanical tolerances and the "transfer of energy in such ways and amounts, and at such rapid rates, that inanimate or animate structures are damaged" (Haddon, 1970). He elaborated a ten-point strategy to reduce the harmful interactions of this energy transfer which has played a major role in road safety policy making ever since.

A further evolution in injury prevention theory has been James Reason's focus on systemic organisational weaknesses. His work, illustrated by the "Swiss Cheese" model of injury causation, shows how active and latent failures can open "a trajectory of accident opportunities" (Reason, 1997). To avoid this negative outcome a layered system of defence or "cumulative acts" are proposed that will avoid exposing a single point of weakness that would otherwise lead to injury. The ideas of Haddon and Reason have clearly influenced the development and design of Safe System.

Figure 1.1. **Reason's Swiss Cheese Model applied to road safety**



Source: Wegman and Aarts (2006).

By the end of the 1970s, high-income countries started to implement some elements of a Safe System: speed limits, compulsory seat belts and helmets, new infrastructure design, and expansion of the motorway network (the safest category of roads). This resulted in initial large reductions in road deaths, but was then followed by a slowing in the rate of improvement and then later a levelling-off. Based on "blame the victim" attitudes where considerable focus and attention was given to improving the behaviour of the human being, road safety policies lacked the holistic approach needed to achieve further significant injury reduction.

In contrast, a Safe System promotes a wide combination of interventions, including stronger enforcement, safer road and roadside design and improved vehicle technologies, as well as better post-crash response. A Safe System does not view road deaths and injuries as the inevitable price to pay for a highly-motorised society. By seeing any road death as an unacceptable system failure, it counters the risk that transport planners may adopt measures of transport efficiency that tolerate fatalities that are affordably preventable,

Second, a Safe System addresses two persistent public awareness problems of road safety: the limited societal visibility of road crashes and their impact, and the limited perception of risk and the dangers inherent in traffic crash. Unlike high-visibility transport disasters such as plane or train crashes that can cause a large number of victims as a result of a single incident, the continuous daily toll of road deaths remains largely invisible to all apart from those directly involved. Subjectively, road injury represents a remote and low-level personal risk for the majority of people, whereas road crashes are among the leading health risks worldwide, and represent the greatest risk for young people. Awareness of the life-threatening effects of the kinetic energy released in a crash is also low. This combination of low visibility and weak risk perception can create a demand deficit for road safety that undermines public and political support for policies that would help to make traffic safer.

A Safe System anticipates the growing potential of crash avoidance systems and the trend of technology convergence and interoperability that will increasingly characterise our road transport systems. Already, driver assistance technologies such as electronic stability control and autonomous emergency braking are reducing the risk of road trauma. Information and communication technologies are playing an ever growing role in 21st century mobility. Road and vehicles will increasingly be managed in an integrated intelligent transport system relying on collaborative smart infrastructure. By “hard wiring” safety into vehicle technologies and road design there is huge potential to further reduce road deaths and serious injuries, whilst also contributing to related goals of efficiency and environmental sustainability.

Finally, a Safe System encourages a performance dynamic that assesses if all policy instruments are deployed and all relevant actors are fully engaged. It encourages improvements in the supply side of safety by promoting technological innovation, and it stimulates the demand side by constantly identifying performance failures across the road transport system. In this way, a Safe System approach serves as a permanent “nudge” mechanism (Thaler and Sunstein, 2008) challenging those responsible for road safety – the system architects – to think ambitiously and alter their own and the public’s perceptions about what can be achieved. An important consequence is that all casualty reduction targets are intermediate, in the sense that their achievement is not regarded as a total success but rather a reason for reassessment and renewal. This prevents any target becoming a measure of an acceptable level of fatality.

The challenge at the mid-term of the UN Decade of Action is to harness the inherent dynamism of a Safe System so that it can contribute to the UN’s ambitious casualty reduction target and reduce the road safety performance gaps that afflict far too many countries, particularly low and middle income economies. In 2008, the ITF’s *Towards Zero* report recommended “that all countries, regardless of their level of road safety performance, move to a Safe System approach to road safety”. Of course, the priority policies and measures that will be most effective depend on the characteristics of each country’s road transport system and the profile of injury they experience. Nevertheless, Safe System principles, based at their core on laws of physics and the vulnerability of the human body to uncontrolled levels of kinetic energy, have universal applicability. A Safe System, therefore, serves well as a unifying framework for the road safety policies and plans of every UN Member State.

References

European Commission (2011), Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, White Paper, Brussels, 28.3.2011 COM (2011) 144 final. http://ec.europa.eu/transport/themes/strategies/doc/2011_white_paper/white_paper_com(2011)_144_en.pdf

Haddon, W. (1970), "On the Escape of Tigers: An Ecologic Note." American Journal of Public Health and the Nations Health, Vol. 60/12, pp. 2229-2234.

ITF (2008), Towards Zero: Ambitious Road Safety Targets and the Safe System Approach, OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/9789282101964-en

ITF (2016), Road Safety Annual Report 2016, OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/irtad-2016-en

Reason, J. (1997), Managing the Risks of Organizational Accidents, Ashgate Publishing.

SLoCaT (2014), "Updated Results Framework on Sustainable Transport", Partnership on Sustainable Low Carbon Transport. www.slocat.net/sites/default/files/u10/updated_draft_sustainable_transport_results_framework_9_feb_.pdf

Thaler, R. and C. Sunstein (2008), Nudge: Improving Decisions about Health, Wealth and Happiness, Yale University Press.

Wegman, F. and L.T. Aarts (2006), Advancing Sustainable Safety: National Road Safety Outlook for 2005-2020, Dutch Institute of Road Safety Research (SWOV), Leidschendam.

Notes

1 See http://who.int/violence_injury_prevention/road_safety_status/2015/en/

2 See: http://www.who.int/violence_injury_prevention/road_traffic/Brasilia_Declaration/en/

3 See: http://www.un.org/en/ga/search/view_doc.asp?symbol=A/RES/70/260&referer=/english/&Lang=E

4 UN General Assembly Resolution A/RES/64/255, 2 March 2010

5 UN General Assembly Resolution A/RES/64/255, 2 March 2010

6 Brunei Action Plan (ASEAN Strategic Transport Plan) adopted in 2010 and *Towards a European Road Safety Area – Policy Orientations on Road Safety 2011-2020.*

7 See the Moscow Declaration at: http://www.who.int/roadsafety/ministerial_conference/declaration_en.pdf

8 See http://www.who.int/roadsafety/decade_of_action/plan/global_plan_decade.pdf

9 See: http://www.nyc.gov/html/visionzero/pages/home/home.shtml

Chapter 2. Principles and description of a Safe System

The traditional approach to road safety accepts a trade-off between mobility and loss of life. The main reason for crashes is seen as "wrong" human behavior, and policy aims at influencing road users' behaviour towards full compliance with rules and requirements. A Safe System recognises that humans will make mistakes, and that the human body has a limit to which it can absorb crash forces without suffering injury. It posits that safety is a shared responsibility of all actors in a traffic system, not only that of a road user. Thus, all elements of the road traffic system should come together in an integrate safety chain in which the elements will combine to prevent a crash, or at least prevent serious injury, even if one or more elements fail.

Principles of a Safe System

In road safety analysis and crash studies, two approaches are possible (Hauer, 2016, forthcoming). The traditional approach takes a backward-looking perspective. Standard crash causation analysis strives to understand all the factors involved in a crash that happened in order to suggest ways how such a crash could have been prevented. Alternatively, a forward-looking view will consider what crashes might potentially happen in the future and identify all possible ways how such crashes can be prevented. This proactive approach is the basis of a Safe System. Table 2.1 illustrates the major differences between these two approaches.

Table 2.1. **Comparing the traditional road safety approach and a Safe System**

	Traditional road safety policy	Safe System
What is the problem?	Try to prevent all crashes	Prevent crashes from resulting in fatal and serious casualties
What is the appropriate goal?	Reduce the number of fatalities and serious injuries	Zero fatalities and serious injuries
What are the major planning approaches?	Reactive to incidents Incremental approach to reduce the problem	Proactively target and treat risk Systematic approach to build a safe road system
What causes the problem?	Non-compliant road users	People make mistakes and people are physically fragile/vulnerable in crashes. Varying quality and design of infrastructure and operating speeds provides inconsistent guidance to users about what is safe use behaviour.
Who is ultimately responsible?	Individual road users	Shared responsibility by individuals with system designers
How does the system 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.

Source: Inspired from New Zealand Transport Agency and VicRoads.

Four principles underpin a Safe System in road traffic:

1. People make mistakes that can lead to road crashes
2. The human body has a limited physical ability to tolerate crash forces before harm occurs
3. A shared responsibility exists amongst those who design, build, manage and use roads and vehicles and provide post-crash care to prevent crashes resulting in serious injury or death
4. All parts of the system must be strengthened to multiply their effects; and if one part fails, road users are still protected.

Thus, the design and operation of the road transport system should guide the road user to safe behaviour and mitigate the consequences of common human errors.

Human error

Human beings can never be relied upon to repeatedly perform correctly in all traffic situations over many years, even if it is their intention to manoeuvre in a safe manner at all times. Hence the capabilities and limitations of the human being must be taken into consideration when designing and operating a safe road transport system.

There are numerous reasons road users commit errors and misjudgements. In many cases they originate from the interaction between the road user and the complex physical, social, organisational and technical environment that constitutes traffic and in which the road users act. Errors arising from interaction with the traffic and road environment can be limited by understanding these interactions and designing the road transport system from these interactions, in order to guide the road user to behave in way that is as safe as possible. Yet, as human error cannot be fully eradicated there is a need, at the same time, to mitigate the consequences of mistakes.

In simple terms, this basic principle of a Safe System starts with the insight that human error should no longer be seen as the primary cause of crashes. Instead, road crashes are seen as a consequence of latent failures created by decisions and actions within the broader organisational, social or political system which establishes the context in which road users act.

Limited physical crash tolerance

The human body has a limited physical ability to absorb the kinetic energy a crash exerts before harm occurs. As early as 400 B. C. the Greek physician Hippocrates noted:

Of those who are wounded in the parts about the bone, or in the bone itself, by a fall, he who falls from a very high place upon a very hard and blunt object is in most danger of sustaining a fracture and contusion of the bone, and of having it depressed from its natural position; whereas he that falls upon more level ground, and upon a softer object, is likely to suffer less injury in the bone, or it may not be injured at all.

Behind Hippocrates’ sentences lies the strong relationship between speed and the energy released when an object suddenly stops the movement, and an observation how resulting injuries can be avoided (or at least reduced): by lower speeds on the one hand and the composition of the obstacle on the other. Reduced operating speeds thus not only limit the risk of errors, they also result in a less strong impact and less serious injuries when crashes do occur. The risk of injury in crashes can be mitigated to a large extent by reducing dangerous kinetic energy, be it through low impact speed, contact surfaces that absorb kinetic energy in case of a crash, or a combination of both.

While this may be clear and logical, the road transport system has not been designed with the principle of mitigating common human error or absorbing the consequences as its foundation. For example, increased numbers of vehicles and higher travel speeds (often accompanied with smoother road surfacing) have negative consequences for road safety that have often overwhelmed efforts to improve the safety of road infrastructure, thus producing, on balance, reduced levels of safety.

Shared responsibility for road safety

There is a shared responsibility amongst those who design, build, manage and use roads and vehicles and provide post-crash care to prevent crashes resulting in serious injury or death. While it is the individual responsibility of every road user to abide by safety-related laws and regulations (with education and enforcement being important factors to induce such behaviour), it remains a fact that human beings are not infallible and will always make mistakes, no matter how educated or law-abiding they may be.

In a Safe System, therefore, safe human behaviour in the first instance is informed and guided by the design, layout and operation of the road network, in addition to traditional education and enforcement actions for safe behaviour. Road designs and operations that provide feedback to users or are "self-explaining" can help create an environment that prompts safe road use. Chapter 5 deals extensively with this aspect.

In a system where user mistakes are compensated for in a way that they will not result in serious or fatal injury, a large share of the responsibility for safety automatically shifts from the road users themselves to all those who design the road transport system. These include road managers, the automotive industry, the police, transport operators, health services, the judicial system, schools and road safety organisations and, not least, politicians and legislative bodies. All these bear joint responsibility for providing a road environment that increasingly anticipates potential mistakes and deals with them in a way that avoids serious harm. Box 4.4 provides an example of shared responsibility and the various roles and contributors that different stakeholders or "system designers" make in a Safe System.

Strengthen all parts of the system

The fourth principle underlying a Safe System addresses the potential weakness that if one element fails, serious injury may occur. This is illustrated by the "Swiss Cheese" model (see Figure 1.1), in which a hole represents a latent error. In isolation, a latent error may not result in dramatic consequences. Latent error becomes a danger when they allow for a chain of event leading to a crash (Wegman, and Aarts, 2006). To counter this, a Safe System strengthens all dimensions of road safety so that the combination of measures cover for each other in a way that if one element fails, road users are still protected due to the layered nature of the system and failures cannot result in "a trajectory of accident opportunities" (Reason, 1997). The dynamic interaction of the different elements of a Safe System instead combines to multiply the protective effect so that the overall safety is greater than that provided by adding up the effect of the individual elements.

To provide a greater overall effect, the layers that together build a Safe System – the design and operation of road infrastructure, operating speeds, vehicles, human behaviour – will be managed holistically and not as separate parts in "silos". In those countries at the forefront of Safe System thinking, the four guiding principles are being translated into concrete design principles for safety across the system safety, rather than for each component individually. This is a main difference with the traditional approach in which responses are often managed and implemented by different agencies.

The Integrated Safety Chain

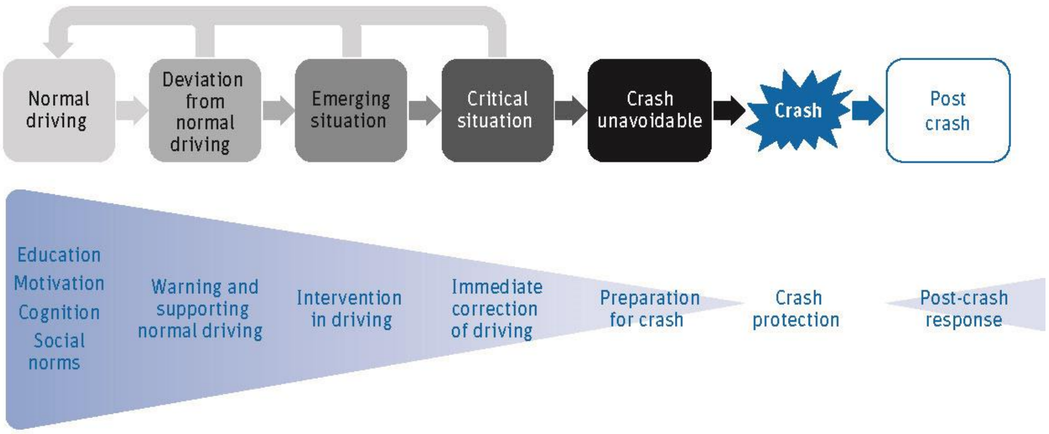
The Integrated Safety Chain (see Figure 2.1) is used in some advanced countries to match the first two principles of human error and human tolerance to force to progress implementation of a Safe System. The Integrated Safety Chain was conceived to encourage thinking about injury prevention in a way that takes a potential crash event as its starting point, and then works backwards to solutions that avoid such an outcome. The challenge then becomes to prevent the hazardous event at the earliest possible stage of the integrated safety chain.

It is, however, necessary to simultaneously acknowledge that this will not always be possible. Measures are also needed that can limit the amount of kinetic energy in case of a crash and thus the risk of injury. The key is to link the possible outcome with the speed that can be tolerated under normal driving conditions so that any kinetic energy released will not be larger than what can be managed through the chain. For each step, a systems approach must be taken in order to understand and integrate road user rules and behaviour, road and traffic environment, speed management, vehicle systems, post-crash response with the aim to combine them in an effective way.

The chain is described with a loop which symbolises the driver regaining control and then continuing to drive normally. If the driver's attempt to return to normal driving fails, there should be an action to avoid the next stage in the chain (emergence of a critical situation). Even if the return to a less dangerous stage fails and a crash becomes unavoidable, this situation can still be influenced in a way that mitigates the consequences.

It is important to understand that, while efforts should focus on all stages, it is not possible to always rely on solving the problems in the early parts of the crash sequence. The strong focus on upstream efforts in the safety chain inherent in a Safe System goes along with the acknowledgment that there will always be events that fall through and thus make it necessary to also include mitigation of crash consequences.

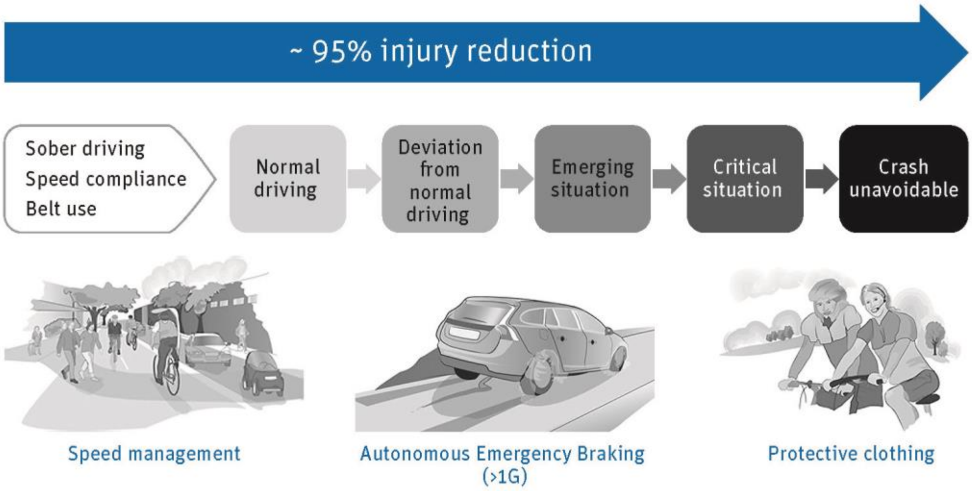
Figure 2.1. **The Integrated Safety Chain**



Source: Adapted from Tingvall et al.

An example of how the Integrated Safety Chain works to create a combined effect to protect cyclists in potential conflict with cars is given in Figure 2.2. What is substantially different from a risk reduction approach is that at the end of the chain, after the crash, there is no harmful consequence. This, in turn, puts the requirement on the chain that all steps are aligned to each other to form a complete net of protection, and more importantly, that the allowed top speed is not higher than the capacity of the chain to protect completely from death and serious injury. For example, if roads are not divided, or have intersections that allow oblique crashes, the speed must be kept below levels that will cause serious harm. In built-up areas, mixing vehicles and pedestrians and cyclists means that the maximum speed should be 30 km/h to protect vulnerable users.[10]

Figure 2.2. **The combined effect of speed reduction, vehicle frontal design, autonomous emergency breaking and helmet use in reducing bicycle injuries**



Source: Adapted from Ohlin M, Strandroth J and Tingvall C. ICSC Gothenburg (2014).

Finally, when a serious crash occurs, post-crash responses and appropriate emergency medical care are vital to ensure that injuries do not become more serious or life-threatening, and to aid in recovery from crash trauma.

Description of a Safe System

The term Safe System refers to:

- the vision or aspiration that zero fatalities and serious injuries from road crashes are ultimately possible
- four principles to guide the design, operation and use of a road system with a view to reducing fatalities and serious injuries to zero
- the implementation of practices, tools and their interactions that will deliver on the principles.

A Safe System moves beyond reactive, crash history based approaches to a proactive approach. A proactive approach includes designers understanding human behaviour to know when we can "rely" on people acting safely but also when they cannot act safely and take measures in the infrastructure, in the vehicles and in the management of operating speeds to support the road user to act safely.

A proactive approach also entails understanding risk and where the risk inherent in a road network is assessed and priority interventions are identified. A proactive approach also involves assessing infrastructure and where it is not in accordance with Safe System design principles; there is a plan for treatment on a priority basis before crashes begin to occur. Safety is a pre-requisite for the effectiveness of the transport system. By increasing safety it is possible to get greater efficiency and higher output.

"Vision Zero", "Towards Zero", "Sustainable Safety" and "Safe System" are different names for similar policies that fundamentally do not accept death and serious injury as an acceptable product of mobility. A discussion on the differences can be found in Vaa (1999).

The Safe System approach posits that road trauma is a public health issue, and one of epidemic proportions. It takes as a starting point the moral and ethical imperative to alleviate human suffering, and is, at least in the first instance, less focused on the aspect of financial cost. It postulates that human beings participating in road traffic should be seen as citizens with a right to safe mobility, not merely as road users with associated obligations. This right to safe mobility is linked to the notion that the different providers within the road transport system are ultimately responsible for its safety, too. A Safe System focuses on preventing the most serious, life-changing harms and accepts a certain amount of minor injuries caused by the transport system which cannot be overcome without exceptional cost. The clarification of which serious injuries should be prevented in a Safe System is thus a central issue.

Box 2.1. **Case study: Introducing seatbelts and air bags**

The first seatbelts in cars appeared during the 1950s, but their use remained voluntary. For a long time, seatbelt systems were not optimally designed. Only the use of lap belts or lap belts with detachable shoulder straps (in the United States) was initially advocated. Although the technology for automatic seat belt systems was already available in the 1980s, they were opposed by most of the industry.

The airbag was invented in 1951. Airbags were installed in some vehicles in the US as early as 1973, but it took until the 1990s for them to become standard equipment on many vehicles. Similar opposition occurred more recently with the introduction of centrally high-mounted rear brake lights, which have proven beneficial in reducing rear-end collisions (Somers and Hansen, 1984).

With respect to safe vehicle design and legislation, it has become clear that improving safety cannot be left to vehicle manufacturers alone. Government intervention is needed and, indeed, widely occurs now in the United States, Europe, Japan and Australia. Along this path, road safety research has accompanied vehicle safety legislation and provided evidence to support enhanced standards.

In a Safe System there is a clear distinction between the responsibility of the system designer and that of the road user. Whilst in conventional road traffic legal frameworks, the driver is ultimately held responsible for crashes, in a Safe System, the road user is responsible for following the rules for the safe use of the system and for behaving appropriately. This is a major difference in that conventional policies go downstream towards the sharp end while Safe System goes upstream towards the blunt end.

In some countries pioneering the implementation of a Safe System, the shared responsibility falls to the system designer. That is, if the road user does not follow the rules, the responsibility ultimately falls back to the system designer, and this is achieved through policy or practice. Policy states that the system designer is ultimately responsible and must take additional measures to account for when humans will make predictable errors so that crashes do not result in serious outcomes. A Safe System policy framework can be a common catalyst for system designers to influence the design and use of the road transport system. The user responsibility is often formulated in laws and regulations but the “system designer’s” responsibility is more of an ethical statement but could, if necessary, be a matter of legislation.

Of course pioneering countries adopting a Safe System are still faced with the realities of considering network mobility and efficiency with safety. However by focussing clearly on working towards a Safe System ultimately, these countries are identifying new possibilities and solutions that can be practically implemented today, that may not have been considered or possible if the thinking at the outset had been to “balance” safety with other criteria.

The dynamic and complex interactions among the various layers, actors, activities and components of a Safe System are illustrated in Figure 2.3. This diagram shows how the four principles of a Safe System come together in the design and operation of the road transport system. As the illustration shows, a Safe System places humans at the centre of the road transport system. This is the case regardless of what type of transport they are using – be it walking, riding to driving or as a passenger. The young and the elderly have different capacities to use the system safely and have increased frailty and vulnerability. While people are generally educated and compliant, they do make mistakes when moving on the road network (as they do in life generally), and there will always be mistakes that result in crashes. This illustrates the first principle of a Safe System: people make mistakes that can lead to road crashes.

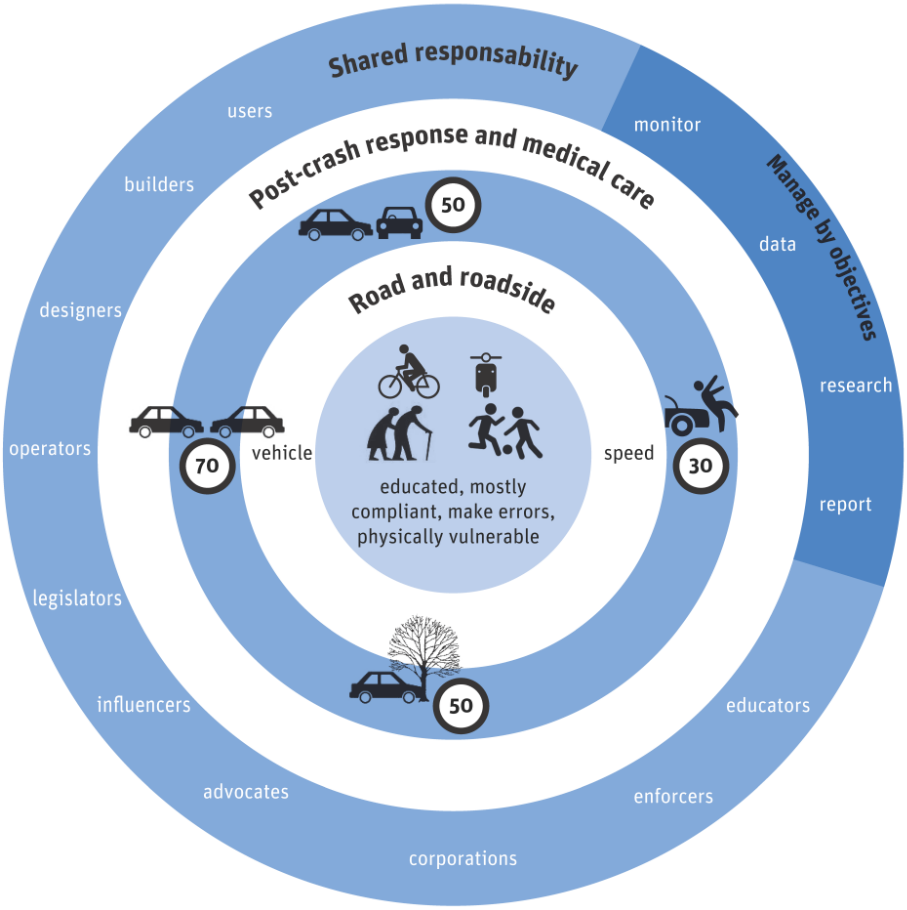
The second circle of the model captures the relationship between speed, roads and roadsides and vehicles in a) nudging users to behave safely in traffic, then b) acting to ensure that when a crash occurs it does not have serious injury consequences. These two outcomes are achieved through the interaction of physical design, the layout and operating conditions of the road and roadside environment, and vehicles to enable safe operating speeds, safe vehicle operation and safe outcomes. Vehicles in a Safe System use active technology (e.g. intelligent speed assistance or collision avoidance systems) to assist the driver to take action (or to intervene if he does not) as well as secondary crash protection for occupants and people outside the vehicle.

The third circle represents the second Safe System principle that the human body has a limited physical ability to tolerate crash forces (for example, serious injury will often result from a collision between a vehicle and pedestrian above 30 km/h). A Safe System seeks to mitigate the risk of serious harm by anticipating potential causes and managing the three components of the second circle and their interactions to avoid collisions where the impact forces exceed dangerous levels. While they offer the most protection in combination, each of the components of a Safe System is expected to provide protection from impact forces so that when one component part of the system fails, the other parts will provide sufficient protection.

The fourth circle in the Safe System diagram covers post-crash medical care. This is a vital element where a system failure has permitted a crash with impact forces that have caused serious physical harm. In such cases, the health outcomes for crash victims depend on the ability of the emergency medical care system to quickly locate and provide emergency first responder medical care to stabilise the victim and then transport the person to appropriate emergency hospital treatment. Together, the second and fourth circles illustrate the third principle of a Safe System that all parts of the system must be strengthened to multiply their effects; and if one part fails, road users are still protected.

The fifth and outermost circle of the diagram illustrates the fourth principle of shared responsibility for a Safe System: a shared responsibility exists amongst those who design, build, manage and use roads and vehicles and provide post-crash care to prevent crashes resulting in serious injury or death. This is a responsibility of individuals as well as groups, and it comprises government as much as private-sector companies or civil society organisations. It pertains to educators who inform and motivate users to act safely; to legislators who design traffic and safety laws; to police and other government agencies who enforce them; to researchers, engineers, technicians, policy makers, advocates and opinion leaders. The use of data and evidence to inform practice and enable results-focused “Management by Objectives” is essential to underpin collaboration with shared responsibility.

Figure 2.3. **Conceptualisation of the Safe System**



Conclusion

A Safe System is a pro-active, forward-looking approach to road safety that constitutes a departure from traditional ways of addressing safety on roads. A Safe System is based on four guiding principles that inform thinking and policy with a view to manage design and operation of the road network so that ultimately zero road deaths and serious traffic injuries will occur. Thus, unlike some approaches, a Safe System, in principle, does not accept a trade-off between road safety and other priorities, where traffic deaths and serious injuries are regarded as a price to be paid.

The Safe System principles acknowledge that people make mistakes in traffic and there are known limits to the capacity of the human body to absorb kinetic energy before harm occurs. A Safe System requires understanding and managing the complex and dynamic interaction between operating speeds, vehicles, road infrastructure and road user behaviour in a holistic way. The aim is that the sum of the individual parts of the system combine for a greater overall safety effect in which another part will prevent serious injuries even where one part fails.

In a Safe System, road users bear the responsibility to obey traffic rules and use roads with due care for safety. Those responsible for designing, building and operating the road system (the "system designers") bear responsibility to ensure it encourages and supports safe use, addresses inherent safety risks, anticipates errors that users will make and ensure they do not result in serious harm. A safe and sustainable speed management and limit system that safely manages the interaction between vehicles, users and road infrastructure is a key feature of a Safe System. As crashes will still occur, optimal emergency response and post-crash medical care are part of a Safe System to prevent injuries from having serious health consequences and to ensure optimal recovery.

References

European Commission (2016), Road Safety: New statistics call for fresh efforts to save lives on EU roads, press release, Brussels, 31 March 2016, http://europa.eu/rapid/press-release_IP-16-863_en.htm

Hauer (2016, forthcoming), "An exemplum and its road safety morals", Accident Analysis and Prevention

Ohlin, M., J. Strandroth and C. Tingvall (2014) "The combined effect of vehicle frontal design, speed reduction, autonomous emergency braking and helmet use in reducing real life bicycle injuries". International Cycling Safety Conference (ICSC), 18-19 November 2014, Gothenburg, Sweden.

Reason, J. (1997), Managing the Risks of Organisational Accidents, Ashgate Publishing.

Somers, R. L., and A. Hansen (1984), "The cost of rear-end collisions in Denmark and the potential savings from a high, center-mounted auxiliary brake light", in Accident Analysis and Prevention, Vol. 16/5-6, pp. 423-432.

Vaa, T. (1999), "Vision Zero and Sustainable Safety: A comparative discussion of premises and consequences", Institute of Transport Economics Working Paper O-2506; Swedish National Road Administration (SNRA).

Wegman, F. and M. Hagenzieker (2010), "Scientific Research on Road Safety Management", in Safety Science, Vol. 48/9, November 2010.

Wegman, F. and L.T. Aarts (2006), Advancing Sustainable Safety: National Road Safety Outlook for 2005-2020, Dutch Institute of Road Safety Research (SWOV), Leidschendam.

Note

10. Further examples of this concept and a more detailed discussion are included in a special edition of Safety Science (Wegman and Hagenzieker, 2010).

Chapter 3. Leadership for a paradigm shift towards a Safe System

A paradigm shift in the way the road safety problem is viewed and responded to requires, first and foremost, leadership to initiate a change in mind-set and to guide stakeholders on the journey towards a Safe System. It will also require a sense of urgency to drive this change and raising awareness among all concerned that a Safe System is the best approach to deliver improved road safety.

Leadership for a Safe System

After five firemen were killed by a speeding car in 2002, President Jacques Chirac of France used the head of state's traditional Bastille Day speech to publicly declare "the fight against poor road safety" a top priority for his second mandate, stating that he was "absolutely horrified by the fact that French roads are the most dangerous in Europe". Following the presidential declaration, an automated speed camera programme was launched in France in 2003, resulting in a decrease in speeds and of speed limit violations which contributed to an estimated reduction of road fatalities by more than 16 000 over the period 2003 to 2010 (Carnis and Blais, 2013).

The French speed camera example highlights the role of leadership in creating a change in road safety policy making. Leadership at the highest political level as illustrated in the French example is very powerful to induce change. Yet, strong leadership may equally come from road safety professionals and civil society representatives, for instance from victims associations or public personalities. A transformational initiative that aims to shift an existing paradigm and establish a new foundation for action needs leadership that is visionary and strong as well as sustained.

Where leaders effectively communicate the vision that road traffic does not need to be deadly, their contribution can be critical in creating a sense that road safety must improve and that a Safe System is the way to go. Beyond creating the initial momentum, effective leadership for a paradigm shift must also be sustained and focused on not only bringing the different stakeholders together, but also to keep them together and lead them through the change process.

The experiences in those countries that have decided to address the issue of road deaths by adopting principles for a Safe System underline the importance of leadership. In all of them, leaders and change agents initiated, fostered and supported transformational changes in culture and practice that enabled the adoption of Safe System thinking and allowed the countries to embark on the journey towards a Safe System.

- In Sweden, the leadership of both the Minister of Transport and the newly installed director of road safety at the Swedish Road Administration played a crucial role in convincing members of parliament that "Vision Zero" was a viable and promising concept. Thanks to their strong ambitions to improve road safety and their leadership on this issue, "Vision Zero" was adopted by a large majority in the Swedish Parliament in October 1997, despite initial resistance.
- In 2007 and 2008 in Western Australia, parliamentary support for the adoption of a Safe System (called the "Towards Zero" vision) was built by the Minister responsible for Road Safety inviting Members of Parliament to a road safety advisory group supported by the state's Road Safety Council and Government Office of Road Safety. In the Netherlands, leadership of the director for road safety in the Ministry of Transport helped to convince the minister to adopt a Safe System.
- In Argentina, victims associations launched the country on the path to a Safe System. The initial bottom-up pressure from civil society, triggered by a horrific road crash in 2006, was then complemented by strong political leadership including the President of Argentina. The Minister of Interior and the executive director of a newly-created lead agency became vocal champions of the Safe System vision. By communicating effectively with both political actors across different ministries and levels of government, as well as with society and grass-roots organisations, they managed to keep road safety a high-visibility issue on Argentina's political agenda and convinced major stakeholders to engage in building a Safe System.

Leadership for change in road safety does not operate in isolation. There are many opportunities to connect safety priorities and agendas with mutually beneficial, connected agendas, interests and concerns in the wider community. Seizing them will mobilise supporters and leaders for whom safety may not be the first priority for the Safe System cause. For example, some countries have been very effective in connecting the issue of speed management (speed limits and speed enforcement) for improved safety with the benefits of lower speeds to the environment and public health through reduced noise pollution, lower emissions, healthier lifestyles as a result of more active mobility, and so on.

The above examples focused mainly on the importance of leadership vis-à-vis other stakeholders. But leadership is no less critical within the organisations involved – such as the police, road authorities or transport companies. Support for a Safe System must be built throughout any organisation that shares responsibility for road safety, and focused guidance is required throughout the change process towards assuming that responsibility. Thus, organisation leaders need to rally their colleagues to adapt Safe System thinking, policy and practice to their specific situation.

Grooming the leaders that will be needed requires understanding what might motivate them to assume a leading role and tap into latent motives. These can vary: one person may feel a moral or ethical obligation to do something to reduce the number of people killed in traffic. Another's willingness to step to the plate might be triggered by a personal experience. Yet someone else may find themselves in a specific position from which influence can be exerted and decide to act, and another may be driven to action by picking up a growing sense of urgency in society to "do something" about road deaths. Others involved in research or on senior roles in government may be compelled to apply their knowledge of the scientific evidence for solutions when continually confronted with road crash data that shows the full picture of the burden on their community. Last but not least, taking the lead on creating a better, safer built environment for current and future generations can be seen as a substantial and rewarding professional opportunity.

Leaders come and go with election cycles, promotions and organisational restructurings, while the journey to a Safe System will last many years. For example, in some countries (notably low and middle-income countries), senior government officials and police officers often take over new responsibilities after a relatively short period of time, which can hamper sustained leadership on an issue. Because the initiators and strongest proponents will often not be able to guide a country, city or organisation throughout the process, their particular challenge is to ensure that structures, agency vision and strategic plans, organisational structures, management systems, policies, guidelines and processes are put in place in a sustainable way to support the adoption of a Safe System over a longer period of time.

Establishing a paradigm shift for a Safe System with stakeholders and the community

In its original meaning, the term paradigm shift denotes a scientific revolution that completely changes the way in which science looks at the world (Kuhn, 1962). The term has, however, broadened over time and is now used in numerous contexts beyond the theory of science. Thus, a paradigm shift in its broader sense describes a fundamental change in the way an individual, organisation or society as a whole views "how things work" in the world. In this sense moving from a traditional road safety approach to a Safe System can be described as a paradigm shift, in that a Safe System takes a radically new perspective on the road safety problem, and potential solutions to it.

This paradigm shift towards a Safe System has taken place in some countries and is underway in others, while elsewhere it still has to be set in motion. The concept of a Safe System for road safety originated in Sweden and the Netherlands in the 1980s and 1990s, when scientists and, in the case of Sweden, policy makers began to question the prevailing view that safety was the responsibility of the road users, and that the main remedy was to change their behaviour through education, information, regulation and enforcement. While such measures have an effect, it became obvious that the decreases in the number of fatalities and severe injuries were levelling out. Analysis suggested that the policy focus on changing how individual road users behave was no longer effective and needed to be reconsidered.

It was in this context that scientists and other pioneers developed the thinking for a Safe System, as a scientifically based reaction to the prevalent road safety policies. Safe System thinking and practice is now being adopted by a number countries, cities and companies. They have made zero preventable fatalities and serious injuries the ultimate goal of their policy and are working to create a Safe System.

The first step for establishing a Safe System is to change the mind set about road safety. Adopting a Safe System starts with accepting the validity of the simple ethical imperative that no human should be killed or seriously injured as a result of a road crash. This axiom logically requires that a traffic system should be designed and used with this imperative in mind. The Dutch “Sustainable Safety” vision states it this way: “Sustainable Safety aims to prevent (serious) crashes, and where this is not possible, to eliminate the risk of severe injury as much as possible” (SWOV, 2013).

A central aspect of the Safe System mind-set that differs from the traditional road safety approach is its acceptance of a shared responsibility. In a Safe System, everybody involved in road traffic in one way or another, from system designers to users of the system, bear part of the responsibility to prevent serious crashes. This also requires a shift in the traditional way of thinking of governments and practitioners.

Financing road safety is also viewed from a new angle in a Safe System. In a traditional approach, the main question related to financing is “Which measures are most effective, given the available budget for improving road safety?” In the case of working towards a Safe System, the question should be “How much money do we need to create a Safe System and how do we get the necessary funding?” While the amount of money for a Safe System treatment may be more than a traditional, cost-effective, retrofit treatment for the short term, it is important to take into account the savings from applying a holistic Safe System solution that will deliver greater crash savings over a longer period even though initially more expensive in the short term.

A complex social process underlies the replacement of an old paradigm by a new one (Kuhn 1962). Policy and social innovation and change rarely occurs as a sudden, revolutionary switch but rather as a continuous process of exploration, error, trial, failure and success (Bornstein 2007, Shove and Pantzar, 2005). This also applies to establishing a Safe System to improve road safety. There is no strictly logical, orchestrated step-by-step approach for adopting, establishing and implementing a Safe System, as the experiences of pioneering countries attest to. Instead, moving to a Safe System is a learning-by-doing process in which opportunities are leveraged as they arise and innovative policy instruments are developed on a continuous basis. The learning process can be described as a journey that presents opportunities, hazards and challenges along the way. Box 3.1 provides an illustration for the type of challenges and opportunities that occur in adopting a Safe System.

Even in countries that have made a Safe System their official policy and where road authorities have committed to it in principle, numerous examples exist of agencies being slow to adapt practices across their mandate. Part of the explanation is that many established practices are not fully transparent with respect to the implicit trade-offs made in relation to safety. For example, underlying economic modelling and assessments conducted on road projects may unequally assess the impact in terms of safety versus time saved in terms of network efficiency. Understanding these and adopting new approaches can be time consuming and run up against the pressures to deliver outcomes for efficient mobility. All these issues cannot be resolved at once, so time is required.

Creating a sense of urgency for change

In countries that have adopted a Safe System, innovation occurred where it was felt that the current approach did not deliver sufficient progress any longer and that change was needed. This sense of urgency can manifest itself in several ways: in the realisation that existing road safety targets are not being met, that progress in relation to other countries is poor, or in a single incident that galvanises policy making.

Both in the Netherlands and Sweden the fact that existing targets for road safety performance were not being met contributed to the paradigm shift. In the Netherlands, road safety policy had been shaped by a reactive approach aimed at specific issues, but by the early 1990s it was no longer taken for granted that targets could be met with the existing policy. At the same time, there was an increasing awareness that the reactive approach was not addressing safety problems at the root (Wegman and Wouters, 2002). This triggered the development of the "Sustainable Safety" vision, the Dutch version of a Safe System. The 1991 road safety policy plan for the Netherlands adopted a two-pronged policy: on the one hand, it intensified the focus on specific road safety issues; on the other hand, it targeted the development and implementation of a proactive approach to road safety encapsulated in the concept of "Sustainable Safety".

A similar experience led Sweden to reconsider its overall approach. By the mid-1990s, the country no longer met established road safety targets as the number of fatalities and severe injuries showed signs of levelling out. Analysing this trend, the Swedish road safety community concluded that "more of the same" would have only marginal effects. A radical rethink of road safety strategy was the result.

Box 3.1. **Case study: Changing old thinking about road safety**

In 2007, Western Australia launched a major road infrastructure project to duplicate a section of the National Highway, at the western end of the major east-west link across the Australian continent. This duplication created a median dividing two lanes each way with a speed-limit zone stipulating 110 km/h maximum speed.

At the same time, Safe System working groups were being established for a number of major new road projects, with the intention to put Safe System principles into practice. However, the Western Australian highway project was not subject to the new Safe System review process.

The leaders of one of the Safe System working groups then identified a section of this new duplication where a new wire-rope road-side barrier had been installed to protect a newly installed open drainage sump. However, along the road side for some 100 metres each way on either side of the sump were mature trees. These trees represented a significant road-side hazard.

When asked why the cable barrier installed in front of the sump was not extended either side to protect from the trees, the reply was "the sump is a man-made introduced hazard we have to protect", while "the trees are natural and were there before". While some additional cost for the longer barrier could have also been invoked, this was not the reason given for not protecting the tree-lined part of the new road.

This and other examples have been used as learning opportunities in change management processes, education, training and problem solving that continues in the evolution of change towards Safe System practice amongst professional in state and local agencies designing and building road infrastructure in Western Australia.

This reflection and critical thinking has brought about changes in practice firstly on new, major, innovative road projects and, more recently, changes in road agency vision, planning, policy and procedures to imbed Safe System thinking in aspects of the business of operating the road network.

Use of targets

Road safety targets are a useful tool that can help capture the attention of political leaders and the public, and support the push for a more ambitious approach to road safety. Aspirational targets such as "zero road deaths and serious injuries" are vulnerable to criticism that they are unrealistic or irrelevant. If they are supported by operational short-term targets, however, these can help to demonstrate that, while the end goal is highly ambitious and even visionary, significant progress can be demonstrably achieved. By way of example, the Swedish government was able to report that in 2008 no child had died in a bicycle crash – a powerful narrative that, while acknowledging the ultimate eradication of all road deaths was still a long way away, highlighted that such an outcome could be achieved in principle, and that taking step after step leads to more safety.

The UN Sustainable Development Goal target of reducing road deaths from roughly 1.2 million in 2010 to around 600 000 by 2020 has created a sense of urgency in many countries. The target is based on benchmarking performance by income group (low, middle and high income country). If all countries matched the best in class, deaths would be half their current level. At the global level, the UN SDG target for reducing deaths from road crashes represents a step change in the level of ambition compared to the goal set at the beginning of the UN Decade of Action (Figure 3.1). The gap between the trend in road deaths projected in 2010 and the SDG underlines the size of the challenge and the urgency for change.

The nature and structure of targets, for instance expressed in Safety Performance Indicators (SPI, see Chapter 4) needs to be carefully considered, and they need to be systematically monitored and reported in order to help drive the adoption of better road safety policies. An indicator or target must build upon the available state of knowledge, i.e. reflect the fact that serious crashes are generally not the result of risk-taking but mostly due to simple and inadvertent errors of judgement, perception or concentration. SPIs that focus solely on behavioural measures, for instance, may, through their limited scope, result in more of the same being prioritised - with wider questions only asked once improvements in fatality rates are stalling.

Pioneering countries are setting targets and using SPIs that reflect the paradigm shift to a Safe System and collect and analyse data accordingly. For example, measures of human risk-taking behaviours (speeding, drink driving, seatbelt use, helmet wearing) are complemented with other behavioural measures that focus on errors. Further, performance measures relating to the safety of road infrastructure, the appropriateness of speed limits, or vehicle safety also help to focus attention on monitoring the performance of all aspects of a Safe System.

Relevant road safety data is absolutely essential for penetrating analyses that will convince leaders to explore new avenues. The quality of road safety data varies considerably, however, and different standards make international comparisons challenging.[11] In many countries, the collection of road safety data is based on reporting of crashes by the police - yet information gathering by the police, under most road traffic legislation, focuses on establishing culpability and, potentially, prosecution. Such data are therefore often recording primarily human behaviour. Information about the safety performance of the road, the appropriateness of the speed limits and the vehicle may be collected by other agencies, but are usually regarded as secondary.

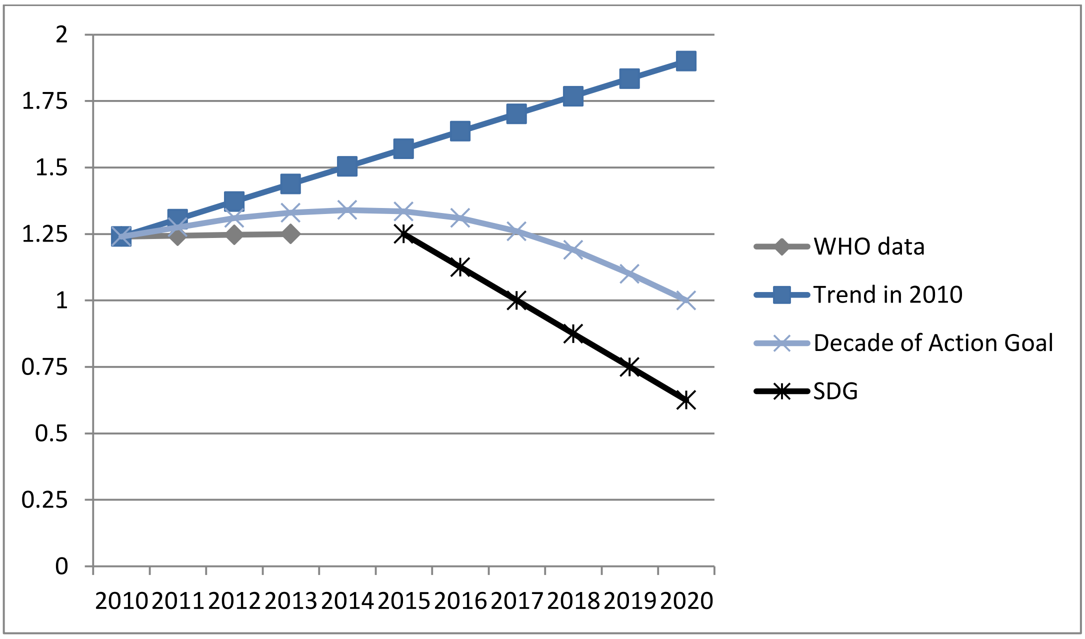
Similarly, data on the severity of crash injuries is difficult to obtain, as this requires hospital data to be matched with crash records (see also Box 4.4). Pioneering countries are linking police and health data to provide a complete overview of serious crashes. This consolidated information helps them to form a more complete and balanced picture of the overall serious crash problem, establish new crash criteria, and to assess and monitor road safety performance in a way that enables proactive assessments of inherent risk in the road system as well as a gap analysis between current state and ideal or targeted state.

Benchmarking

Another useful tool for creating the preconditions for a rethink of road safety is benchmarking. Benchmarking means comparing the performance, processes or strategies of an entity (an organisation, a country) with those of other entities, in particular with the best in class. Road fatalities can also be considered as an entity in itself and can be compared to other causes of death. When the World Health Organization (WHO) in 2004 established that road crashes rank among the ten leading causes of death (Peden et al., 2004), this helped to create an awareness of the importance of – and demand for – road safety.

Benchmarking creates transparency. It exposes problems, but at the same time points to potential solutions by highlighting which measures work best in a certain context. Benchmarking is a powerful lever to encouraging countries to follow best practices and learn from each other.

Figure 3.1. **UN Decade of Action Goals and Sustainable Development targets (millions killed)**



Comparing mortality rate and injury risk between jurisdictions (cities, regions and countries) can foster a positive competitive spirit, whereby a jurisdiction wants to perform better than another one. In addition, performance on Safety Performance Indicators, for instance speeding infractions or helmet wearing rates, can be compared between jurisdictions (see Chapter 4 for a more detailed discussion of SPIs).

Equally, benchmarking can be effective in keeping road safety on the political agenda. Poor performance of road safety in relation to other fields (for instance occupational safety, safety in other transport modes), other causes of serious injury and death in public health (such as malaria, tuberculosis or heart disease) or in relation to other countries (for instance neighbouring countries or countries on a similar stage of economic development) will often create an acute sense of falling behind and foster a sense of urgency that prods governments to take action.

Benchmarking can also serve as a catalyst for a change in thinking about the underlying assumptions of established policies and encourage consideration of policies employed by the best-performing countries. Almost automatically, benchmarking against the better results of a leading country will lead to an examination of the approach used there, the philosophy underlying that approach and therefore the concept of a Safe System.

A useful example of a benchmark exercise in road safety is the SUNflower study of Koornstra et al. (2002). Within this study, road safety strategies and developments were compared for Sweden, the United Kingdom (UK) and the Netherlands (abbreviated as “SUN”), the countries with the lowest crash rates in Europe. The study aimed to determine the underlying elements in road safety policy that make these countries successful and thereby identify policy improvements most likely to produce casualty reductions. One conclusion was that all three countries have achieved similar levels of safety through continuous improvements. Another was that, although the policy areas targeted were similar, at the detailed level the policies implemented differed. The study provided recommendations for both SUN countries, other European Union member countries and the European Commission.

The SUNflower study inspired a project conducted in 2015-16 by the International Transport Forum to benchmark road safety performance in Latin American countries. The objective of this project was to offer policy makers in Latin America a tool to assess the weaknesses and strengths of each country, and to identify areas deserving policy attention where the experience of other countries might be usefully applied.

Another useful multi-country initiative is the Ibero-American Road Safety Observatory (OISEVI), established in 2012 by the directors for road safety from 18 Latin American and Caribbean countries with a remit to share information on best practices concerning policymaking, planning and road safety indicators. OISEVI has made a significant contribution to raising the profile of road safety in the region. Its regularly published safety data and performance indicators stimulate knowledge transfer and the adoption of lessons learned elsewhere.

A third example of a successful benchmarking project is the Road Safety Performance Index (PIN) created by the European Transport Safety Council (ETSC) for countries in Europe. Since 2006, ETSC publishes cross-country comparisons on a range of different road safety indicators in so-called PIN Flashes, on subjects like pedestrian safety, impaired driving, and safety of roads. An annual PIN Report is also launched at an annual PIN Event in Brussels. These reports facilitate the comparison of data on strategic performance indicators in Europe by presenting trends and comparing achievements in relation to EU road safety targets. They also give room to comments from experts and aim to drive action by making recommendations. The ETSC works with a panel of road safety experts from 32 countries who supply data, information and comments on road safety policies in their country and also make suggestions for further research. This inclusive approach and the broad co-operation with many organisations involved in road safety is critical to the success of benchmarking, notably where efforts from the partners are needed to put lessons learned into practice for improved safety.

Last but not least, the work of the Global New Car Assessment Programme (Global NCAP) and the International Road Assessment Programme (iRAP) provide two further examples of how benchmarking can be effectively used to enhance road safety. Both NCAP and iRAP have created rating systems for the safety of, respectively, vehicles and roads. By awarding stars for good safety performance, they create transparency in an easy-to-understand and easily communicable way that can be used very effectively to advocate for safer roads and safer vehicles. The Three-Star Coalition[12] for example advocates for safer roads in the developing world, urging infrastructure investors like the World Bank to adopt a minimum standard of three-star roads.

In-depth studies of fatal crashes

Sometimes a single, serious road crash can make people realise that a change is needed, as the example of France and Argentina mentioned above shows. In that sense, in-depth studies of fatal crashes can also at times help to generate a sense of urgency. In 1996, Sweden began to investigate every single fatal road crash in detail. The original objective was to create a deeper and shared understanding among decision makers of the problems of road safety by looking at all aspects related to a crash and what would be required to pre-empt such a crash in the future. In-depth crash analyses allow a better understanding of the Safe System principles along the chain that leads to a crash.

These detailed examinations equally increased awareness among the wider public that road crashes represent a major threat and a public health hazard. Systematic reflection on each case not only highlighted the individual catastrophe it represented. It also pointed to the fact that preventive solutions often were in the hands of the decision makers and system designers, as much as in those of the crash victims. This way of working created new insights, fostered a willingness to take responsibility and often started a process of creative thinking around road safety issues.

Raising awareness, convincing stakeholders, increasing demand for road safety

When a comprehensive reorientation of established policy paradigms is suggested, some initial resistance must be expected. In Sweden, for example, the elevation of the "zero road fatalities" vision to a policy-guiding objective was criticised as idealistic and unattainable. Equally, the proposed sharing of responsibility caused some disquiet among stakeholders, notably the system designers who were asked for the first time to assume responsibility for reducing injuries and fatalities. To enter into a meaningful debate about the new approach, it was necessary to first open up minds by demonstrating the potential of a Safe System and address concerns regarding the changes that were being demanded.

A critical step in adopting a Safe System is to convince all stakeholders that:

- A new approach to road safety is needed (urgency for a change).
- A Safe System is the way to go.
- Creating a Safe System is possible and within reach.

All Safe System pioneer countries undertook considerable efforts to involve, engage and convince all those stakeholders whose contributions would be required to make a Safe System work: politicians and policy makers, road authorities and construction companies, vehicle manufacturers and the police, road safety educators and health professionals, as well as the general public and road users specifically.

The experience of Safe System pioneers shows that there is no single way to do this. How to best engage them depends on the local and temporal context. In France, for example, political leaders have a strong role in initiating change in road safety policy, whereas in Sweden government road safety officials and transport planners played a leading role. In the Netherlands, the vision of a Safe System was introduced and popularised by the Institute for Road Safety Research (SWOV), and New Zealand implemented a detailed "cultural change" campaign to reorient thinking about road safety (see Box 3.2).

Political support for a Safe System approach in Sweden came in the form of strong backing by the Minister of Transport, whereas in the Netherlands political support from the minister was generated via parliamentarians in the Dutch House of Representatives, with support from the road safety research community. Both in Sweden and the Netherlands, policy makers also played a role in securing support from the Minister of Transport. The important role of senior officials and public servants in governments in harnessing leadership for a Safe System should not be underestimated. While it is always elected government that makes critical decisions, senior officials are exposed to key information about the public health issues on the road network, they see data and information and analysis that compels them to act with strong leadership and conviction to ensure they effectively communicate to guarantee their Ministers are fully aware of the size and scope of the trauma problem and the most effective plans, strategies and approaches to respond. It can be argued these senior officials have a moral and ethical professional requirement to act to ensure Ministers and key decisions makers are fully informed and supported with good information, policy and strategy advice to enable good decision making to respond effectively for the community.

Despite the different experiences and approaches, a number of general lessons can be learned from Safe System pioneer countries. First, consensus among road safety experts and professionals on the desirability of a Safe System and clear positioning in favour of it is important. If experts disagree, policy makers and politicians will feel uncertain and decisions might be postponed.

Box 3.2. **Case study: Popularising a Safe System in New Zealand**

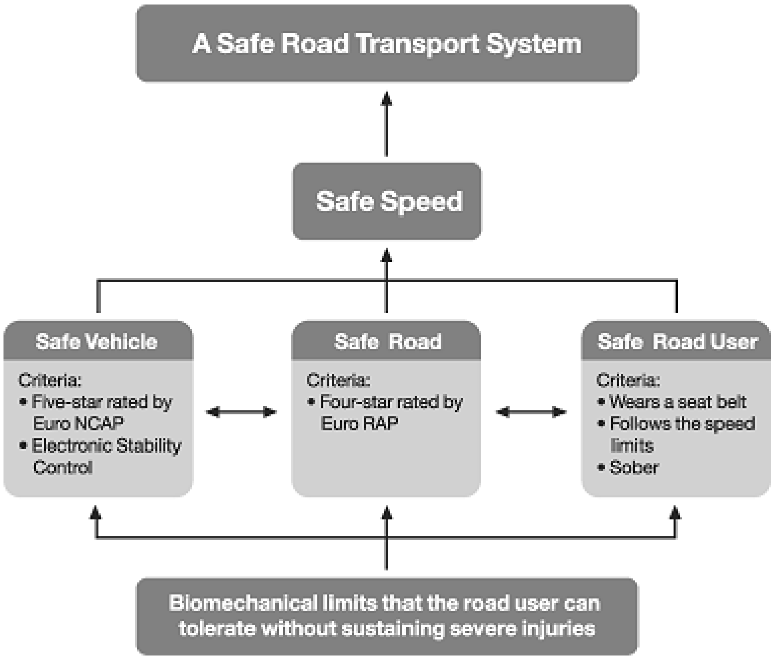
New Zealand adopted a Safe System in 2010 with the launch of its Road Safety Strategy 2010-2020, called “Safer Journeys”. Two focus areas of the first action plan (2011-12) were to embed Safe System thinking, policy and practice throughout New Zealand and to generate a broad conversation about road safety and the Safe System. Among the actions identified for this was the development of indicators to monitor the embedding of a Safe System. The second action plan (2013-15) continued this theme with actions to “Advance the Safe System approach”. A three to four-year programme of initiatives was developed to create the necessary cultural change. Initiatives included:

- Developing a stakeholder map to identify those with the greatest level of interest, impact and influence, with which to engage and communicate initially, and undertaking a targeted programme of engagement. Stakeholders included staff and elected officials in national and local governments, implementing staff in road authorities, police and transport agencies and road safety community organisations
- Developing a range of Safe System resources including a communications guide, standardised presentations for different audiences, pamphlets specific to various system designer groups, and case studies.
- Sponsoring international Safe System experts as guest speakers at key conferences to lead seminars and workshops with staff and sector partners.
- Develop a set of Safe System-based best practice manuals (many of these can be found on the Safer Journeys website www.saferjourneys.govt.nz).
- Developing a two-day, hands-on, exercise-based Safe System training workshop. To date more than 1 200 staff and key stakeholders have attended this workshop (Climo et al. 2013).
- Modifying a long running, one-week road safety engineering workshop so it took a wider Safe System approach in addressing road safety issues primarily from a speed management and infrastructure perspective.
- Developing a 20-minute Safe System film entitled “The difference between life and death”.

Incorporating Safe System messaging into national road safety advertising programmes to change the road safety conversation and raise awareness of the need for a safe road system. The main messages were “People make mistakes”, “People are vulnerable” and “We need to take shared responsibility for road safety”. These campaigns have won multiple international awards for excellence in influencing public opinion.

Second, it is imperative to show that a Safe System delivers results, and to communicate those results in a clear and consistent way. In Sweden, for example, a concise visualisation of what constitutes "A Safe Road Transport System" was developed which summarises the underlying principles of a Safe System in an easy-to-grasp way (see Figure 3.2.) It has been used in communication especially with researchers, experts and policy makers.

Figure 3.2. **Model of a safe road transport system**



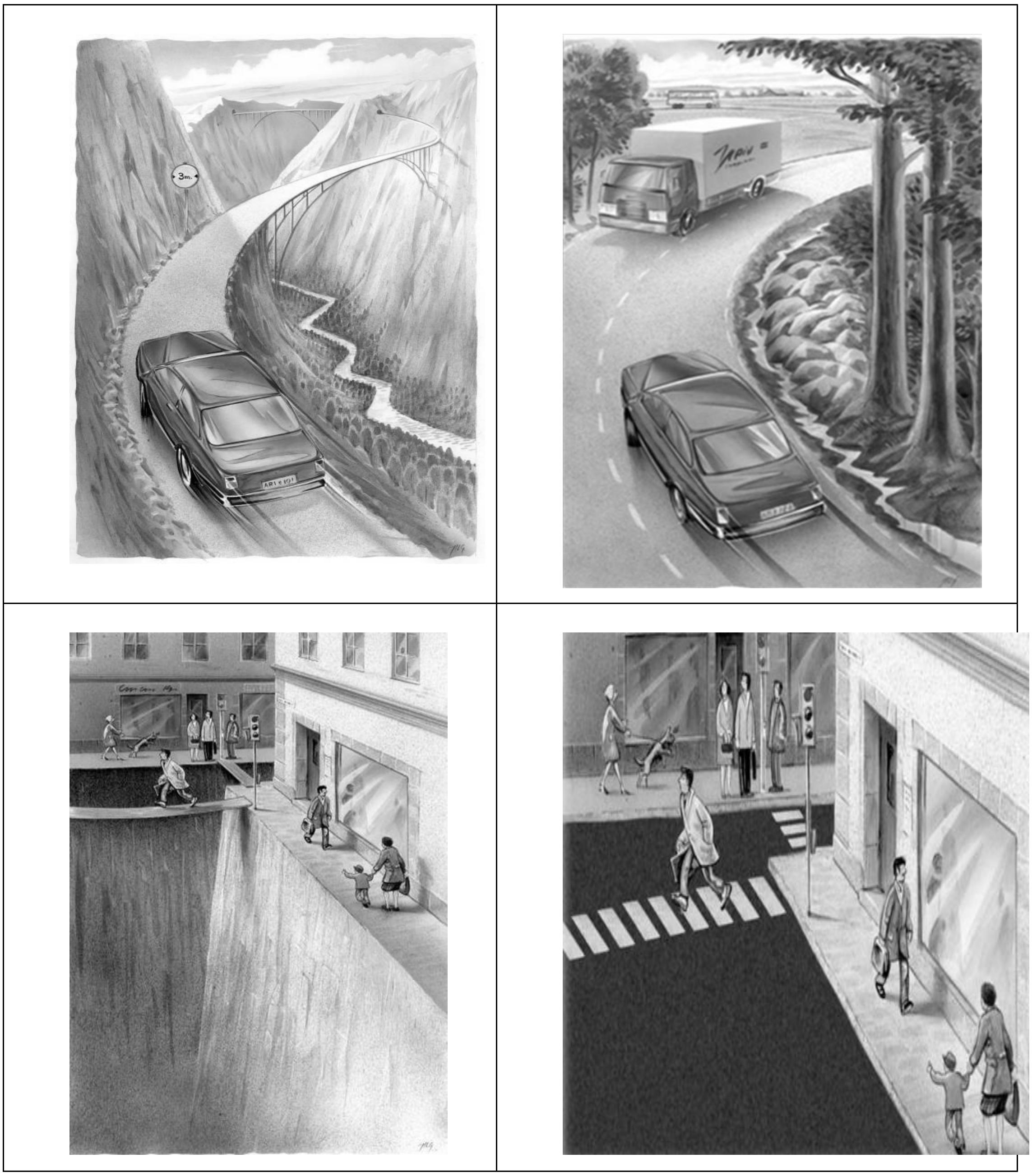
Source: Swedish Transport Agency.

In Sweden, so-called precipice pictures (Figure 3.3 below) were used in public communication to illustrate in a pedagogic way the risks we expose ourselves to in road traffic every day. The picture on the left is designed to show the risk of harm from the forces associated with falling from a great height due to gravitational forces and the resulting impact velocity. The pictures on the right in each example seek to illustrate that in everyday traffic situations, people are exposed to similar levels of potential impact forces from horizontal velocity as they would be from gravitational impacts associated with a fall from great height. It is thought that most people have a much better developed understanding and risk appraisal of falling from height compared to horizontal velocity.

In Victoria (Australia), the Transport Accident Commission (TAC) developed a long-term "Towards Zero" public education campaign to cement the goal of zero deaths on Victoria roads (see Box 3.3).

Demonstrations and pilot projects can also be helpful to raise awareness among road users, system designers and politicians that a Safe System improves road safety. At the same time, they are a useful way to test and evaluate interventions before implementation on a larger scale. An important demonstration project in Sweden was the so-called 2+1 road, a three-lane road with two lanes in one direction and one lane in the other that alternate every few kilometres, as an alternative to traditional motorways. The pilot project provided evidence for a positive safety effect of this concept and convinced road designers and engineers that this was an appropriate solution for the Swedish situation.

Figure 3.3. **Precipice pictures used in Sweden to communicate inherent road safety risks**



Source: Swedish Transport Agency.

In the Netherlands, demonstration projects were also used to test, for instance, 60 km/h zones on roads in rural areas, road designs for speed reduction, and enforcement programmes. In Western Australia, a range of demonstration projects were carried out to illustrate the effects of speed limit reductions, adjust speed limits to complement road infrastructure, introduce more consistent speed limits and develop a community education programme to enhance understanding of the benefits of lower speed limits. These demonstration projects were introduced as a reaction to divided opinions in the community regarding the desirability of speed limit reductions that emerged in a consultation process (Corben et al., 2010).

Bringing in international experts can give credibility to the new approach and help build trust among stakeholders that the vision is implemented in a good way. Both in Australia and New Zealand international experts were brought in to hear about and learn from others' experiences. In New Zealand for example, international Safe System experts were invited as guest speakers at key conferences and were asked to lead seminars and workshops with staff and sector partners. How implementation of the Safe System vision is organised can also help in engaging stakeholders. In the Netherlands for example, the chairman of the steering committee responsible for developing an implementation strategy for the "Sustainable Safety" approach (as the Safe System is known in the Netherlands) was a representative of the Dutch provinces and not of the lead agency. This likely contributed to securing support from other levels of government for implementation of the strategy.

Box 3.3. **Case study: Engaging the community for "Towards Zero" in Victoria (Australia)**

In August 2015, the first phase of Victoria's "Towards Zero" campaign was launched, with the aim of putting the ethical principle that no one should be killed on the road on the community's agenda. The initial campaign personalised the issue of road trauma and helped the community to understand why zero road deaths is the only acceptable goal to aim for and to create buy-in from the public. The communication concept was centred on the theme that no one wants their family to become the victim of a road crash. This helped raise awareness for the fact that everyone who dies in a crash is someone's relative and that there is no person who will not be missed. Therefore, the only acceptable road trauma goal is zero. (The campaign can be viewed at: www.tac.vic.gov.au/road-safety/tac-campaigns/towards-zero#towards-zero).

In November 2015, the second phase of the campaign was launched to help the community understand what a safe road system can look like and how it can protect people when mistakes occur. By looking back at historical trends and what has been achieved, the aim was to demonstrate to the community that Victoria can continue to do better, until the goal of zero road deaths is reached. The campaign emphasised that the way forward is to build a safe road system involving safe roads, safe vehicles, safe speed and safe people that can accommodate people's mistakes (www.tac.vic.gov.au/road-safety/tac-campaigns/towards-zero#then-and-now). The next phases of the campaign will focus on other keys areas of the Safe System philosophy including human vulnerability. The Victorian Government "Towards Zero" road safety action plan was launched in May 2016 and can be accessed at www.towardszero.vic.gov.au/what-is-towards-zero/road-safety-action-plan.

Create an increased demand for road safety among citizens

A highly effective way to engage politicians, policy makers and system designers in a debate on a Safe System is to create increased demand for road safety among citizens. The traditional societal view holds that road users bear the main responsibility for road safety hazards. It is they who should be "blamed and shamed" for incidents and measures should focus on correcting their irresponsible behaviour. In contrast, a Safe System is based on the notion that road users are citizens with rights and should be able to take part in road traffic without risking death or serious injury – even if and when they make simple human mistakes. A Safe System also posits that road safety is a shared responsibility, and thus gives citizens the right to demand safe road traffic from society.

The impetus for change often stems from the awareness that a better alternative and more effective solution exists but is not being used (Belin et al., 2012). Convincing citizens of the potential of a Safe System could create an increased societal demand for road safety. In such a scenario, road safety NGOs and advocacy groups have an important role to play. They can actively contribute to safer road traffic partly by increasing the knowledge and insight of their members regarding alternative interventions in relation to the risks of injury in traffic, and partly by supporting and channel the demands of citizens for safer roads, vehicles and road transport to the decision makers. As the case studies in Box 3.4 and Box 3.5 show, the concept of a Safe System for road safety was communicated to the public in both Sweden and Australia with the aim to increase public demand for road safety.

Box 3.4. **Case study: Increasing public demand for road safety in Sweden**

The success of Sweden's "Vision Zero" initiative relied heavily on engaging road users, the public and the business sector as agents of change. Their role was to make clearly-stated and powerful demands on the designers of the system to improve road safety. To this effect, comparisons were made between road safety and other safety-critical areas, such as the electrical system in private homes, which are conceived to be extremely tolerant of human mistakes, or legislation on safety in work places, which squarely puts responsibility for employee safety on the employer. Such comparisons showed the incongruity of holding the road user responsible for the safety of the road traffic system with safety principles applied elsewhere.

The media and Sweden's National Society for Road Safety (NTF), a non-governmental organisation for the promotion of road safety, also played an important role by channelling citizens' demands into the political system by levelling criticism at the government for accepting a poor road safety performance. This helped to raise awareness of the problem and led to an 11-point government programme for improved road safety. Early successes and the resulting positive media coverage also raised awareness of "Vision Zero" and brought a positive shift in public opinion.

The media was also influential in other ways to create support for "Vision Zero at an early stage. A motor journalist with one of Sweden's leading newspapers wrote several articles about the problems created by putting all responsibility for safety on the individual road user and pointed out the necessity of giving others such as vehicle manufacturers and infrastructure providers, more responsible for road safety.

In the Netherlands, one approach taken to communicate the Safe System principles was to link them to the existing experiences of citizens by using the analogy to safe drinking water. However, this did not work as intended. The public did not seem to be interested in the concept. Alternatively, an attempt was made to convince the public that zones with speed limits of 30 km/h and 60 km/h were needed to improve road safety specifically for children in residential areas. This resonated better and led to increased public demand for such zones with reduced speeds.

Maintaining support from stakeholders

Stakeholder support is not only important for enabling the paradigm shift, but also throughout the process of establishing and implementing a Safe System. Especially when the number of fatalities is decreasing, in times of economic recession, and/or in times when there are other social problems that seem more urgent and get more political priority than road crashes, it may be a challenge to maintain sufficient political attention for road safety and to keep stakeholders focused on the establishment and implementation of a Safe System. Box 3.6 shows that in the Netherlands for example it appeared to be difficult to maintain full support from all stakeholders for a system-wide implementation of a Safe System.

Some of the instruments that were previously discussed for creating support are also useful for maintaining support from stakeholders. It continues to be important to communicate that it is necessary to further improve road safety. Instruments like short-term road safety targets, benchmarking and in-depth analyses of crashes are useful for communicating this. Moreover, it is important to sustain a high public demand for road safety and to make sure that citizens keep on asking for safer roads, safer vehicles and safer transport in general.

Box 3.5. **Case study: The experience with community consultation in Western Australia**

During 2007, a new road safety strategy for the state of Western Australia known as “Towards Zero” was developed for the period 2008 to 2020. In this context, the Western Australian Road Safety Council (RSC) received the support of the Minister for Road Safety to undertake an extensive consultation process prior to submitting its recommendations for a new long-term strategy to the Government. This consultation aimed to engage community and stakeholders with a view to raising awareness for the nature of existing road safety problems, and to seek feedback on the level of support that existed for various countermeasures. It was based on the fundamental belief that the community should be provided with the best evidence about what works, no matter how controversial, so that it can debate and consider the options available to improve road safety (Corben, Logan et al., 2010).

To inform a dialogue with the community, the Road Safety Council drew upon the expertise of researchers from Monash University in Melbourne to develop a discussion paper which introduced the Safe System and outlined a series of options for road safety countermeasures. The community was then invited to make general comments online and to respond to a questionnaire based on the paper.

Additionally, Western Australia’s Minister for Road Safety invited all Members of the state parliament to host a road safety forum in their local community if there was sufficient community interest. At more than 40 such forums throughout Western Australia, representatives of the RSC engaged in a dialogue on road safety problems and the packages of potential countermeasures; typically with local secondary school students in a morning workshop and community members and leaders in an afternoon workshop. The feedback received online, from other written correspondence and from the community workshops was then reviewed and compiled by the RSC into a “Recommended Strategy” document, which reflected “both community views and expert advice, for presentation to the government”.

To build understanding and support, the Minister also invited members of parliament to a bipartisan Parliamentary Reference Group which received briefings and discussed the evidence of the road safety problem, potential solutions and the feedback from the community consultation. The feedback from the community showed a high degree of concern about road deaths and serious road injuries, as well as recognition that reducing both is a shared responsibility of the entire community. Predictably, the different measures proposed received varying levels of support. There was generally strong support for additional measures to further improve vehicle safety, improve the safety of roads, and for education and enforcement actions to improve driver behaviour including reducing speeding, drink and drug driving and to increase seatbelt and helmet wearing. Community support was mixed for systematically reviewing and reducing speed limits, while support existed for reducing speed limits in high-risk locations, for example in areas with high pedestrian and cyclist activity.

As a result, the RSC recommended introducing a comprehensive Safe System approach for Western Australia, involving a range of measures designed to achieve a 40% reduction in road deaths and serious injuries by 2020. While expert advice suggested even more ambitious results could be achieved with widespread speed limit reductions, the mixed community support for these was respected by the RSC in its recommendations to the government. By being able to clearly demonstrate both the benefits and citizens’ views on the new strategy, the RSC gave both government and parliament a high level of assurance that the proposed strategy would be widely supported by the public, thus making both the executive and the legislative more receptive for, and ultimately supportive of, the “Towards Zero” strategy. It was established by Western Australia’s parliament in March 2009 with bipartisan support.

The critical role of blending scientific, expert advice and community views in developing a road safety strategy that is both ambitious and in line with community wishes is summed up in a comment received from a community member who attended one of the forums, reacting to a proposal to widespread lowering of speed limits to improve safety: "You have done your homework and presented the evidence clearly and I have appreciated our debates this morning. My head agrees with you - but my heart does not. But someone needs to make a decision and get on with it, I may grumble initially but then I will get over it and our community and my grandkids will benefit.”

Providing continuous evidence that a Safe System is effective in delivering improved road safety is a powerful way of maintaining momentum. This is one of the reasons why SWOV analysed the impact of the Dutch "Sustainable Safety" programme after ten years of operations. The main conclusion from this study was that "Sustainable Safety" has been (cost-) effective in reducing the number of fatalities in the Netherlands (Weijermars and Wegman, 2011).

For maintaining stakeholder support and continued political commitment for the implementation of a Safe System, both the long-term vision as well as the implementation strategy should be subject to a regular review process, and updated and improved as necessary. In the Netherlands for example, SWOV published a first update of the "Sustainable Safety" vision, called *Advancing Sustainable Safety* in 2006 and is currently working on a second update (Wegman and Aarts, 2006). The main aim of these updates is to make sure the vision optimally responds to (future) developments in road safety, such as technological innovation or an aging population. They also explore new ways to involve and commit stakeholders, based on experiences in other countries. At the moment, the Netherlands is for example exploring the use of interim targets related to Safety Performance Indicators.

Box 3.6. **Maintaining support of stakeholders and political commitment in the Netherlands**

The Dutch version of the Safe System approach in road safety, called "Sustainable Safety", was first introduced in 1991. Following the adoption of this vision, various actions were taken to implement it. Initially, research institutes elaborated the vision into principles and guidelines for road authorities and a Steering Committee Sustainable Safety was created to develop an implementation strategy. It was decided to implement "Sustainable Safety" in two phases: an initial "start-up programme" would be followed by system-wide implementation. The start-up programme (see also Box 4.3 was a five-year covenant signed between the Minister of Infrastructure, the Dutch provinces, the municipalities and the water boards. It comprised 24 action items that the partners agreed to carry out between 1998 and 2002. The start-up programme also contained an outline of intentions regarding the decision-making process required for the full-scale implementation of "Sustainable Safety".

This second phase, however, has not yet been formally launched. Despite enormous improvements, especially in infrastructure, at the time of writing (Summer 2016) a Safe System is not yet fully implemented in the Netherlands. Moreover, although the principles of "Sustainable Safety" are incorporated in national, regional and local road safety policies and despite various actions that have been taken to increase the safety of roads, vehicles, road users and to improve post-crash care, efforts sometimes seem to be less ambitious than during the start-up programme. Paradoxically, the positive effects of the measures implemented then may have contributed to this.

Conclusion

No country has yet reached the ultimate destination, i.e. achieved a state where road traffic truly functions as a Safe System and holistic thinking and integrated practices shape all relevant road safety processes and decisions but many countries have started and are at different points in their journeys.

The first step in establishing a Safe System is to change the general mind-set about road safety. All stakeholders need to understand and accept that a) the traffic system should be designed and used in such a way that no human is killed or seriously injured as a result of a road crash; and b) the prevention of crashes and their consequences is a shared responsibility of everybody involved in road traffic, from system designers to users.

There is no fixed roadmap for the adoption, establishment and implementation of a Safe System. Instead, it is more of a learning-by-doing process which can be described as a journey that presents opportunities, hazards and challenges along the way. Each country follows its own journey, depending on the culture and temporal and local context. From the countries that already adopted a Safe System, it can be learned that three elements are critical for changing the general mind-set: a) creating a sense of urgency for change; b) convincing all stakeholders that a Safe System is the way to go; and c) having leaders available to initiate and persistently support the change towards it. As election cycles and other factors can work against continuity in leadership, it is important that leaders organise the change process in such a way that agency vision, strategic business plans, policy and organisational structures and processes are in place to continue the journey to implement a Safe System.

Road safety targets, benchmarking and in-depth studies of road safety crashes can be used to create a sense of urgency. To be able to apply these instruments, it is very important to collect relevant and reliable data on road safety performance. Convincing citizens of the potential of a Safe System can increase public demand for road safety which can subsequently help to engage politicians, policy makers and system designers.

References

Bhalla, K. (2014), “Institutionalizing Road Safety Management in Argentina”, World Bank.

Belin, M. A., P. Tillgren and E. Vedung. (2012), “Vision Zero - a road safety policy innovation”, in International Journal of Injury Control and Safety Promotion, Vol. 19/2, pp. 171-179. DOI: http://dx.doi.org/10.1080/17457300.2011.635213

Bornstein, D. (2007), How to Change the World: Social Entrepreneurs and the Power of New Ideas, Oxford University Press.

Carnis, L., and E. Blais (2013), “An assessment of the safety effects of the French speed camera program”, in Accident Analysis and Prevention, Vol. 51, pp. 301-309. DOI: http://dx.doi.org/10.1016/j.aap.2012.11.022

Climo, H., M. Dugdale and L. Rossiter (2013), “The safe system in practice - a sector-wide training programme”, paper presented at the Australasian College of Road Safety Conference A Safe System: The Road Safety Discussion, Adelaide.

Corben, B. F., D. B. Logan, L. Fanciulli, R. Farley and I. Cameron (2010), “Strengthening road safety strategy development ‘Towards Zero’ 2008-2020 – Western Australia’s experience scientific research on road safety management SWOV workshop 16 and 17 November 2009”, in Safety Science, Vol.48/9, pp. 1085-1097. DOI: http://dx.doi.org/10.1016/j.ssci.2009.10.005

Koornstra, M., D. Lynam,G. Nillson, P. Noordzij, H.-E. Petterson, F. Wegman and P. Wouters (2002), SUNflower: A Comparative Study of the Development of Road Safety in Sweden, the United Kingdom and the Netherlands, Dutch Institute of Road Safety Research (SWOV), Leidschendam

Kuhn, T. (1962), The Structure of Scientific Revolutions. University of Chicago Press.

Peden, M. et al. (2004), World Health Report on Road Traffic Injury Prevention, World Health Organization, Geneva, Switzerland.

Shove, E., and M. Pantzar (2005), “Consumers, Producers and Practices: Understanding the Invention and Reinvention of Nordic Walking”, in Journal of Consumer Culture, Vol. 5/1, pp. 43-64. DOI: http://dx.doi.org/10.1177/1469540505049846

SWOV (2013), “Sustainable Safety: Principles, Misconceptions and Relations with other Visions", fact sheet, Dutch Institute of Road Safety Research (SWOV), Leidschendam www.swov.nl/rapport/Factsheets/UK/FS_Sustainable_Safety_principles.pdf

Wegman, F. and L.T. Aarts (2006), Advancing Sustainable Safety: National Road Safety Outlook for 2005-2020, Dutch Institute of Road Safety Research (SWOV), Leidschendam

Wegman, F., and P. Wouters (2002), “Road safety policy in the Netherlands: facing the future", in Annales des Ponts et Chaussées, nouvelle série, no. 101, janvier-mars 2002.

Weijermars, W. and F. Wegman (2011), “Ten Years of Sustainable Safety in the Netherlands. An Assessment”, in Transportation Research Record, Vol. 1-8. TRB, Washington.

Notes

11. In this context, the work of International Traffic Accident Data and Analysis Group (IRTAD Group) in carrying out in-depth reviews of country data and validating them by inclusion in the IRTAD database represents an important contribution to improving road safety policy. Many countries regard reaching the IRTAD standard for crash data as an objective and are putting considerable efforts into strengthening their national crash data system. To help with this, IRTAD country twinning programmes also assist interested governments in improving their data. For 2014-15, data from 32 countries were collected, validated and included in the IRTAD database.
12. www.fundforglobalhealth.org/join-the-3-star-coalition

Chapter 4. Safe System management and governance

Safe System thinking must be embedded into a systematic and sustained way of working. It requires re-orientation from top-down management to a bottom-up approach, with governance and management structures that focus on outcomes through setting objectives, rather than on prescribing methods. Safe System management acts as facilitator in a broad coalition of stakeholders that share responsibility for improve roads safety in a mutually reinforcing manner and a process of continuous improvement. It relies on data and factual evidence to set targets, monitor progress and adapt measures in consultation with stakeholders.

Adopting the paradigm shift in thinking to a Safe System is only the first step in its implementation - it enables a toehold on the new path to road safety improvement to be established. This chapter discusses how to imbed Safe System thinking into a systematic and sustained way of working. The four principles set out in Chapter 2 are fundamental and essential to guide the journey to a Safe System. Its implementation is a continuous exploration process of learning by doing. What works well in some policy and cultural settings may not necessarily work in others. The point of departure in terms of institutional development, road safety performance and so on varies from country to country or jurisdiction to jurisdiction when initiating this path. The best way to establish a Safe System reflects the local context and opportunities, and also evolves over time. Nevertheless, there are some useful guidelines and instruments that can be applied under many circumstances. Some valuable lessons can be learnt from those pioneering countries that have made most progress in the establishing a Safe System on their roads.

A core take-away from this is that a Safe System requires a re-orientation from governing to governance. While governing is a purposeful act to steer, guide and control behaviour, governance is a mode of social coordination focused on outcomes. Governance structures are optimised to organise negotiation processes, determine objectives, influence motivations, set standards, resolve disputes as well as performing allocation functions and ensuring compliance. They effectively exercise of power through managing networks of interconnected actors, in which all actors contribute to a mutually desired outcome through knowledge, resources, money and rights granted to them under the governance arrangements

Managing a Safe System by results

Effective management of a Safe System has a focus on results and the achievement of safety objectives or outcomes. A focus on results involves monitoring road safety performance against a set of safety performance indicators. Analysis of results, trends and research into underlying contributing factors then informs planning, prioritisation and the allocation of resources for effective interventions. Good management also requires coordination of the different agencies and organisations so that interventions across all parts of Safe System are implemented in such a way so as to optimise their effectiveness in combination with other interventions. Leading practice in the management of road safety for ambitious results includes:

- The political will and leadership to adopt a paradigm shift towards zero deaths and serious injuries, while setting and achieving ambitious interim targets on this journey.

- The implementation of systematic and co-ordinated interventions based on evidence for the achievement of improved results.

- Ensuring the required management functions are in place and operating optimally to provide the “production line” that will generate the necessary interventions. (ITF, 2016)

Once stakeholders are engaged and ready for change, the management structure must support them in assuming their share of responsibility. This also includes support for close co-operation between authorities and stakeholders. An effective Safe System management structure will include multi-stakeholder processes (Wageningen University, 2016) that involve joint agreement on road safety targets and how to achieve them. In this set-up, the role of the authorities changes from a traditional management role to a networking role to facilitate the management of networks, negotiation processes and so on, rather than managing interventions in detail. For some countries, notably among low and middle income countries, knowledge transfer, resourcing and strengthening of public administration is essential to provide a strong foundation for the journey to a Safe System.

Seven management functions that are important for road safety have been identified by the World Bank (Bliss and Breen, 2008):

1. Results focus
2. Co-ordination
3. Legislation
4. Funding and resource allocation
5. Promotion (communication)
6. Monitoring and evaluation
7. Research and development, knowledge transfer.

Management for a Safe System should exemplify the good governance principles of transparency, accountability, participation, inclusiveness, responsiveness and promotion of the rule of law. All of these are highly relevant and applicable to road injury prevention. Generalising from experiences from the Safe System pioneer countries, two main strategies for the establishment and management of Safe System in a country can be distinguished: The "top-down" or centrally driven approach uses policy and regulatory instruments that specific exactly what should be done and by who. The "bottom-up" approach stresses the fact that road safety is a shared responsibility and thus cannot be successful without a democratic process where public demand for better safety is initiated, sustained and developed further.

Both approaches highlight the importance of a lead agency and of the development of institutional management capacity as a critical condition to the elaboration of an ambitious and coherent road safety program, its promotion, and the co-ordination of the efforts for its implementation. It is just the approach to implementation that varies from "top down" to "bottom up". In most cases, however, both approaches will be helpful and even necessary, as they emphasise different but complementary elements of the process. In the top-down approach, the central role is performed by government, with policy, standards and regulations issued centrally and specifying in detail what a stakeholder in the system should do, achieve and how they should do it. Prescribed penalties often apply for non-compliance.

Other top-down or centrally driven policy instruments and strategies include communications (e.g. information, marketing and promotion) and economic (e.g. grants, subsidies, taxes and user charge). These instruments are used with the main purpose to create and ensure "correct" behaviour among different stakeholders.

The top-down approach contains an inherent risk that road safety becomes an isolated process in society, with its own separated management and funding, rather than being incorporated into a more integrated societal policy. Safe System pioneer countries learned that safety needs to be an integrated and proactive dimension within many different societal processes, and not a separated, reactive process. Integrating road safety into wider transport and societal policy is important not least to motivate stakeholders to take more responsibility and not count on "someone else" to solve the road safety problem. Within the framework of shared but integrated responsibility for a Safe System, mechanisms to ensure accountability, individually as well as collectively, of the actors are of great importance. Performance indicators are one way of establishing clear accountability for the different parts of a Safe System and to allow focusing collaboration on better results.

In low and middle-income countries, road safety management structures with strong and clear mandates can be very effective to help launch the change process and ensure appropriate multi-sectoral co-ordination, sustained commitment and action to deliver lasting results. This can help mitigate risks from political disruptions, lack of ownership of the change process or weak responsiveness to multi-sectoral interventions. Under such circumstances, a lack of strong overall management may also lead to a dispersion of valuable expertise and capacity (e.g. universities, insurance associations, statistical offices, etc.). While the institutional set-up for a Safe System should be designed to ensure sustained authority, care needs to be taken where overall authority is absent to preserve and utilise the capabilities that do exist. A number of elements have been observed to contribute to successful road safety management structures, notably independence, accountability, strong leadership, adequate and reliable funding, and well-trained and adequate human resources.

In countries like Sweden, for example, it became clear that traditional top-down and centrally driven management structures and approaches with traditional policy and regulatory instruments connected to them were not effective enough in terms of shared responsibility. These management structures needed to be redesigned from the bottom up in order to foster innovation and responsibility-taking by the different actors in the system, as well as in influencing market forces so as to create a market for road safety (see Box 4.1). The establishment of a Safe System in Sweden was very much focused on such a bottom-up approach to develop and establish new and innovative policy instruments and processes to raise the awareness of, educate and mobilise stakeholders and the community about the safety problem and to encourage engagement in, and contribution to, the actions for solutions to improve road safety outcomes.

Box 4.1. **Safe System in a governance context**

To understand the implementation and establishment process of a Safe System it has also to be viewed in a governance context. Governance relates to "the processes of interaction and decision-making among the actors involved in a collective problem that lead to the creation, reinforcement, or reproduction of social norms and institutions." (Hufty, 2011).

The traditional way of achieving a desirable state in a system in society is through a command-and-control approach: the authorities specify in detail what a stakeholder in the system should do and achieve, and how this is to be achieved (Carnes, 2011). However, in some areas, there is a shift away from an authority-based form of governing which relies on the capacity of governments to exercise hierarchical control over society. In the shift away from hierarchical control it is recognised that societal actors have assumed an increasing involvement and responsibility in governance activities. In these versions of governance, the process of steering involves an interaction of the public and the private sectors, and also an interaction between top-down and bottom-up conceptions of how society can be steered.

The so-called garbage can model of organisational behaviour provides a description of how governance can be exercised exerted in society which is less clearly governed through authority and hierarchy.

It is a model which expands organisational decision theory into the then uncharted field of organisational anarchy (Cohen et al., 1972). This model rejects conventional linear models of organisational decision-making in favour of less determinate and less rational forms of making decisions. The fundamental assumption underlying this model is that decisions in many situations result more from coincidental confluence of opportunities, individuals and ideas than they are programmed or predictable (Peters, 2002), that is a lot of different factors all come into a garbage can and are mixed together in decision making. It is argued that “policy windows” open and that policy entrepreneurs must then be prepared to exploit the opportunities (Cohen et al., 1972).

The bottom-up approach to mobilising and building support for road safety intervention in a shared responsibility is also an increasing way of working in a number of the countries pioneering the implementation of a Safe System. These policy instruments and tools will be further described and exemplified in the following section. Box 4.2 shows a bottom up example of working in safety from Japan.

There is no standard management structure for a Safe System; it has to be tailored to the political, social and cultural context. In some countries, a top-down, centrally driven management structure based on strong institutions with clear mandates and accountability may be appropriate. In others (like Sweden), a more philosophical, visionary focus on the paradigm shift will be taken and translated into a more bottom-up management approach that supports this. One element that is required in every Safe System management structure is strong and dedicated leadership, especially political leadership. The fact that management structures and processes are still very much in development in some of the countries achieving good results with a Safe System highlights how vital an ingredient this is.

Box 4.2. **Case study: Bottom-up approach to a Safe System in in Japan**

Japan follows a bottom-up type approach to implement safety measures for streets used for school commuting. With the current birth rate in Japan (1.42 in 2014) far below replacement level, assuring children's safety is seen as a major responsibility of the Japanese government. In April 2012, a series of traffic crashes killed a frightening number of children, and injured others, on the way to school in April 2012, partly in Kameoka, a city in Kyoto Prefecture. As a reaction, emergency inspections of school-commuter roads were carried out jointly by schools, boards of education, road administrators and the police, in collaboration with parents as well as with other community leaders from May 2012. These inspections targeted commuting roads for 20 160 schools across the nation.

By the end of November 2012, a total of 74 483 distinct locations were identified as requiring remedial safety measures and an action plan was adopted for each of these. Responsibility for implementing the programme rests with the locality concerned. Since that time to the present, schools, school boards, road administrators, and the police have been working together to solve the problems identified, beginning with those for which solutions are readily available. As of the end of March 2015, 90% of all the improvements called for as a result of the joint inspections had been completed. Beginning in December 2013, local authority-level committees were created in order to address all on-going problems relating to school-commuter roads. The role of the committees is to co-ordinate with the stakeholders mentioned above and to implement the safety measures year by year.

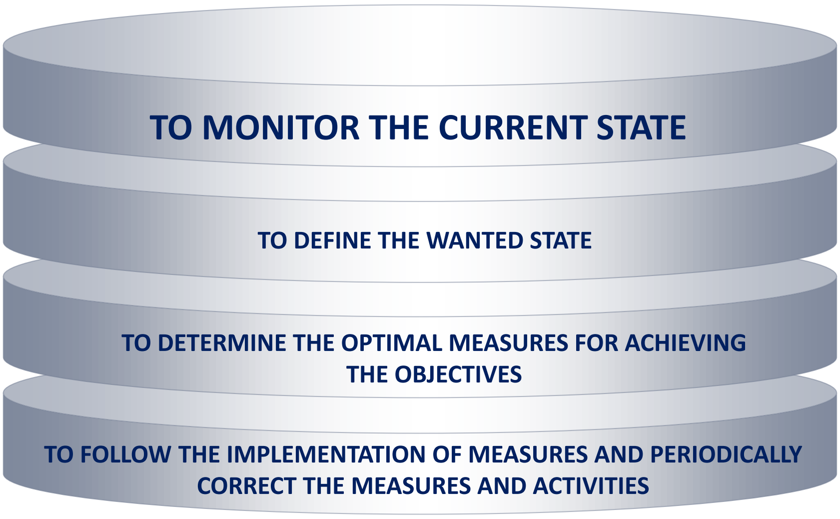
Systematically managing for a Safe System

A small cell of professionals to establish a Safe System can be very helpful, as the experience from leading countries shows. In Sweden, a special Safe System task force was created within the Swedish Road Administration (now the Swedish Transport Administration), the national authority which then had the overall responsibility for road transport. This task force was a small but dedicated team which saw it as their mission to spread the philosophy of "Vision Zero" across the country. In the Netherlands, a steering committee consisting of representatives from different levels of government was appointed to develop an implementation strategy for the Dutch "Sustainable Safety" strategy.

Whether such a core group needs more formalisation or less is open to debate. As Safe System implementation is a learning-by-doing process, a degree of flexibility is needed at least in the early phase to be able to seize opportunities that arise along the way. Once a steady state is reached, it becomes more important to have a strong lead agency to continue to drive the process and keep the political and societal interest in road safety alive. Yet this does not necessarily mean that formal institutional structures and a "top-down" approach are best suited. The lead agency should still apply work processes that are "bottom up", inclusive and enable all stakeholders to take active responsibility in the planning, implementation and monitoring of road safety interventions and performance to achieve a Safe System Regardless of the management structure chosen, its operational model must ultimately support the development and implementation of Safe System interventions. A systematic way of thinking and designing interventions that is not based on the basic principles of a Safe System will very likely result in suboptimal outcomes in terms of improving road safety performance.

In particular, it is vital that the management approach reflects the need for close collaboration with, and among, stakeholders. In practical terms, such an approach could follow the steps of a "Plan-Do-Check-Act" (PDCA) process. PDCA is an iterative four-step management method used in research and business for continuous improvement. A crucial aspect of PDCA is the active involvement of system designers and stakeholders at every stage, and hence the sharing of understanding of the Safe System and responsibility for the outcomes. Figure 4.1 details how the PCDA process, which is cyclical in nature, translates into different levels of managing road safety.

Figure 4.1. **The levels of the management of road safety**



With respect to road safety, the PDCA process is very much dependent on the availability of high-quality road safety data. Meaningful monitoring is not possible without easily and promptly accessible road safety databases that are up-to-date, fed by a well-designed collection system, have the best possible scope and structure, and include standardised indicators to allow comparisons.

Analyses of relevant road safety data allow a good understanding of existing conditions, help to define the wanted state and thus formulate objectives, to identify those measures most suited to achieving targeted road safety improvements, and to finally evaluate their impact with a view to seeking further improvements in the next iteration in a cycle of continuous improvement.

While there is a consensus about the importance of developing and improving road crash databases, in practice the effective use of crash data is hampered by problems such as different definitions in different countries and the lack of detail. In Europe, the European Commission has proposed a standardised accident dataset (known as CADaS) to address these issues.

In recent years, the value of bringing together road safety data from various sources in integrated road safety databases has been increasingly recognised. To be useful, such consolidated databases should contain at least the following sets of data:

- General data (e.g. population, socio-economic indicators, geographical indicators)
- Road data (e.g. category of road, sections, star ratings, footpaths, length, traffic signs, markings)
- Traffic data (Average annual daily traffic, structure of traffic flows, vulnerable road users, etc.)
- Road crash data
- Injury data (Maximum Abbreviated Injury scale)
- Behavioural data (e.g. safety performance indicators, traffic fines)
- Road crash costs data.

Road safety databases often contain quantitative data on a more or less aggregated level. This allows evaluating factors such as the number of crashes or the number of fatalities/injuries, and these are necessary to allow an initial diagnosis relating to risk factors or road-user groups and monitor their evolution. Yet there is a need to also complement these aggregated statistical figures with more qualitative data that allows a deeper understanding of the factors and mechanisms contributing to both crashes and their consequences.[13]

Defining targets in a Safe System

Targets have proved effective in focusing attention on road safety at the highest decision-making levels and, as a consequence, in securing resources for road safety interventions to progress implementation of a Safe System. They help achieve transparency, accountability and deliverability and - when they include the operational dimension - drive concrete results.

Aspirational targets such as “zero road deaths” are often dismissed as unrealistic; to counter this perception they need to be supported by concrete interim targets. Short-term targets may include a certain percentage reduction in road deaths or serious injuries over a given time, or to achieve zero road deaths for a specific group (e.g. children). For short interim targets to be effective in demonstrating the legitimacy of a larger vision, it is critical that they are realistic and achievable. However, it is important to set the level of targets to be set having considered the importance of being either “conservative’ in setting targets that may be easily achieved or “ambitious” and setting targets that are more of a “stretch” and thus drive more effort to achieve results. Stretch targets ultimately may not be achieved but may achieve more improvement than if a lower, more conservative target was set. This is an important consideration politically in managing expectations and road safety achievements.

Most importantly, set targets must be regularly monitored and backed by an agreed and fully funded package of interventions that is selected based on evidence of the results they can be expected to produce.

Countries at the cutting edge of road safety performance employ detailed ex-ante impact assessment for road safety measures they envisage. The United Kingdom sets targets for specific users or crash types based on such ex-ante assessments. In the Netherlands, overall targets for reducing deaths and serious injuries are tightened periodically and the effects of safety measures are modelled to assess whether they will deliver the improvement needed to meet the target (see Box 4.3).

On the opposite end of the spectrum, low-quality crash statistics in the majority of low and middle- income countries do not allow adequate planning, designing, and evaluation of road safety efforts. The absence of reliable data collection leads to underreporting of deaths and injuries and hampers the kind of analyses that could guide such efforts. However, there are still evidence-based safety improvements that can be introduced without detailed ex-ante analysis. For instance, where pedestrians mix with fast-travelling vehicles, a footpath that physically separates the vulnerable road users from high-speed traffic should always be included. There are many other proven safety measures that can be part of a systemic approach where case-specific analysis is not possible. For low and middle-income countries, this is the quickest and most viable way to implement Safe System solutions.

Targets should be set at different levels, as illustrated in Figure 4.2. Typically, countries set targets for final outcomes (deaths and serious injuries) or intermediate outcomes measured by safety performance indicators (e.g. speeding, seatbelt wearing rate).

Box 4.3. **Case study: Road safety forecasting in the Netherlands**

The quantified road safety targets for the Netherlands are part of the Road Safety Strategic Plan 2008-2020 of the Dutch Ministry of Infrastructure and the Environment. The Strategic Plan calls for a maximum of 500 fatalities and 10 600 serious road injuries (i.e. hospital admissions with a Maximum Abbreviated Injury Score of 2 or more) by 2020. These targets are evaluated every four years. As part of the first evaluation round in 2011, the Institute for Road Safety Research (SWOV) provided forecasts for the number of fatalities and serious injuries in 2020. From these, it was concluded that the injury target most probably would not be met without additional policy measures. The analysis showed in particular that cyclists and older people required extra attention, as the number of seriously injured road users from these groups was growing. It also showed that achieving the fatality target will depend on investments in infrastructural road safety measures and on the general development of mobility patterns.

Based on this, the Minister of Infrastructure and the Environment decided to take additional measures and launched a consultation process with road safety stakeholders (provinces, municipalities, police and interest groups). This resulted in a proposal for additional measures under the title The Policy Impulse for Road Safety.

To estimate whether the additional initiatives set out in Policy Impulse would succeed in reaching the road safety targets for 2020, an ex-ante evaluation of the proposed measures was carried out. This concluded that the measures in Policy Impulse would most probably not suffice to meet the target for reducing serious injuries and that more far-reaching and expensive steps would be required. The Minister of Transport considered these to be out of reach; she decided to implement the Policy Impulse as proposed and to make further steps dependent on the results of the next four-year evaluation round due in 2015.

In the autumn of 2015, SWOV carried out new forecasts. The projections again indicated that the 2020 target for reducing serious road injuries would most probably not be met. The Minister, the Dutch provinces and the municipalities involved decided, however, that it was too early to rescind or adapt the target. Instead they are currently exploring whether intervention-related interim targets, as used in Sweden, can further improve road safety. The use of forecasting and ex-ante evaluation in road safety policy making in the Netherlands is discussed in more details in Weijermars and Wesemann (2013).

Figure 4.2. **A target hierarchy for road safety**

Source: Koornstra et al. (2002).

Box 4.4. **Defining "serious injury"**

In many countries, a "serious injury" in a road crash is defined by the police as an injury requiring at least 24 hours hospitalisation, and recorded as such in their reports. This definition, however, invariably include a very wide range of cases, from minor injuries requiring a period of hospital observation to the most serious injuries leaving the victims incapacitated for the rest of their lives. A Safe System focuses on preventing the most serious, life-changing harms.

In parallel to the injury definitions used by the police, hospitals in many countries are applying a medical definition of injury based on the amount and severity of the injuries sustained. These definitions are contained in the widely used the Injury Severity Scale (ISS), the Abbreviated Injury Scale (AIS) and the Maximum Abbreviated Injury Scale (MAIS). They reflect the threat to life associated with the injury, rather than a comprehensive assessment of the severity of the injury. International fora are moving towards agreement that a level of injury of MAIS3+ should be the accepted cut-off for a serious injury, with anything below would fall in the category of minor injury. A recent European Commission (EC) document adopted the MAIS3+ definition and states that in Europe in 2014 there were 135 000 serious injuries according to the MAIS3+ definition (European Commission, 2016).

The ISS and MAIS standards do not reflect the risk of being permanently disabled. In Sweden, ISS and AIS have been combined with data from insurance companies to determine the level of disability associated with an injury. An injury which produces a permanent disability of 1% or more is thus considered as serious. This criterion on disability is directly linked to post-crash response and health service quality.

Assessing the current situation

A good understanding of current (and past) road safety performance is the logical starting point for defining priority areas and actions. It also sets the reference point for future ambitions. In most countries, road safety performance is usually measured by the trends or rate in the number of fatalities. Yet crashes also cause serious injuries on a large scale, and these are equally the focus of a Safe System. However, two factors complicate the monitoring of serious road injuries.

First, it is difficult to collect reliable data on injury crashes. In many countries, the number of serious road injuries is based entirely on police reports, which may misreport some injury cases and fully miss others. This makes underreporting a serious problem, particularly acute for vulnerable road users. The limitations of the data, in turn, lead to skewed perceptions of the road trauma problem. Complementing police data with other sources, in particular health data can help to focus on overlooked issues. Matched database tools that assign individual crash victims unique codes or identifiers to share data and personal details in confidential ways are becoming available to link different data-sets from police, emergency services and hospitals to produce better estimates of the true number of seriously injured (see in particular the IRTAD report on Reporting Serious Road Injuries, ITF/OECD, 2012). The Netherlands and Western Australia use this approach to correct the figures published on total deaths and total serious injuries. Sweden uses the approach systematically at a disaggregated level as outlined in Box 4.5.

A second impediment is that different countries use different definitions of serious injury, resulting in large variations in the reported numbers. The European Union in 2012 adopted as its common definition of a serious injury hospitalised patients with an injury level above 3 on the Maximum Abbreviated Injury Scale (MAIS3+). Fourteen countries were able to report figures for seriously injured on this basis in 2016.

Using Safety Performance Indicators

Safety Performance Indicators (SPI) can be highly effective in determining road safety policies and interventions. They constitute an essential tool for diagnosing problematic areas, for understanding the processes leading to road crashes, and for helping stakeholders to understand how they can contribute to improved road safety.

It is important that Safety Performance Indicators focus not only on the final crash outcomes (i.e. people killed and seriously injured) but also intermediate outcome indicators that are thought to contribute and also measure the outputs being delivered to address the outcomes.

For example in the case of people being killed in crashes while unrestrained, the final outcome measures are the number of people killed and seriously injured in crashes not wearing a seatbelt, an intermediate outcome indicator is the number of people driving not wearing a seatbelt and output measures would include the number of vehicles fitted with seatbelt reminder systems and the number of infringements issued by Police.

Measuring and evaluating the precise effects of specific interventions on the number of deaths and serious injuries requires skill and effort. The relatively sparse data available requires long measuring periods (especially in small countries or cities where the number of casualties are relatively low) to collect enough relevant information to assess the effectiveness of interventions.

An alternative is to measure an intervention’s effect based on intermediate outcomes through safety performance indicators. The types of intermediate outcomes are various and cover the principal elements of the road transport system, such as the road environment, road-user and vehicles and their interactions. They include factors known to be causally related to final outcomes (e.g. speed and drink driving are well-known to increase crash risk, seatbelt use has well-documented effects on lowering the injury risk and the quality of the road design decreases the likelihood of a crash and the severity of the outcomes of crashes that nevertheless do occur). Safety performance indicators may also concern the post-crash factors (e.g. quality of emergency services intervention). The report *Road Safety Performance Indicators Theory* (Hakkert et al., 2007) provides a good theoretical framework for the elaboration of SPIs.

Box 4.5. **Understanding road safety trends**

The trend in the total number of fatalities is the result of a combination of trends of many different groups of fatalities, stratified for example by transports mode, conflict type, age and gender. For some groups of road users, the number of fatalities shows a decreasing trend, whereas for other groups the number of fatalities is not changing or even increasing.

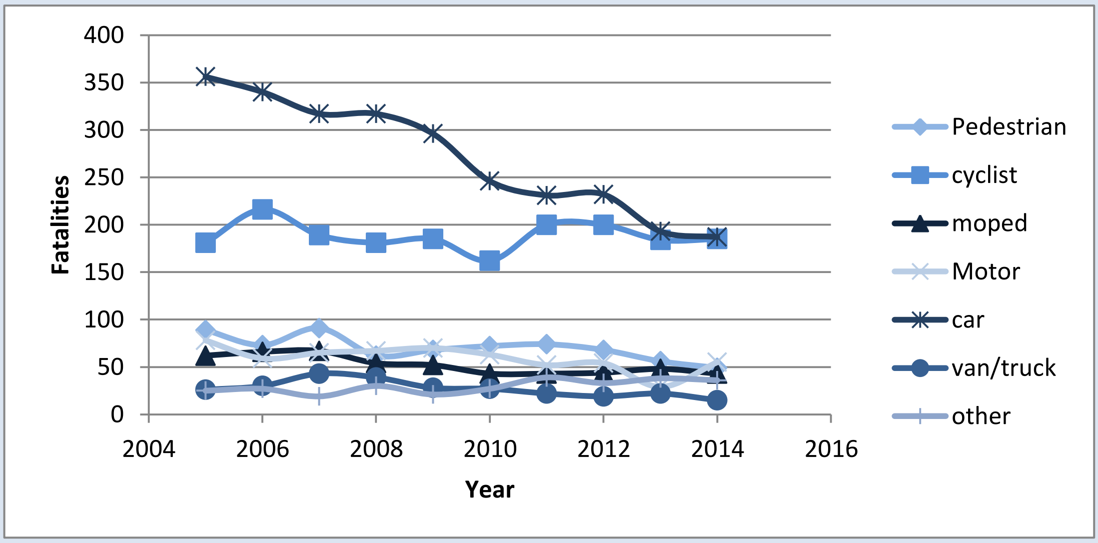
As an example, Figure 4.3 below shows the trends in fatalities for different transport modes in the Netherlands between 2005 and 2014. While the total number of fatalities fell by an average of 4.2% per year over this period. Figure 4.3 shows that different transport modes behaved very differently: Motorised four-wheelers showed the strongest decrease in the number of fatalities (-7.1% per year), whereas for cyclists the number of fatalities did not decrease substantially (-0.3%) and deaths in the category “other” in fact increase significantly, with a rise in the number of fatalities of 5.9% per year. Further analysis revealed that the latter resulted from an increase in the number of fatalities involving all kinds of vehicles for disabled persons.

Similar figures can be produced for different crash opponents, road types, age groups etc. and for different combinations of factors. Further analysis of trends for different groups of cyclists for example shows that the number of fatalities among older cyclists (60+) seems to increase, whereas the number of fatalities among cyclists under the age of 60 seems to decrease. Moreover, the number of fatalities among cyclists resulting from crashes with motorised vehicles has decreased, whereas there was an increase in the number of deadly cyclist-cyclist crashes.

The trend in the number of fatalities is the result of a combination of developments in distance travelled (or “exposure”) and risk (number of fatalities per distance travelled). The increase in the number of fatalities among older cyclists in the Netherlands for example is the result of a combination of an increase in distance travelled and a small decrease in risk (Stipdonk, 2013).

A stratified approach which includes a detailed analysis by type of road users and type of roads is very helpful for selecting priority target groups to focus interventions. Analyses of recent trends in the Netherlands show that fatality trends are worse for cyclists, vehicles for disabled and older road users compared to other groups. Moreover, fatality risks are relatively high for cyclists compared to, for example, car occupants (12.4 vs. 1.4 fatalities per billion kilometres travelled) and for older road users compared to younger road users. Road safety measures should therefore be targeted at these groups in particular.

Figure 4.3. **Trends in the number of fatalities for different transport modes in the Netherlands (2005-2014)**



To determine whether intermediate outcomes are relevant they need to be readily measureable. Indicators should offer an accurate and reliable reflection of the state of each intermediate outcome, and be measured on a regular basis to allow monitoring their evolution over time. Ideally, one should obtain a good overview of the performances for the different system components. The indicators should be evidence based, especially regarding their connection to final outcomes and Safe System principles. In most cases, their measurement requires the organisation of surveys, based on adequate sampling methods, to ensure representativeness of the sample with respect to the state of the particular problem investigated. For example the trends in the population use of seatbelts relies on observational, road side studies that can be then extrapolated and generalised to describe the trend in the overall population.

To have a complete assessment of the road safety performance, SPIs should be defined and selected so that no element of the system should be omitted as far as this is possible. The set of indicators selected should be as comprehensive as possible in reflecting the "health" and effectiveness of a Safe System. For example if monitoring is limited to measuring driver behaviours (speeding, drink driving, not wearing restraints) then it may be wrongly concluded that driver behaviour is the sole problem and therefore all solutions must focus on behaviour. A narrow set of indicators will convey a "piecemeal", distorted and thus biased image of the road safety problems. Limited monitoring and reporting will likely skew media coverage and the public debate around road safety issues. The result of a biased debate can lead to popular but misguided "common sense" interventions being adopted that have limited effects. Hence the information gathered through SPIs should aim to reflect the breadth of the issues in a Safe System so it enables adequate debate and decision making about resource allocation. In Sweden, ten Safe System-related SPIs have been developed and assigned target values for 2020. They are measured and analysed annually in relation to their targets, together with an assessment of trends in fatalities and serious injuries and used to inform planning, prioritisation and resource allocation for interventions annually. The SPIs are regularly reviewed and these reviews may result in target values being changed, SPIs being abandoned or new ones introduced. Examples of basic and relevant SPIs for the elements of a Safe System, based on experiences from some countries and suggestions made by Hakkert et al. (2007) include:

Safe System infrastructure SPIs:

- Percentage of vehicle-kilometres driven on median-separated roads with a speed limit above 80 km/h
- Percentage of vehicle-kilometres driven by passenger cars of the highest Euro NCAP safety rating

Safe System vehicle SPI:

- Percentage of vehicle-kilometres driven by motorcycles equipped with Anti-lock Braking Systems (ABS)

Safe System speed management SPIs:

- Percentage of vehicles driving within speed limits
- Average speed of vehicles

Safe System behavioural SPIs

- Percentage of drivers and passengers in passenger cars using seat belts
- Number and proportion of severe and fatal injuries resulting from crashes involving at least one road user who was intoxicated
- Percentage of moped users and cyclists wearing helmets.

These SPIs do not focus exclusively upon road user behaviour, but also include indicators on the safety levels offered by the vehicle, the infrastructure and the interaction of all elements through the management of speed.

A number of countries are now setting 4- and 5-star performance targets based on Road Assessment Programme (RAP) standards for high-volume road networks and major new construction projects. There are also countries which are setting policy targets at the national level in the form of "X% of travel on roads with three-star rating or better for all road users". In a Safe System context the percentage of travel on five-star roads for each road user provides the performance metric of most interest, however.

Setting targets

Setting targets for the total number of fatalities and serious injuries has shown to be an important driver for initiating and realising effective national road safety strategies However, targets need to be specific, measurable, achievable, realistic and time-bounded (Van Herten et al., 2000).

The Management by Objectives (MBO) approach posits that defining overall goals and targets to be achieved will be more effective in delivering results than setting detailed rules about how actors in a system should behave, by encouraging flexible strategies focused on problem solving within an organisation (Belin et al., 2010). While its origins lie in the business world, MBO is equally applicable in public administration context (Parsons, 1995). Instead of formulating detailed rules about how the administration should behave, the political level determines strategic goals and sets quantified targets that the administration should achieve (Vedung, 1997). In road safety work, MBO offers a way to engage stakeholders and commit them to take responsibility for achieving specific objectives. MBO therefore supports a key element of a Safe System in a way that is harder to achieve via the traditional top-down approach, where government stipulates not only what the stakeholders must achieve but also how they should go about it.

An interesting approach to target setting in road safety is "back-casting". In Western Australia, system designers worked backwards from the ultimate aim of "zero road deaths and serious injuries" to determine what elements could be implemented as first steps on the journey towards ultimate Safe System solutions. In Sweden a similar approach has been taken. Instead of starting from an existing problem and applying existing road safety interventions to it, the Swedish "Vision Zero" strategy takes as its point of departure an absolute future state: safe road traffic. Thus, rather than asking "What can be done?" the question becomes "What must be done to create a safe road transport system?" (Kane, 2009).

When setting intermediate targets it is important that they are related to the ultimate goal of a Safe System. Else there is a risk that the targets, especially those based on the final outcome of fatalities and injuries, will lead to the interventions which may be effective in the short term but may not be in line with a Safe System. Complementing such targets with targets for SPIs which are based on the condition states of a Safe System may for that reason be effective.

Identifying and realising interventions

The time scale required for interventions to achieve their maximum effectiveness is an important consideration. The time needed for measures to show results will differ substantially across the range of policy areas and instruments. Behavioural measures to avoid speeding or drink driving, for example, are most effective when they include strong enforcement accompanied by powerful awareness-raising campaigns. They can have an immediate impact in reducing road deaths and injuries, but need to be repeated regularly to foster a cultural shift towards safer behaviours. They are also highly resource-intensive, requiring substantial effort by road police in particular. In contrast, investment in safer road infrastructure - such as roundabouts or median barriers - represent a one-off expenditure and once constructed should achieve a permanent reduction in casualty risk. Similarly, safe vehicles will deliver improvements but these will depend on the vehicle fleet turnover rate. While safety gains from new technologies will likely be permanent, these technologies may take between 15 to 20 years to be fully available in vehicle fleet. These differences in impact delivery and sustainability needs to be understood and integrated into the timing and implementation of interventions in support of the overall target adopted.

Particular care should be taken to ensure that the agreed programme of action is effectively implemented across the spectrum and stakeholders fully participate and take practical responsibility for carrying out “their” part of the programme. A lead agency may be important here in ensuring that the appropriate funds, technical tools and legal instruments are available. This section presents different models, methods and tools for identifying and realising interventions in a Safe System context. The concrete interventions themselves are described further down in Chapter 5.

Box 4.6. **Case study: Sweden’s integrated traffic-crash data system**

In 1996, the Swedish Road Administration was commissioned by the government to develop a new information system that would register all road crashes and resulting injuries. The system was to include both police and hospital data and integrate the entire process from data collection to data presentation. This was the start for the Swedish Traffic Accident Data Acquisition (STRADA), which today is used to support the traffic safety work in Sweden on the national, regional and local level. In 2009, the Swedish Transport Agency became the authority responsible for STRADA.

The Swedish police report traffic crashes to STRADA since 2003. This is regulated by law and is a mandatory assignment for all police districts. At a crash scene, a special form is filled in by the police and the collected information is then registered in STRADA. The police reports on approximately 16 000 crashes each year.

While the police reports focus on the crash, the hospital reports focus on the injuries of a person requiring medical care after a crash. Hospital reporting to STRADA is not mandatory but based on agreements between the hospitals and the Swedish Transport Agency. The first hospital started reporting in 1999 and as of June 2015, all but one of Sweden’s hospitals provide STRADA with data. Their reporting is based upon informed consent from each patient. Any person seeking medical care after a crash is asked to fill in an injury registration form with information on the crash. This form is later complemented with injury diagnosis before it is registered in STRADA. In 2014 there were over 44 000 reports filed by the hospitals.

By bringing together data from two sources, STRADA can provide more detailed information on road traffic injuries and crashes. The police can supply good information on the crash as such, the traffic-related elements and road conditions, while the hospital data broadens the knowledge about resulting injuries. For instance, the medical diagnoses can be used for different health-loss calculations. Importantly, the crashes reported by police and hospitals do not always fully match. The police may not hear about some incidents , mainly involving unprotected road users, that are registered by hospitals – for example bicycle accidents not involving cars with minor injuries. On the other hand hospitals cannot report all casualties, for instance in cases where a person dies at the scene of the crash and is not always taken to hospital.

The STRADA database has helped to better assess crashes resulting in impairing injuries, which together with deaths is the focus of the Swedish Zero Vision strategy where no one is killed or severely impaired for life. As a result, injured cyclists, for instance, have become a new focus for road safety interventions. STRADA has deepened knowledge about crash and injury scenarios for this road user group that will in the longer run help to put in place prevention strategies based on Safe System principles. The data in STRADA is accessible to road safety professionals via a web-based system.

Taking a Safe System perspective

A Safe System is based on a multi-dimensional approach that investigates and improves the road traffic system as a whole. Crashes are seen as the result of unexpected, uncontrolled relationships between parts of the road transport system, rather than having a simple cause and effect relationship (Underwood and Waterson, 2013). Thus, instead of focusing on improving one element of traffic safety in isolation, a Safe System aims to understand how the elements affect each other at any given moment, and how these interrelations can be exploited to provide efficient solutions to road safety problems (Stigson, 2009). In the behavioural approach, human error is seen as the primary cause of traffic crashes. A very different view emerges when crashes are investigated from a systemic angle in which the needs, limitations, and capacities of the road users are integrated in the traffic system (Shinar, 2007).

Factors that contribute to crashes can be identified at the various levels of the system, suggesting countermeasures beyond those focusing on the direct causes connected only to the actual situation and the road user. Informing, educating or punishing drivers can reduce the number of crashes but will not address the underlying problems of, to give some examples, road authorities permitting rigid lamp posts in close proximity of roads, governments allowing speed limits too high for the level of protection provided by vehicles and infrastructure, or employers failing to take responsibility for the safety of their drivers.

Systemic countermeasures with a documented positive effect on crash avoidance or injury reduction should always be considered. In most cases, the error of an individual road user is the symptom of a systemic problem to which other road users may be equally vulnerable. The latent factors which shape the behaviour or contribute to the injury outcome will still remain in the system. For that reason, countermeasures on a “higher”, organisational level, in a complex, dynamic system like the road transport system, are often effective and more stable or resistant to different pathways to crashes and injuries. This is the principle of Safety Management Systems conforming to the ISO 39001 standard.

Building on in-depth crash studies

As crash data usually focuses on crash causation and behavioural risk factors, relying on them may lead to a bias towards behavioural responses. For that reason, in a Safe System aggregate statistical analysis needs to be complemented by detailed post-hoc investigation of the events, behaviours and conditions that combined to make a crash happen and at some point made inevitable. Particular care should be taken to collect information on the victims’ medical condition, so as to allow a better understanding of all the aspects of the crash process that generated injuries or affected their severity.

In-depth analyses based on Safe System principles in Western Australia, for example, found that behavioural risk factors such as speeding, drink driving and not wearing restraints were more prevalent in fatal crashes compared to serious injury crashes (of which there are many more). In serious injury crashes, factors such as errors, mistakes and inattention become much more prevalent. The investigation exposed more of the underlying risk present in the road transport system thus highlighting the importance of a Safe System (infrastructure, speeds and vehicles) in addition to behavioural responses (e.g. education, legislation, enforcement).

The two main questions that in-depth crash studies should answer are a) why a crash occurred and b) if there was serious injury, why the consequences of the crash were so grave. The investigation should identify the conditions (technical, infrastructural, but also regulatory, political or organisational) that made it possible for the error (if one was involved) to suffice to lead to the crash and for the level of injuries. The question “Why?” must be asked to get to the root causes of the problem inherent at each level in the system: Why was the vehicle not able to avoid or absorb the severity of the crash? If the vehicle could not, why not the road infrastructure? And so on.

In-depth studies require large amounts of information if they are to cover the different levels of the road transport system and include all aspects of a Safe System. The access to different information and data sources related to the accident which are important for the analysis must be secured. Examples are driver license data, vehicle data, infrastructure data (technical data about the road and its surroundings), injury data (hospital data, autopsy reports etc.), rescue data, organisational information (e.g. information about road safety management of the road authorities and buyers and sellers of transports) etc.

From a strict safety perspective, in-depth studies should be a fact-finding activity aiming to learn from the experience of the accident. The emphasis should be on identifying the underlying root causes in a chain of events leading to an accident and its injury outcome, the lessons to be learned, and ways to prevent and mitigate similar accidents or injuries in the future.

Mobilising shared responsibility in responding to crashes

The OLA method (Objective data, List of solution/actions, Addressed in action plans) is an approach for identifying and realising interventions. OLA is an approach to guide co-operation and shared responsibility among different system designers in developing solutions for shared road safety problems (Belin and Tillgren, 2012). On the basis of facts, they discuss potential solutions to one or more crash problems. A key question is what can we each do that will contribute to preventing this type of crash from occurring again? Through this approach, everyone is given the opportunity to show what measures they want and can take, and thereby contribute to improved road safety.

The OLA method is being used at a local level to discuss and prevent a local crash from occurring again. OLA has also been used on problems affecting a group of people, for example fatal crashes of scooter riders. OLA is very much an example of a bottom-up approach that engages and educates stakeholders, media and the community in the road safety problem, the evidence based solutions and a shared responsibility for road safety in a Safe System

Choosing policy instruments

The shift from government to governance, from hierarchy to markets and networks, has led to a "multi-stakeholder game". This requires new, second-generation policy tools to implement interventions, notably multi-lateral instruments such as covenants, public-private partnerships and voluntary agreements. Generally, policy instruments fall into three broad categories:

- Communication tools (e.g. information campaigns, promotion, assessment programmes)
- Economic tools (e.g. grants, subsidies, taxes, user charges)
- Regulatory tools (e.g. regulations, prohibitions).

These instruments have often been used in a top-down or "command-and-control" approach targeting road user behaviours but also specifying in detail how other players in the system should act. With the government taking the majority of responsibility, however, this leaves very little incentive for innovation and responsibility among the other stakeholders. Further, the traditional approach often targets policy instruments on individual system components (i.e. road user, infrastructure or vehicles) without much regard to how they interact in the overall system, and separate regulations often exist for the components. In the way they are traditionally being applied, these instruments are therefore not fully aligned with a Safe System approach.

Box 4.7. **Example of a guided line of enquiry to encourage a system-based crash investigation**

Consider this crash scenario: A professional truck driver falls asleep at the steering wheel and his vehicle veers off the road at a speed of 70 km/h, hitting a lamp post. The driver is killed in the crash. The following questions could be asked in an in-depth analysis of the incident to establish the root causes inherent in the system:

- Why did the truck drive off the road? Because the driver fell asleep (most accident investigations end here and the interventions are directed towards the driver behaviour).
- Why did the driver fall asleep? Because he had volunteered to take an extra shift outside the permitted driving hours even though he was very tired (he needed the money).
- Why was the driver able to take the extra shift? Because the employer did not have a management system or something similar to prevent the driver from driving outside the permitted driving hours.
- Why didn't the employer have a safety management system? Because the legislation does not provide that and hence there is no authority supervision.
- Why was a rigid lamp post placed in close proximity to the road? Because the regulations governing the design of the road permitted such a design.
- Why did the regulations permit such a design? Because the road authorities do not have a systematic way of investigating crashes (e.g. as a part of a safety management system).
- Why do the road authorities not need a safety management system? Because politicians are unwilling to pass a law which may increase expenditures.

Another answer to the question "Why did the driver fall asleep?" could be that the truck was not equipped with a driver alert system. From this answer, further questions could be asked which may result in answers showing that vehicle manufacturers do not find them economical or other reasons for not marketing such devices and politicians or authorities are not willing to pass laws or regulations stipulating that the manufacturers must install such systems in their vehicles.

There are, however, alternative ways to use the standard instrumentarium to stimulate innovation and encourage responsibility-sharing. Part of this is the realisation that other actors than government authorities may be better suited to employ the available instruments effectively in a given context. Although authorities are often a useful catalyst, implementation tools may also be developed and brought to bear for instance by non-governmental road safety organisations or advocacy groups. The ability of public authorities to let go of their customary role in exercising authority and becoming more of a facilitator for collaborative processes will greatly enhance the ability for effective development and shared responsibility for implementation of Safe System measures.

There are many practical examples of how traditional policy instruments have been redesigned, in ways consistent with a Safe System, to foster innovation and shared responsibility, and to influence market forces.

Pertinent case studies of how communication can be effectively leveraged by a non-governmental player for more road safety are the New Car Assessment Programmes (NCAP) and Road Assessment Programmes (RAP). NCAPs rate car models on the basis of their safety properties, with a view to providing information for car buyers. By testing new models and attributing between one star (for a low safety standard) and five stars (for high standard), NCAPs provide transparency via a rating system that is highly visual and easy to grasp for consumers facing a choice between different offers. The star rating also enables to compare vehicle standards in different counties and regions, shining light on the fact that many car manufacturers sell cars with lower safety standards in some countries than in others. Since the mid-1990s, these programmes have thus significantly contributed to improved vehicle safety through a "market-based" approach complementing legislative measures but being able to implemented in most cases, faster than legislative change which in some cases often waits for demonstrated market failure before being able to be considered.

Similar star ratings are awarded by RAPs for the safety standard of road infrastructure. The specification of minimum star rating targets for new road projects provides a powerful regulatory instrument for project owners. For example, the Asian Development Bank, a big infrastructure funder, recommends minimum four-star safety standard for pedestrians in linear settlements. In New Zealand, a minimum four-star safety standard was stipulated for a Public-Private Partnership toll road project. Such performance specifications provides the road owner with the confidence that certain safety standards will be met, whilst allowing the design teams some freedom to determine what specific speed environments and road features they will include to reach the target. The star rating of the new road can then also be communicated as a quality feature to the public once the road is opened.

A further example of how communication instruments can be used to implement a new policy measure is the dissemination of scientific research. Electronic Stability Control (ESC) systems for vehicles were scientifically proven to have great potential to reduce road trauma. In Sweden, the time lag between the publication of scientific studies on the potential of ESC and the introduction of ESC as standard equipment by car manufacturers and importers was extremely short: Within 48 months, the market penetration of ESC increased from 15 to 90%. The key to this success was active dissemination of the scientific results by governmental officials through the media and other channels. As a consequence, important customers of the car industry expressed their intentions of exclusively purchasing vehicles equipped with ESC in the future. As in the NCAP example, it was factual information that affected consumer demand, which in turn influenced the supply of safety technology.

Another example how factual information can be used to drive implementation is via quality assurance, by making road safety concerns a part of quality assurance programmes for transport-related services. This could involve aspects like business trips, commuting by employees, or goods transport. If road safety is systematically included in quality assurance throughout society, the improvement will be significant – not least through growing consumer demand for quality assured mobility. Under shared responsibility, leadership for such an initiative should come from the management of private-sector companies or public authorities.

A management system standard for road traffic safety could play an important role where organisations want to improve their road traffic safety performance and implement a systematic way of working. An important tool in this respect is a standard defined by the International Organization for Standardization (ISO). ISO management standards have positive records for quality management (ISO 9000 family) and environmental management (ISO 14000 family), helping organisations to deliver better results through systematic work and management. Against this background, ISO 39001 was launched in 2012 as the international standard for road traffic safety management systems. ISO 39001 is a voluntary tool, complementary to legal regulations, aimed to disseminate best practices in road safety among organisations interacting with road traffic. When ISO 39001 is more widely applied, more organisations will address road safety in a more systematic way and it will become a standard topic in the interactions between organisations.

The last example relates to public procurement. Governments have used procurement for many years as a tool to achieve public policy objectives, for instance in relation to environmental protection. Some countries, for instance Sweden, now also use procurement to contribute to road safety goals. In 1997, the (then) Swedish Road Administration introduced a travel policy for employees stipulating that for work-related trips, certain internal safety requirements would have to be met in order for the agency to approve. This travel policy then spread to other public, non-profit and private transport stakeholders.

Experiences from pioneer countries showed that involving stakeholders to a greater extent in the establishment of a Safe System is helpful. Initiating a journey from government to governance and using multi-stakeholder processes, for example, may foster the stakeholders' engagement and commitment, and hence shared responsibility." The stakeholders' awareness of how their operations impact road safety will also increase, which may in turn contribute to the engagement and responsibility taking. An example of the involvement of stakeholders is the Via Sicura programme in Switzerland.

In the Netherlands, implementation of the "Sustainable Safety" vision was kicked off with the signing of a covenant by the Minister of Infrastructure, the Dutch provinces, the municipalities and the water boards. The five-year agreement constitutionalised the tasks and shared responsibilities of the different stakeholders and comprised 24 actions (see Box 4.9) that the partners agreed to carry out between 1998 and 2002 (Wegman and Wouters, 2002). The national government provided EUR 110 million for the implementation of the Start-up Programme. To qualify for financial support, the other levels of government had to supplement the subsidy with an equal amount (Weijermars and Wegman, 2011). Municipalities, Provinces and Water boards were very interested in obtaining the subsidy, especially for the realisation of 30 km/h and 60 km/h zones. Besides, the measure costs were higher than expected. As a result, the investments in a safe infrastructure were much higher than expected. Since the amount of subsidy provided by the central government was limited, regional governments paid more than 50% of the costs of the road safety measures. This example shows that providing subsidy may help to involve other stakeholders and to motivate them to make investments for the implementation of road safety measures.

Another interesting example of a systematic way of working in partnership with stakeholders using engagement and communication, is the way Western Australia introduced Safe System principles through major road projects.

To overcome some of the above problems, the traditional "command-and-control" regulatory instruments need to evolve. One example of this involves allowing the system designers greater freedom to find solutions. Instead of defining the detailed procedure to be followed, the performance outcomes to be achieved – or the function that the system or subsystem should fill – is defined. It is then up to the system designers to find the most appropriate way to achieve this performance. For instance, the authorities could demand a defined safety performance level, or the use of specific quality management systems from various system designers.

Using regulatory authority this way turns the focus to the achievement of outcomes and results rather than specifying particular methods and helps to drive new thinking in the approaches and responses to problems developed by the system designers. The flexibility on the operational level places greater responsibility for safety on the various stakeholders involved and brings to bear their practical knowledge on the development of solutions. It should also leave them with more opportunity for innovation, and favour the development of a safety culture among them. Applied in the right way, such "light touch" regulation should also foster co-operation among system designers on more effective solutions at the system level, e.g. vehicle manufacturers and infrastructure managers in the field of road traffic. However, there is a dilemma in respect to the optimum level of "self-regulation" and the latitude an industry should be given – take for example the implicit messages about road safety conveyed (or not conveyed) in car advertising. Combining regulatory measure and consumer information is a very effective strategy to create a "push-and-pull" demand mechanism on the market for road safety.

Box 4.8. **Case study: Implementation of the Via Sicura programme in Switzerland**

The Via Secura programme was launched by the Swiss government in 2012 as the latest of several road safety initiatives. The programme is committed to a Safe System approach, focusing on safer road infrastructure. Additionally, legal measures focus on safe behaviour among all road users (e.g. mandatory daytime running lights; car owner held liable for violations when driver is unknown) and on high-risk groups (e.g. longer periods of licence revocation for speeding; more driver rehabilitation courses for delinquent drivers, zero tolerance for blood alcohol among novice drivers). Development and implementation of the programme have shown that the following factors are crucial for the success of a national road safety programme:

- A public discussion has been launched.
- As a consequence, a change in paradigm towards shared responsibility was achieved and the political will for action was generated.
- An evidence-based report made the potential of new measures visible.
- Working groups composed of stakeholders, interest groups and experts developed ideas on how to improve road safety.
- Based on a thorough methodology, a forecast on the safety benefits was made and accepted as a benchmark for the road safety programme.
- Stakeholders, regional decision makers and the national parliament discussed suggestions and finally agreed on a revised list of measures.
- Instruments facilitating implementation of infrastructure measures were developed, local staff trained and data on progress collected.
- A multi-level evaluation is planned; this will not only control progress made but also serve as a steering instrument.

Box 4.9. **Case study: The Start-up Programme Sustainable Safety in the Netherlands**

The Start-up Programme Sustainable Safety comprised 24 action items. Some of these concern specific road safety measures, mainly relating to regulatory aspects and road design questions. The most important of the specific road safety measures in the Start-up Programme are:

- Categorisation of the road network (access roads, distributor roads and through roads)
- Expansion of 30 km/h zones (inside urban areas) and 60 km/h zones (rural areas)
- Relegation of mopeds from the bicycle path to the carriageway on urban roads.

Further action items of the Start-up Programme:

- Development of guidelines for the safe design of roads
- Inclusion of traffic enforcement in the priorities of the police options to increase traffic enforcement
- Strengthening the role of Regional Road Safety Authorities (ROVs) in education and communication
- Introduction of regular road safety education in schools
- Creation of an Information Desk for Sustainable Safety.

Evaluating performance and addressing challenges

The progress of a road safety initiative should be carefully monitored and the programme evaluated. Results against targets should be published regularly, for instance in an annual report. Its evaluation should cover both the targets as such and the interventions implemented to reach them (ITF/OECD, 2012) While monitoring the progress with regard to overall fatalities and severe injuries is important, tracking performance based on specific SPIs is even more critical in order to be able to adapt strategies and action plans at an early stage where necessary. The analysis then provides the starting point of a new Plan-Do-Check-Act cycle (see section Systematically managing for a Safe System). Including stakeholders in the evaluation will provide valuable insights from different perspectives (see Box 4.11 for an example).

In the United Kingdom, the Road Safety Foundation has a long history of publishing risk maps and performance tracking of the road network in the country (http://roadsafetyfoundation.org). Their reports highlight roads with persistent high risks as well as those roads with the strongest improvements. This is complemented with information on Safe System actions deployed by the local authorities to achieve that improvement and data on the economics and cost of road crashes in individual local areas. The launch of the reports attracts high-level political and media interest and helps prompt progress towards targets.

One of the main challenges for the successful implementation of a Safe System is that it needs to be understood and accepted across the board, from the highest level in politics to front-line staff, such as traffic managers, infrastructure and vehicle engineers, police officers, town planners, funders, educators, health professionals and many others across the full range of agencies whose work directly impacts traffic safety performance. In particular transport agencies responsible for road system design, construction and maintenance or traffic operations should ensure their staff understand, accept and apply Safe System principles. In the short term this will require regular in-service training within the workplace and in the longer term to build the capacity of the professions, the inclusion of appropriate units of study in university courses that prepare professional and technical staff. This can be particularly challenging for low- and middle-income countries (LMICs), often confronted with unstable technical teams, outdated curricula in professional courses, outdated design manuals and norms, lack of co-ordination among sectoral agencies involved in road safety management and amongst different levels of government, and so on. Efforts for capacity building thus need to go hand in hand with strategies for strengthening management structures (see above section Managing a Safe System by results).

Despite historic successes in reducing road deaths, even the Safe System pioneer countries still face a number of road safety challenges. Indeed, new road safety problems emerge in these countries, for instance as a result of the promotion of active mobility that is increasing the share of vulnerable road users like pedestrians and cyclists.

To begin with, the number of serious road injuries has been decreasing at a significantly slower rate than the number of fatalities. In some countries, the number of serious road injuries has even been rising. The trends in reported fatalities and injured between 1990 and 2009 are shown for a selection of countries in Figure 4.5. In this period, road deaths reported by the police decreased by roughly 50% in these countries, while reported serious injuries decreased less (in the UK and Spain) or even increased (in Sweden and Japan). Australia and the Netherlands also registered a decrease in the number of fatalities and an increase in the number of serious road injuries (Berecki-Gisolf, Collie et al., 2013; Weijermars, Bos et al., 2015).

One explanation for the difference in development between fatalities and serious road injuries is a decrease in crash impact speed thanks to traffic calming measures (e.g. roundabouts). Also the growing number of safer cars in the vehicle fleet (e.g. improvements of secondary vehicle safety and increased use of seat belts) contributes to reduce the severity of crashes. This probably has a stronger effect on reducing the number of fatalities than serious injuries.

Box 4.10. **Case study: Introducing Safe System Principles through Major Road Projects in Western Australia**

In Western Australia, the application of Safe System principles in major new road projects began in 2007. The state road authority Main Roads WA were then building Western Australia's highest value road project (AUD 700 million) to complete 30 kilometres of highway leading south from the state's capital city, Perth.

The agency's Chief Executive Officer supported a significant focus on safety and required ambitious safety performance targets to become part of the project. This provided economic incentives for the contractors to find innovative ways to build additional safety into the projects and obtain a share of the incentives for safety provided for the projects. An independent Safe System Working Group of outside experts that reported directly to the Chief Executive was established to assist the consortium to meet set performance conditions for the highway. The Working Group developed a Vision Zero Logical Framework to connect the project's aspiration with practical operational targets on which the road designers could focus their designs (Petrossian and Marsh, 2010).

The use of the Vision Zero Logical Framework raised awareness, educated and influenced engineering attention to the most serious injury and death risks expected for the operation of the project road. These Safe System risks were identified as:

- Run-off-road and head-on crashes at vehicle speeds exceeding 70 km/h
- Side-impact crashes at vehicle speeds exceeding 50 km/h;
- Crashes involving unprotected road users at vehicle speeds exceeding 30 km/h.

The road building consortium project team, together with the Safe System working group and other key members of the road authority also participated in a Safe System road design workshop with contributions from several eminent experts from the Swedish Road Administration, Monash University in Victoria, the University of NSW and the Australian Road Research Group (ARRB).

The workshop enabled numerous practical Safe System suggestions at each level of intervention that could be considered for inclusion in the project. As the project had already commenced, the opportunity for changes to the design were limited by timing and budget, however a number of Safe System changing challenges were incorporated to the traditional design including the use of wire rope barriers above the design standard required at the time. Most importantly the lessons learned from the Safe System working group process were then incorporated into following major road projects as an essential requirement; from the start of new projects enabling more significant Safe System changes to be achieved including full length median barriers, innovative use of roundabout design and extensive applications of roadside barriers.

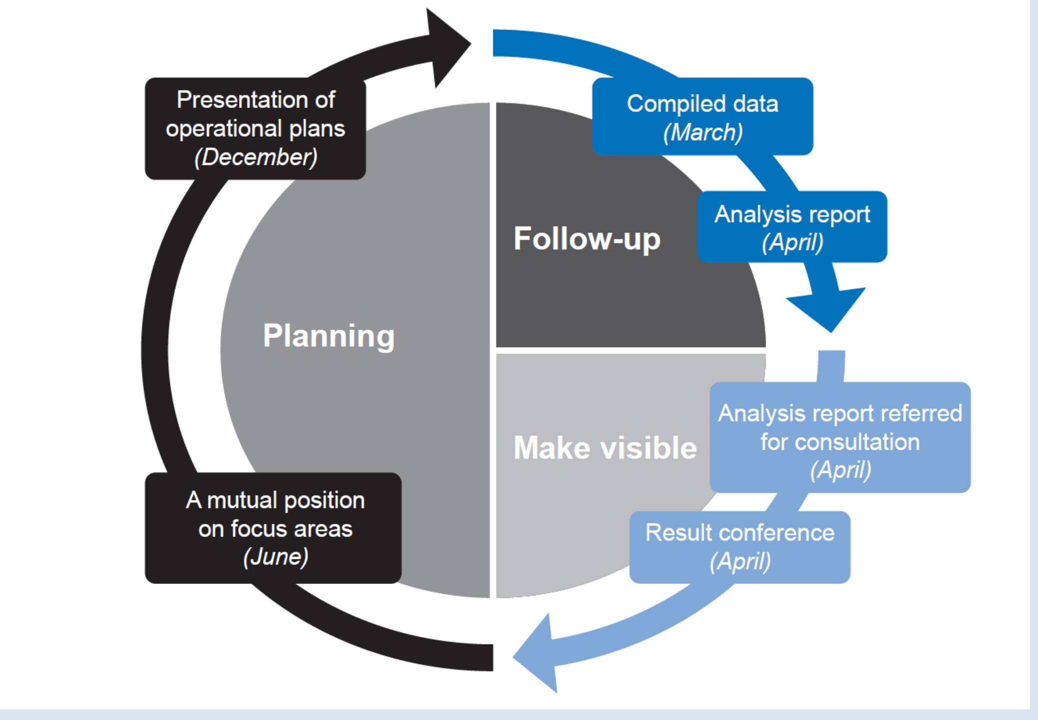
Main Roads Western Australia continue to use the Safe System working group processes to inform major road projects with increasing attention now firmly on how to institutionalise or "imbed" Safe System learning from projects into whole of agency policies, procedures, practices and standards. The ISO 39001 Road Safety Management Standard is assisting with this change journey.

Box 4.11. **Case study: Evaluation cycle for road safety performance in Sweden**

The cyclical evaluation of road safety performance in Sweden is based on regular analysis of Safety Performance Indicators, the timely communication of these analyses to the road safety community, and extensive consultation about implications with a broad range of actors in the road safety arena. This approach has helped to reinforce the engagement of stakeholders and increased their willingness to take responsibility. The evaluation process involves the following phases:

1. **January to March: Compilation and analysis of data**. In this phase, a national analysis group consisting of representatives from the Swedish Transport Administration, the Swedish Transport Agency and the Swedish National Road and Transport Research Institute (VTI) gather data on fatalities, injuries and the different safety indicators that are being measured.
2. **March: Release of a report** on the road safety trends of the previous year.
3. **April: Review of the report.** The report is shared with stakeholders for comments.
4. **April: Results conference.** At a meeting, stakeholders discuss the findings of the report with the Ministry of Enterprise, Energy and Communications.
5. **June: Definition of a mutual position.** Selected stakeholders discuss and agree on a common position on priorities for the next review cycle. This is co-ordinated by the National Coordination Assembly (NCA), a knowledge-sharing and co-ordination forum for road safety stakeholders committed to "Vision Zero".
6. **December: Presentation of operational plans.** Stakeholders declare what they plan to do and achieve during next year. The work is co-ordinated by the NCA.

Figure 4.4. **Cyclical evaluation of road safety performance in Sweden**



Analysis of this phenomenon for the Netherlands concluded, however, that the main explanation for this development is largely explained by differing trends among crash types. While there was an increasing number of crashes without involvement of motorised vehicles on Dutch roads, these incidents resulted in few fatalities but a relatively high number of serious injuries compared to other types of crashes: less than 0.5% of all killed and seriously injured (KSI) casualties in crashes without a motor vehicle involved were fatalities, while more than 99.5% suffered serious injuries. By contrast, for car occupants in the Netherlands about 11% of the KSI casualties were fatalities and 89% serious injuries.

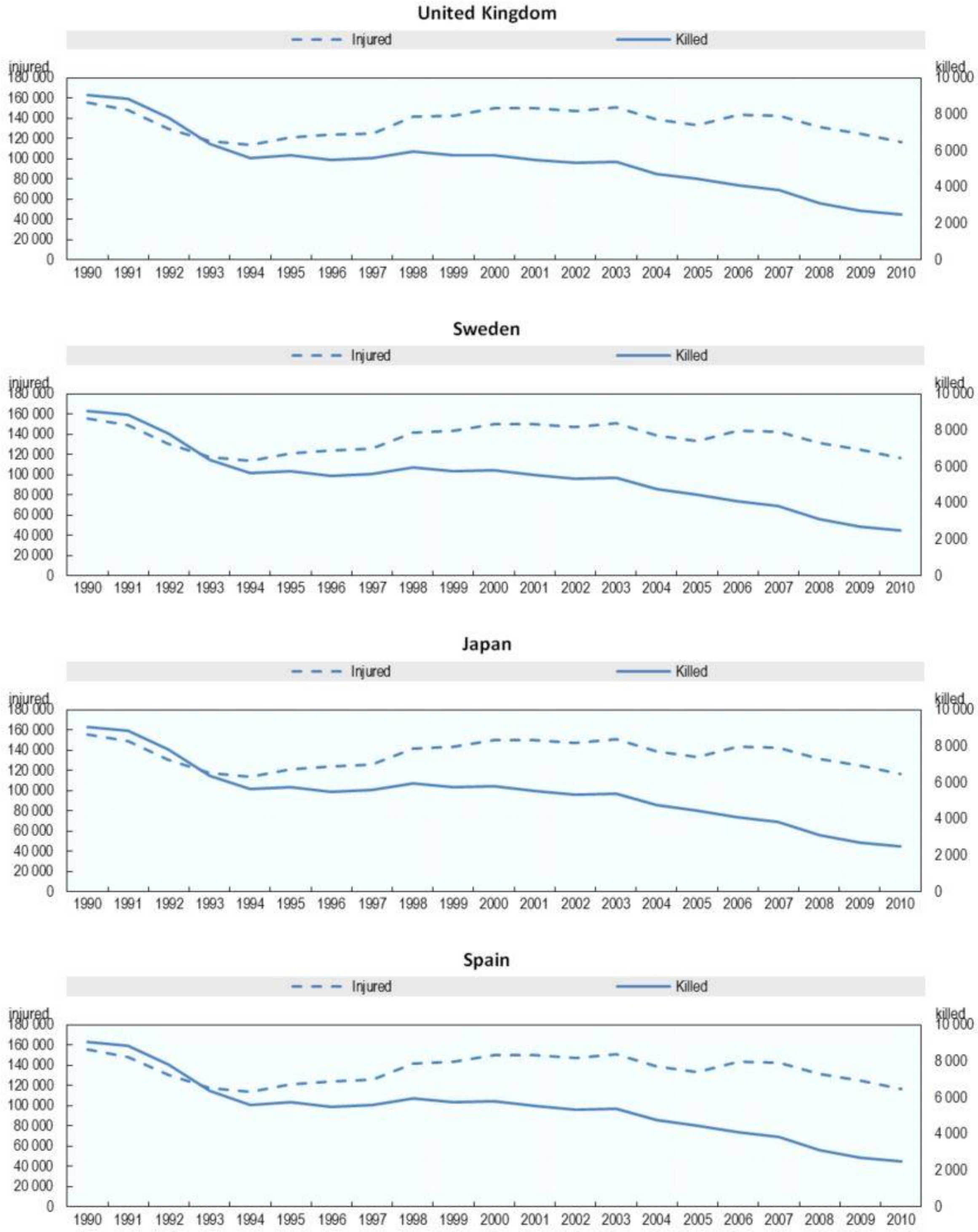
In the Netherlands and Sweden, a major factor at play in the increase of serious injuries was the growing number of crashes involving single bicycle crashes. In the Netherlands, about half of all serious injuries reported were sustained by cyclists who were injured in a crash that had no motor vehicle involvement. Of these, about 90% did not involve any other road users, i.e. they were single bicycle crashes. That more cyclists sustained serious injuries is due in part to older persons becoming more active cyclists (measured in distance travelled). Compared to younger cyclists, seniors on bicycles have a relatively high risk of being seriously injured in a crash or a fall. About half of all single bicycle crashes are related to infrastructure, for instance collision with an obstacle, running off the road, skidding due to slippery road surface, problems in stabilising the bicycle because of an uneven road surface (Schepers and Klein Wolt, 2012). In both Sweden and the Netherlands measures are being developed by national and local governments in the light of these findings to reduce risks for cyclists.

Another growing challenge for Safe System road safety policy is the growing number of motorcycles, mopeds, scooters, electric bicycles and other types of powered two-wheelers (PTW) on the world's streets. Between 2010 and 2013 alone, the global PTW fleet grew by 16%, with the majority of this growth (84%) taking place in low- and middle-income countries (LMICs). At the same time, data from the World Health Organization (WHO) shows that about 276 000 users of PTWs were killed in road traffic crashes in 2013 – that equals almost a quarter of all road traffic deaths in that year (WHO, 2015). Even more significantly, a shocking 91% of these PTW deaths occurred in LMICs. In Cambodia and Thailand, where there is a particularly large PTW fleet, motorcycle fatalities accounted for 70% and 73% of total road fatalities in 2013 respectively. In Latin Caribbean countries, nearly half (44%) of people killed in road traffic are PTW users.

Studies conducted in a variety of LMICs show that the main risk factors that contribute to PTW crashes resulting in injury or death include the non-use of helmets or use of poor quality and non-standard helmets, alcohol, speed, traffic mix, road side barriers, vehicle stability and braking errors. Effective planning for better PTW safety requires a comprehensive understanding of all the risk factors involved in different settings. The Safe System approach has several benefits as a framework for examining key PTW risk factors.

Addressing PTW safety with a Safe System approach should become a high priority for LMICs from both a public health and a socioeconomic perspective. With a lack of alternative transport mean limiting commuter choices, PTWs are used as the primary mode of transport in many LMICs, including for public transport or deliveries. The mean age of motorcycle crash victims in these countries is 25, which means that the majority die at a productive age (ITF, 2015). Studies have found that the injury rate for young PTW riders aged 17 to 19 years from lower income groups (often self-employed with no social or health insurance) is 2.5 times greater than for their peers in higher socioeconomic groups (Huang and Lai, 2011; de Vasconcellos, 2013; ITF, 2015). A crash resulting in serious injury or the loss of life places a big economic burden particularly on individuals and households from poorer backgrounds, and the high incidence of injury and death in the most economically active age groups has a direct negative effect on the national economy.

Figure 4.5. **Reported road crash fatalities and serious injuries in Sweden, Spain, the UK and Japan 1990-2009**



Source: ITF (2011).

Integrating road safety in other areas of public policy

To be able to contribute to the development of the transport system of the future, road safety has to be horizontally correlated with other important areas of the road transport system, e.g. environmental and accessibility issues. There is a convergence of public policy agendas around the notion of sustainable mobility, which should be safe, clean, affordable, healthy, accessible and efficient.

One example for the need of an integrated approach is automated driving. Self-driving vehicles offer possibilities in many areas, including road safety, environmental protection or improved accessibility. There is also a need to better understand new challenges arising from new technologies and societal trends and to continuously monitor and analyse them to be able to relate and react to these changes. Consequently there is a need for more integrated data and knowledge to be able to consider road safety as part of a whole. Horizontal co-ordination is also important for the promotion of road safety among higher-level governmental policies and for the mobilisation of essential resources for the development of a national road safety strategy. In other words, “the integration of road safety into other policy areas can be understood as the systematic mainstreaming of road safety into other related fields of policy” (DaCoTA, 2012).

To begin with, improving work-related road safety contributes not only to improving road safety at work but in general. The benefits of integrating road safety issues into employment policies are numerous, such as the reduction of the costs for the employers (number of days of work incapacity, insurance premiums, repair and replacement of vehicles in the fleet, impact on efficiency and on client satisfaction). Concern for road-safety also fits in the efforts generally developed for work-health promotion, which usually tackle a large array of issues that also relate to safe driving, such as stress management, fatigue, distraction, alcohol, drugs and medicine consumption, pre-existing diseases, ageing.

Environmental protection is another policy area where overlaps and synergies with road safety exist. For instance, travel demand directly affects road risk through exposure. The number of people travelling, the amount of travel and the transport mode chosen clearly influence both the number of road casualties and the environment. In the past decade, efforts have been made, for example in the European Union, for integrating environmental and transport policies, and to promote a modal shift away from road transport – of both people and goods – while increasing the efficiency of infrastructure use and co-modality.

Travel demand management includes land-use planning, fiscal incentives work place travel planning (teleworking, walking and cycling). The integration of environmental and road safety objectives in these measures would require selecting those deterring from the use of polluting and risky transport modes and favouring the shift towards safer and cleaner ones, such as public transport. On the other hand, walking and cycling should be favoured for environmental reasons, yet are also known to be riskier than car use. Then again, their public health benefits are generally acknowledged to outweigh their costs in terms of road trauma. Encouraging the shift towards active transport modes will be greatly aided by a Safe System environment that acknowledges individual risks for the individual and aims to minimise them, adding at the same time to positive public health outcomes.

Road injuries and deaths have long been considered primarily as a mobility or transport issue rather than a public health one. Yet, “there is a strong business case to include the prevention of road traffic deaths and serious injury on the health agenda” (DaCoTA, 2012). Injuries and health conditions resulting from unsafe traffic are obviously relevant to the health system, a point that is reflected in growing concern about underreporting of serious injuries from road crashes and attempts to improve casualty reporting.

Beyond this obvious example, several other areas of concern for public health policy are also relevant in a road safety context and offer opportunities for integrated approaches. This is the case, for example, of alcohol consumption and more specifically problematic consumption patterns which are increasingly recognised as a cause of drink-driving. Targeted programmes to tackle the issue of recidivism and alcohol dependence (reintegration programmes, alcolock-based programmes) are likely to have positive implications both in terms of road safety and public health in general. Another area of overlap with health policy is the link between individual mobility patterns, which can either help prevent health risks like coronary diseases or obesity through use of active mobility options, or aggravate them as a result of sedentary lifestyles.

The appropriate management of travel speed in s Safe System for improved safety is another area of public policy that can be effectively integrated to contribute to connected-up outcomes. In addition to safety outcomes from speed management there are clear benefits regarding environmental (reduced emissions), economic (less fuel consumption, less wear and tear, lower maintenance costs for vehicle owners) and quality of living (reduced noise) impacts.

Funding and resource allocation

Many countries with relatively good road safety performance allocate resource based on cost-effectiveness and cost-benefit analyses. Usually, the “Willingness to Pay” methodology is used to establish the Value of a Statistical Life (VOSL) to ensure lives saved and injuries avoided are taken into account and properly reflected in economic terms. This allows strong, objective business cases to be put forward when competing for resources to improve road safety and to prioritise interventions and projects.

Based on the four Safe System principles, pioneering countries are using new insights into the nature of crash problems to present strong arguments for road safety initiatives in the competition for funding and resources. Proactive emphasis on reducing the types of crashes that result in serious injury or death contrasting to earlier reactive approaches focussed on preventing all crashes (including property damage) is changing road safety business cases and opening up new possibilities for funding sources. Personal injury insurance companies are demonstrating increasing interest in sound business cases for Safe System projects that reduce the burden of serious injury on the road network. People who are severely and permanently impaired for life represent a small proportion of the total number of claims for personal injury insurance support, but make up a disproportionately high part of total costs with lifetime medical and living support required.

Major new road developments in particular are increasingly taking into account Safe System elements beyond current prevailing standards in their project proposals. Safe System improvements add to benefits and costs, yet their value is not always recognised in available budgets. Some pioneering countries are taking a step-by-step approach: they ensure that the initial design includes Safe System elements to the extent possible, so the foundations are in place to progressively add additional protective features at a later stage, when more resources become available. Examples of business case development for a Safe System are found in chapter 5.

Research and development, knowledge transfer, capacity building

The concept of a Safe System in road transport is comparatively new. More analysis, evaluation, research and development are needed to improve and better share knowledge and to build capacity amongst stakeholders and system designers to implement a Safe System.

Research and Development (R&D) and the systematic transfer of knowledge are an important contribution to build the capacities needed for the implementation of a Safe System. They provide new insights to develop a better understanding of the nature of crashes, the errors that humans make and how systems can be made "forgiving" to reduce inherent risk in the road infrastructure and provide effective protection from serious harm in crashes (ITF, 2016).

In addition to informing the development of strategies, action plans, directions and interventions, research and development and knowledge transfer is vital in supporting the paradigm shift changes in thinking, practice and approach required for implementing a Safe System.

R&D and knowledge transfer help build the required human capacity by producing a cadre of professionals who contribute research based approaches and knowledge as informed opinion leaders. Pilot projects and demonstrations are among the most effective measures to explain the Safe System, and some national governments are making subsidies available to local and regional authorities for Safe System demonstration projects. In a number of countries, important resources are being allocated to document Safe System case studies and share the lessons from Safe System demonstration projects. These are also used to update design guides and develop training material to disseminate Safe System knowledge among professionals involved in designing, building and operating road networks.

Conclusions and recommendations

There are no perfect Safe System management structures which will fit every country and automatically deliver a Safe System. In principle, interventions aligned with a Safe System may be implemented irrespective of the specific management structure and working processes. However, experience has shown that a Safe System includes elements that should be reflected in the structures and processes employed to manage the system in order to facilitate a smooth and speedy adoption.

First of all, the governance and management structures and approaches for building and operating a Safe System should reflect the critical importance of shared responsibility for road safety. They should enable and support stakeholders to actively take part in the planning, implementation and monitoring of the road safety work. Second, a systematic way of working will greatly help the move to a Safe System. This could be based on approaches like the Plan-Act-Do-Check cycle of continuous improvement or the adoption of ISO 39001 standard for road traffic safety management systems by more organisations.

As high-level targets for total fatalities and serious injuries do not provide sufficient guidance to stakeholders for activity planning, more intervention-related interim targets are needed. For that reason targets for final outcomes should be combined with targets for intermediate outcomes (known as Safety Performance Indicators, or SPIs). This will help stakeholders to identify measures that can contribute towards changes in condition states on the road transport system that are necessary to achieve targets for the number of fatalities and seriously injured.

All the steps in the process, from defining targets through identifying measures to evaluating performance should be based on evidence. Use of relevant, high quality data is therefore critically important. The data collected and analysed must be chosen from a Safe System perspective, highlighting inherent risks in the road transport system and able to help identify the root causes of serious crashes. Data should provide a balanced and complete picture of crash causation and care should be taken to avoid inherent biases or limited views of the total problem for example by not only focussing on behavioural aspects.

Where possible, aggregate quantitative data should be combined with qualitative data (e.g. from in-depth studies of crashes). This will allow initial mapping of the different road safety problems and then analysis of the root causes from a Safe System perspective. These underlying factors will often be inherent risks present in the road system that apply to similar crashes for a number of people. Effectively treated root causes are likely to provide a larger and more sustained benefit by preventing similar occurrences in the future. Such a systematic approach will increase the ability to identify the most effective interventions.

Traditional policy instruments such as regulations, communication campaigns and economic measures remain useful in a Safe System. However, they should not only be used in a traditional top-down, centrally driven manner that aims to force individual road users and stakeholders to adopt "correct" behaviour, as such an approach based primarily on authority. Instead a focus on outcomes or management by results is encouraged (e.g. through the use of targets) leaving stakeholders enough flexibility to develop the solutions that will deliver the desired results, thus fostering shared responsibility and innovation.

Today's rapid technological innovation and societal change means that the context of road safety policy and strategy will constantly evolve. New road safety challenges are constantly emerging as the pace of digitalisation and automation will increase.

The existing government-centric management structures and processes will be questioned and co-operation among road safety stakeholders will need to take new forms requiring flexible frameworks focused on the achievement of outcomes through shared responsibility. The sharing of information about the root causes and inherent risks in the road transport system and evidence based solutions amongst the community and stakeholders will play an important role in opening up the often hidden knowledge about road safety. It will help to develop understanding and mobilise support for further interventions in a Safe System.

Road safety work cannot operate in isolation. Communities are increasingly seeking improvements in lifestyle, sustainability, environment and connectivity. A Safe System way of thinking and working offers great opportunities for integration of road safety with other community policy expectations for greater potential benefits.

Research and development that increasingly adopts scientific lines of enquiry based on the principles of a Safe System will continue to yield new insights and understandings about the road safety problems. For example, emerging research in countries pioneering the implementation of a Safe System is identifying that the majority of people seriously injured in crashes is the result of a simple error or mistake, contrasting with earlier thinking and limited data collection and analysis that concluded that deliberate risk taking was the primary behavioural cause. Understanding, identifying and responding to inherent risks in the road transport system which allows serious crash outcomes to occur will inform new treatments.

References

Applebaugh, J. (2010), “Governance Working Group”, PowerPoint presentation, National Defense University and ISAF.

Belin, M.-Å. and P. Tillgren (2012), “Vision Zero: How a Policy Innovation is Dashed by Interest Conflicts, but May Prevail in the End”, in *Scandinavian Journal of Public Administration*, Vol.16/3, pp. 83-10.

Belin M.-Å., P. Tillgren and E. Vedung (2010), “Theory and Practice in Sweden: A Case Study of Setting Quantified Road Safety Targets”, in *Journal of Health and Medical Informatics,* Vol.1/101. DOI: 10.4172/2157-7420.1000101.

Berecki-Gisolf, J., A. Collie and R. McClure (2013), “Work disability after road traffic injury in a mixed population with and without hospitalisation”, in *Accident Analysis and Prevention,* Vol. 51/0, pp. 129-134.

Bliss, T. and J. Breen (2008), “Implementing the recommendations of the world report on road traffic injury prevention. Operational guidelines for the conduct of country road safety management capacity reviews and the related specification of lead agency reforms, investment strategies and safety programs and projects”, World Bank Global Road Safety Facility, Washington, DC. http://siteresources.worldbank.org/EXTTOPGLOROASAF/Resources/traffic_injury_prevention.pdf

Carnes, W. E. (2011), “Highly Reliable Governance of Complex Socio-Technical Systems”, Working Paper, Deepwater Horizon Study Group.

Cohen, M., J. G. March and J. P. Olsen (1972), “A Garbage Can Model of Decision-Making”, in: *Administrative Science Quarterly,* Vol. 17, pp. 1-25.

DaCoTA (2012), *Road Safety Management*. Deliverable 4.8p of the EC FP7 project DaCoTA.

de Vasconcellos, E.A. (2013), “Road safety impacts of the motorcycle in Brazil”, in: *International Journal of Injury Control and Safety Promotion,* Vol. 20/2, pp.144-51.

Hakkert, A.S, V. Gitelman and M.A. Vis (eds.) (2007), *Road Safety Performance Indicators: Theory*. Deliverable D3.6 of the EU FP6 project SafetyNet.

Huang, W.S and C. H. Lai (2011), “Survival risk factors for fatal injured car and motorcycle drivers in single alcohol-related and alcohol-unrelated vehicle crashes”, in *Journal of Safety Research,* Vol. 42/2, pp. 93-99.

Hudson, P.T.W. (2001), “Safety Culture: Theory and Practice in the Human Factor in System Reliability”, Nato Series RTO-MP-032, North Atlantic Treaty Organisation, Brussels.

Hufty, M. (2011), “Investigating Policy Processes: The Governance Analytical Framework (GAF)”, in Wiesmann, U., H. Hurni et al. (eds.), *Research for Sustainable Development: Foundations, Experiences, and Perspectives,* pp. 403-424. www.academia.edu/8012331/The_Governance_Analytical_Framework

ITF (2016), *Halving the Number of Road Deaths in Korea: Lessons from Other Countries,* OECD Publishing, Paris. www.itf-oecd.org/sites/default/files/docs/halving-road-deaths-korea.pdf

ITF (2015), *Improving Safety for Motorcycle, Scooter and Moped Riders*, OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/9789282107942-en

ITF (2012), *Sharing Road Safety: Developing an International Framework for Crash Modification Functions,* OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/9789282103760-en

ITF (2011), *Reporting on Serious Road Traffic Casualties*. *Combining and using different data sources to improve understanding of non-fatal road traffic crashes*, International Transport Forum, Paris. Accessible at www.itf-oecd.org/reporting-serious-road-traffic-casualties.

ITF (2008), *Towards Zero: Ambitious Road Safety Targets and the Safe System Approach*, OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/9789282101964-en

Kane, G. (2009), *Three Secrets of Green Business: Unlocking Competitive Advantage in a Low Carbon Economy*. Earthscan, London.

Kingdon, J. (1995), *Agendas, Alternatives and Public Policies*. New York, Harper/Collins.

Parsons D. W. (1995), *Public Policy: An introduction to the Theory and Practice of Policy Analysis*, Edward Elgar Publishing.

Peters, B. G. (2002), “Governance: A Garbage Can Perspective”, in *Political Science Studies,* Vol. 84, Institute for Advanced Studies, Vienna.

Petrossian, S. V. and B. J. Marsh (2010), “Western Australia’s Safe System Working Group”, in *Journal of the Australasian College of Road Safety,* Vol. 21/4, pp. 54-57.

Road Safety Foundation (2015), “How much do road crashes cost where you live? British EuroRAP Results 2015”, accessible at www.roadsafetyfoundation.org/media/32684/british_eurorap_report_2015_final.pdf.

Schepers, J. P. and K. Klein Wolt (2012), “Single-bicycle crash types and characteristics”, in: *Cycling Research International,* Vol. 2, pp. 119-135.

Shinar, D. (2007), *Traffic Safety and Human Behavior*, Elsevier, Oxford.

Stigson, H. (2009), *A Safe Road Transport System – Factors Influencing Injury Outcome for Car Occupants,* Karolinska Institutet, Stockholm.

Stipdonk, H. (2013), *Road Safety in Bits and Pieces: For a Better Understanding of the Development of the Number of Road Fatalities*, PhD thesis, Delft University of Technology. www.swov.nl/rapport/Proefschriften/Henk_Stipdonk.pdf

Underwood, P. and P. Waterson (2013), “Systemic accident analysis: examining the gap between research and practice”, in: *Accident Analysis and Prevention*, Vol. 55, pp. 154-164.

Van Herten, L. M. and L. J.Gunning-Schepers (2000), “Targets as a tool in health policy Part I: lessons learned”, in *Health Policy,* Vol. 53, pp. 1-11.

Vedung, E. (1997), *Public Policy and Program Evaluation*, Transaction Publishers, New Brunswick, NJ.

Wageningen University and Centre for Development Innovation, Multi-Stakeholder Processes Knowledge Co-Creation Portal, www.wageningenportals.nl/msp/topic/complex-adaptive-systems (accessed 31 July 2016).

Wegman, F. and P. Wouters, (2002), "Road safety policy in the Netherlands: Facing the future", in *Annales des Ponts et Chaussées*, nouvelle série, no. 101, jan-mar 2002.

Weijermars, W. and F. Wegman (2011), "Ten Years of Sustainable Safety in the Netherlands. An Assessment", in *Transportation Research Record*, Vol. 1-8. TRB, Washington.

Weijermars, W. and P. Wesemann (2013), "Road safety forecasting and ex-ante evaluation of policy in the Netherlands", in *Transportation Research, Part A: Policy and Practice,* Vol. 52, pp. 64-72.

Weijermars, W., N. Bos and H. L. Stipdonk (2015), "Serious road injuries in the Netherlands dissected", in: *Traffic Injury Prevention,* Vol. 17/1, pp. 73-82.

Note

[13] Data collection, management and analyses is discussed in more detail in *Data Systems. A Road Safety Manual for Decision-Makers and Practitioners* (WHO 2010) and the World Road Association's *Road Safety Manual* (PIARC, 2015). These cover the collection and use of crash as well as non-crash data, and why the latter is needed.

Chapter 5. Safe System practices and tools

A road crash is the result of a failure in the traffic system. A Safe System aims to proactively limit such systemic failures or keep their impact below thresholds that cause serious harm to humans where crashes do occur. Core elements of a Safe System are safe vehicles, safe roads and roadsides, safe road users, safe speeds as well as effective post-crash response. This chapter examines a range of policies, measures and tools that are available in these areas to build a Safe System and provides various case studies from pioneering countries.

Operationalising a Safe System

A road traffic crash, particularly when it leads to someone being killed or seriously injured, is an end result of system failure. The objective of a Safe System is to proactively identify and limit such systemic failures. One approach is to design the system backwards from the end point of the severe casualty and intervene in the integrated safety chain (see Figure 2.1 above) as early as possible in an attempt to avoid a crash.

In the first instance, the design and operation of a Safe System seeks to guide and encourage safe behaviour by users when using the road transport network. When a crash does occur, the amount of energy that is exchanged needs to be limited to remain within the biomechanical tolerances of the human body. Post-crash care actions should also work to reduce the severity of any injuries.

Approaches to understanding the biomechanical tolerances of humans include the levels of kinetic energy, change in velocity and/or acceleration. However, Safe System limits are typically explained or operationalised through reference to Safe System speeds. A Safe System speed is typically defined as the impact speed where the chance of death is less than 10% or the point on fatality risk curves where this changes from shallow to steep (Wramborg, 2005). Commonly referenced survivable impact speeds are shown in Table 5.1.

Table 5.1. **Safe impact speeds for different situations**

Road and section types combined with road users	Target Safe System speed
Roads and sections used by cars and vulnerable users	30 km/h
Intersections with possible side-on conflicts between cars	50 km/h
Roads with possible frontal conflicts between cars	70 km/h
Roads with no possible frontal or side-on conflicts between vehicles and no vulnerable road users	≥100 km/h

Source: OECD/ECMT, (2006).

The quantifiable definition of what is a tolerable level of risk will change over time both with experience and new evidence. Examples of more recent research on critical impact speed curves, particularly for pedestrians, can be found in Rosen et al. (2011), Kroyer et al. (2014) and Jurewicz et al. (2016). The latter report considered fatal and serious injuries combined and suggested critical impact speeds as low as 20 km/h for pedestrians and 30 km /h for head-on and side impact crashes.

Whilst there is, and will continue to be, considerable debate on safe impact speeds and the shape of various fatality risk curves, precise definitions are not possible or meaningful in reality. They represent some form of population average over a sizeable number of cases but there is considerable variability in outcomes, and hence risk, among individuals due to uncontrollable factors such as the type and size of the vehicle, the age and health status of the road user, the point of impact, etc. There is a certain randomness about these factors that is often beyond the control of the system designer or operator. Because of this variability in the incidence and circumstances of real world crashes, a conservative position should be adopted concerning risk so as to account for a broad range of population, vehicles and conditions. We must also be cognisant that the use of fatality risk curves, and the tenth percentile value to determine safe impact speeds, is by definition permitting the incidence of some deaths and serious injuries, notwithstanding the commitment to eradicating deaths and serious injuries from road crashes.

Over time, and with the enlightening experiences of developing a Safe System, insights will develop and evolve. Openness and flexibility are needed with respect to updating views on what constitutes a Safe System and on the speeds that the system can accommodate to provide protection to users. Furthermore, with the steady incorporation of inherently safer vehicles into fleets, with both crash avoidance technologies and occupant protection, a greater part of the injury problem will be managed within Safe System limits. However, reducing the likelihood of fatal injuries may require greater efforts across the entire system.

Taking a system wide approach

Moving the road transport system towards a Safe System relies on the application of measures from a number of the key elements of the system including safe roads, safe vehicles, safe speeds and safe behaviours which individually contribute to reducing crash risk and, in any crash, to reducing the injury severity of the outcome. Interactions between complementary measures to reduce combined crash energy transfers will provide cumulative benefits beyond the impact that individual measures have. To significantly reduce road casualties, road user rules and behaviour, road and traffic environment, speed limits and speed management, driver assistance systems, injury mitigating properties of vehicles, and emergency responses must be combined in an optimised way.

In isolation, each component may have some positive effect, but as each component sets the preconditions to maximise the benefits of the others, the whole combination will give more effect than the sum of the individual impacts of all components. As an example, vehicle design is predominantly led by the private sector whereas road design and operation is predominantly the domain of the public sector. Despite this, there are opportunities to create greater synergies between the two. Thus, intersection geometry can be established to maximise the occupant protection offered by vehicle design.

In other cases, the key to addressing some traditionally difficult safety problems may lie in interventions in other parts of the system. Addressing excessive speed and recidivist drink driving, for instance, have traditionally been targeted through education and enforcement, but may be more effectively addressed via safe vehicle technologies such as Intelligent Speed Assist (ISA) or built-in alcohol locks in vehicles. For more information on the whole of system approach, see Figure 2.3 and the Chapter 4 section Systematically managing for a Safe System.

There is considerable discussion and debate around the various Safe System elements and their roles in creating it. Stigson (2009) looked at factors influencing severe injury outcomes for vehicle occupants, the relative contributions and the interactions of the key Safe System elements in preventing these and the potential for Safety Performance Indicators (SPI) to identify and eliminate systemic weaknesses.

The safe road transport model developed by the Swedish Road Administration (SRA) (see Figure 3.2) uses the biomechanical limits of the human body as its cornerstone and the following system components:

- **Safe Vehicle:** Vehicle supports correct use; protects driver and passengers; protects other road users (Criteria: EuroNCAP 5-star level and Electronic Stability Control, ESC)

- **Safe Road:** Road supports correct use; is forgiving in terms of injury mitigation (Criteria: EuroRAP 4-star level)

- **Safe Road User:** Road user has the knowledge, capability, capacity, willingness to correctly use the road transport system (Criteria: Wears seat belt, complies with speed limits, is sober)

Combined with safe speed, these elements should ensure safe road transport. The study found that compliance with these requirements would go a long way towards eliminating death and serious injuries. Some shortcomings were identified, however; the study found that most fatal injuries occurred when two or all three of the components did not meet the criteria. It also found divided roads were the most effective factor in avoiding fatalities among vehicle occupants. However, it also found that reliance on the human-behaviour elements to have the weakest impact, with 40% of killed vehicle occupants not wearing seat belts (despite an overall 96% seatbelt wearing rate) and a quarter of fatalities among vehicle occupants occurring in alcohol-related crashes. These two factors were also strongly related. The report concluded that while road users may be motivated to change their behaviour over a short period of time, for a more sustainable result both vehicle and road design must support the road user. Stigson proposed a modified Safe System model where the road infrastructure is based on the capabilities and limitations and biomechanical tolerances of human beings, through good road and vehicle design.

The United Nation's Global Plan of Action for the Decade of Road Safety has defined an approach to improving road safety based on five pillars, which broadly align with the elements of a Safe System:

- **Pillar 1:** Road safety management
- **Pillar 2:** Safer roads and mobility
- **Pillar 3:** Safer vehicles
- **Pillar 4:** Safer road users
- **Pillar 5:** Post-crash response.

Road safety management was treated in Chapter 4. Pillars 2 to 5 will be discussed in the following sections. A further section is devoted to safe speeds, as the importance of managing speed in a Safe System cannot be over-emphasised. Safe Roads and Roadsides, Safe Speed, Safe Vehicles, and Safe Road Use are often referred to as the elements, or components of a Safe System.

Safe roads and roadsides

Road conditions can be the single most lethal factor in serious crashes, ahead of speeding, alcohol or non-use of seat belts (ITF, 2015c). However, the role of road-related factors in both the causation and outcome of crashes has been underplayed, often because crash investigations focus on driver causation.

Stigson (2008) reviewed fatal crashes in Sweden based on in-depth crash investigation, with crashes categorised based on factors that contributed to the crash outcome (as opposed to crash causation). The study found that there were strong interactions between three system components (vehicles, road infrastructure and road users), but that road-related factors were most strongly linked to a fatal crash outcome. Put another way, in the event of a crash, regardless of how that crash occurred, infrastructure can have a significant impact on the severity of the outcome. Furthermore, Stigson et al. (2011) found that while vehicle safety standards a potentially have a major beneficial effect on vehicle occupants' serious injuries, road-related factors were most strongly linked to fatal crash outcomes.

While a number of countries have adopted Safe System principles, translating these into practice in the infrastructure delivery is proving difficult. Part of the reason for this is that the present road and roadside infrastructure design guidelines were developed over many years and are often based on the paradigm of maximising mobility and throughput of traffic. While they may also aim to reduce the number of crashes and their impacts, they do not necessarily take an injury prevention approach. Often the design standards rely on drivers making the right decisions, for instance gap-acceptance decisions at intersections.

A review of existing road infrastructure design standards is thus required to better reflect Safe System principles. This is an important step to institutionalise the change to a Safe System and ensure all engineers, designers, policy makers and funders apply the new design philosophy and the approach it entails. To use an analogy from the design of buildings: all balconies must have balcony rails as a default; there is not specific cost-benefit analysis for individual balconies that takes account of height of the balcony, wind exposure, width of the balcony or the age of people potentially using it - all these are embedded in the design manuals for structural engineers and are standard practice.

The right balance between safety and mobility is under continuous debate in Safe System discussions. Sweden, one of the Safe System pioneers, follows the approach that accessibility can only be developed within a framework of safety. To help inform this debate a number of countries are adopting performance measures for road infrastructure to complement the established systems. The use of minimum standards (expressed for instance in star ratings like those used in Road Assessment Programmes) for network management and new road designs provides an evidence-based foundation for road authorities' infrastructure decisions. The United Kingdom, for instance, has set the target that 90% of travel should take place on three-star or better roads by 2020 (Highways England, 2014). The Netherlands have set the objective of no more one- or two-star roads by 2020. New Zealand is planning for all roads of national significance to have a four-star rating. The Asian Development Bank (ADB) is recommending four-star level for roads with pedestrians in linear settlements.

While including Safe System elements into new infrastructure is comparatively easy if included in the conceptualisation from the outset, retrofitting of infrastructure poses a substantial technical and financial challenge that require cost-effective innovation. Safety thus needs to be embedded into planning and design as early as possible. The starting point for safe infrastructure should be a good road hierarchy with a clear distinction between, at one side, inter-urban high-speed roads where the infrastructure needs to be forgiving at the allowed speeds and with separate facilities for vulnerable road users, and at the opposite end, low-speed pedestrian-priority urban streets where vulnerable road users mix with motorised traffic. There also needs to be strong control and management of land use and urban development and planning cities and communities for those without vehicles.

All road users need to be considered when designing or upgrading road infrastructure. The design of road infrastructure and the broader street environment should start with the needs of the most vulnerable users and then progress towards the safety needs of the least vulnerable. A road-design and corridor-planning exercise that considers the needs of pedestrians, cyclists, animal drawn carts, motorcycles, cars, trucks and buses will ensure that appropriate function, speed, road space allocation, and design features are incorporated to deliver the best safety outcomes.

Many useful infrastructure interventions can be found in various guides including PIARC (2015), Elvik et al. (2009) and in on-line tools such as the Road Safety Toolkit (http://toolkit.irap.org) created by the International Road Assessment Programme (iRAP). Often referred to as Safe System treatments, some of these can substantially reduce road deaths and serious injuries. Others may have a relatively small impact, but will still result in safety improvements and help progress towards a Safe System.

Turner et al. (2009) distinguish between “primary” and “supportive” road safety treatments, with primary treatments being those that represent an important step towards a Safe System and supportive treatments those that provide incremental safety gains but not to a level that would create a Safe System. An example of a “primary” Safe System treatment a median barrier, as this will virtually eliminate (in over 90% of cases) fatal head-on crashes, while a “supportive” treatment would be a wide centreline with rumble strips that will make them less likely. It is strongly recommended that the primary treatments are employed where possible.

Some examples of high-performing primary Safe System infrastructure treatments that can provide certain and immediate reduction in crash likelihood and severity include:

- well-designed roundabouts
- grade-separated pedestrian crossings
- wire-rope barriers (also called cable-barrier systems) in the centre and on the edge of roads, in countries with a low share of powered two-wheelers.

However, there are still knowledge gaps regarding Safe System infrastructure designs for some crash types and some road user groups. While it is known that median barriers can reduce head-on crashes by over 90%, that flexible barriers absorb crash energy and can protect from roadside hazards, that roundabouts simplify decision-making for drivers and help to manage speeds at intersections, we know less about effective Safe System infrastructure solutions for intersections in high-speed environments (other than grade separation) and concerning motorcyclists.

Road Infrastructure Safety Management

The International Road Traffic and Accident Database (IRTAD) 2015 report on Road Infrastructure Safety Management (RISM) identifies and evaluates 10 procedures being used for RISM (ITF, 2015c); these procedures and their general purposes are outlined in table 5.2. These procedures are aimed at enhancing road safety at different stages of a road infrastructure life cycle from planning and design through construction, operation, maintenance, improvement and major upgrading and renewal.

While there are overlaps and similarities between some of these, there are also important differences. In general, the choice of which procedure to use is linked to the data available and the stage in the project life cycle. One of the key differences is that Network Safety Rankings (NSRs) are typically based on historical crash data, while Road Assessment Programmes (RAPs) are based on surveys of infrastructure design and quality.

An example of RISM in practice is the European Directive (2008/96/EC) which outlines the mandatory requirements for an infrastructure safety management process for the trans-European road network (TEN). The components of this directive include:

- Road Safety impact assessment
- Road Safety audit including the certification of auditors
- Road Safety inspections
- Ranking of road sections

- Data management
- Adoption and communication of guidelines
- Certified auditors for safety audit.

This directive puts the responsibility on the infrastructure provider or manager for the safety management of a road network. It encourages a generalised use of RISM procedures, which are now established in all EU member states linked by the Trans-European Transport Network (TEN-T) and have been extended to some non-TEN-T roads. Thus, the directive certainly triggered a different way of thinking and dealing with road safety management in the European Union (Transport and Mobility Leuven, 2014).

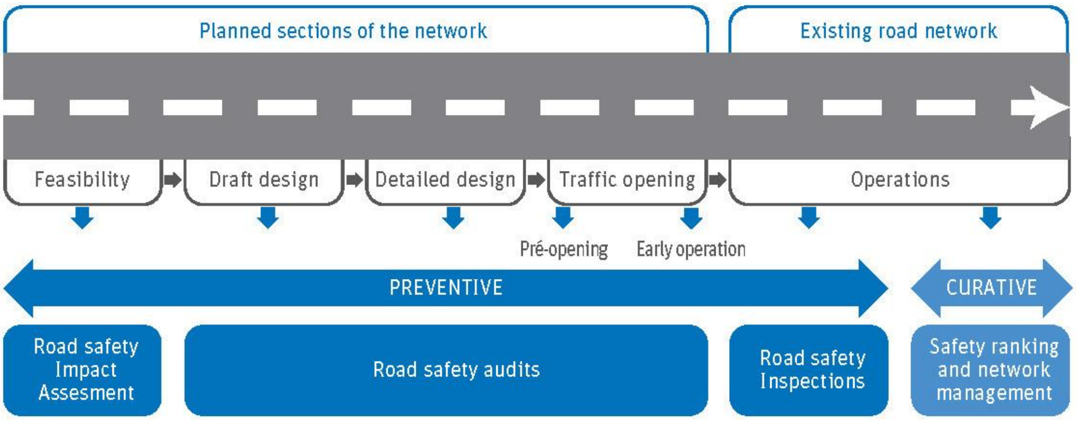
RISM procedures are effective tools to help road authorities reduce the number of crashes and casualties. However, in a Safe System environment we need to move towards a more pro-active approach with a focus on the infrastructure elements and designs that do not result in the higher severity casualties. Pro-active procedures are particularly important for LMICs, who may not have good crash data. They provide an opportunity to develop a pro-active culture of road safety amongst those responsible for the planning and delivery of road infrastructure.

Table 5.2. **Road Infrastructure Safety Management Procedures**

Procedure	Purpose
Road Safety Impact Assessment	Compare different implementation scenarios from a road safety point of view.
Efficiency Assessment tools	Compare different scenarios from road safety point of view and identify the most efficient measure from a list of potentially effective measures.
Road Safety Audit	Identify infrastructure or traffic related factors increasing injury or accident risk.
Network Operation	Maintain the current level of safety of roads.
Road Safety Performance Indicators	Assess the safety of a road network.
Network Safety Ranking	Rank elements of a road network based on their safety level.
Road Assessment Programme	Rank elements of a road network based on road safety and identify infrastructure or traffic related factors increasing injury or accident risk.
Road Safety Inspection	Identify infrastructure or traffic related factors increasing injury or accident risk.
High Risk Sites	Identify infrastructure or traffic related factors increasing injury or accident risk.
In-depth Investigation	Identify infrastructure or traffic related factors increasing injury or accident risk.

Source: ITF (2015c).

Figure 5.1. **Planning processes of the European Directive 2008/96/EC on Road Infrastructure Safety Management**



Road Assessment Programmes

Road Assessment Programmes (RAPs) carry out systematic assessments of risks associated with road infrastructure in order to identify the major shortcomings that can be addressed by practical road improvement measures. A common rating system awards stars to roads depending on their standard of safety, with one star indicating low safety and five starts signifying very high level of safe road infrastructure. Through the star ratings, RAPs create transparency for road users but also for infrastructure designers, builders or operators. Ratings are also highly effective in communicating road safety improvements, and a number of countries are using RAP star ratings as benchmarks for setting road standards and targets.

Following the European Road Assessment Programme (EuroRAP) launched in 1999, the Australasian programmes (AusRAP and KiwiRAP) and the United States programme (usRAP) were created in the early 2000s. In 2006 the International Road Assessment Programme (iRAP) was established as a charity to oversee the global programme and support governments; development banks and automobile clubs in their efforts to improve road safety. Since its inception, the programme has rated more than 900 000 km of roads in over 70 countries worldwide.

The philosophy and evidence-based approach used by RAPs worldwide is driven by Safe System principles. Together with its sister organisations of the New Car Assessment Programmes (NCAPs), the RAPs provide the cornerstone for a Safe System in relation to speed, vehicle and infrastructure performance. Safe System principles are captured in the "Roads that Cars can Read" partnership, EuroRAP (2011). RAPs are currently planning to develop infrastructure star ratings for roads used by self-driving cars.

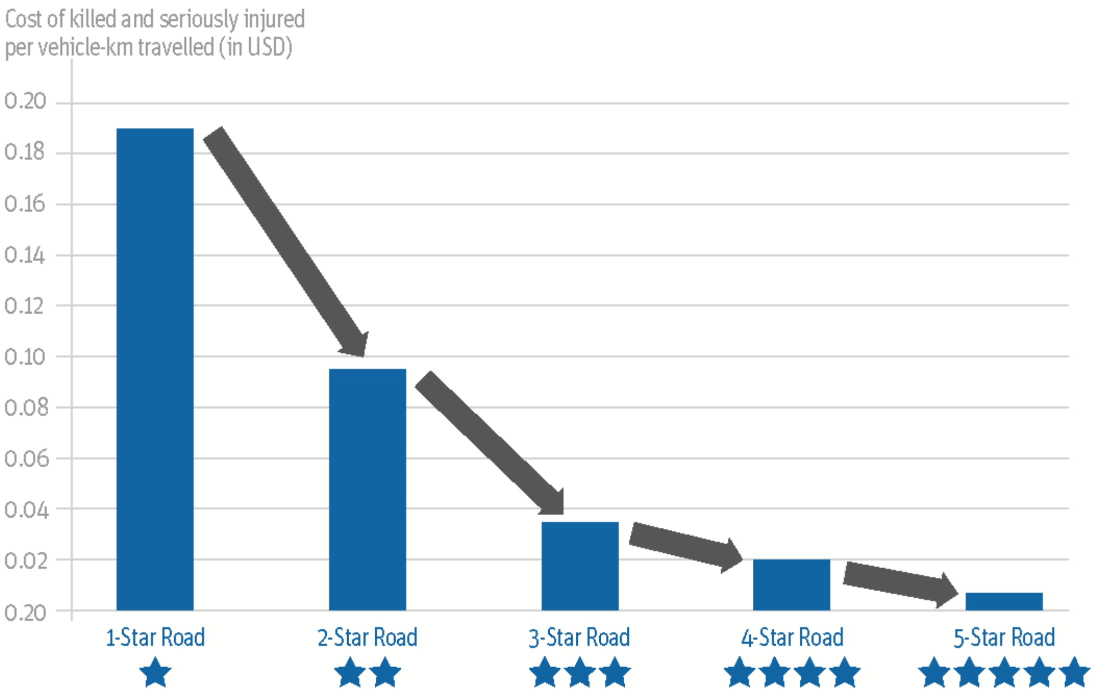
The star-rating protocol pro-actively rates the road safety performance of infrastructure at a specific location or across a network of roads by assessing the features that are present for safety. Star ratings are based on an objective, evidence-based methodology for assessing the safety of road infrastructure, taking into account the speed and mix of traffic at the location. Safer Road Investment Plans provide the complementing economic analysis to support Safe System-related improvements.

Star ratings are awarded for roads overall and differentiated for pedestrians, cyclists, motorcyclists and vehicle occupants. They are based on the typical crash types that kill and injure and the specific safety needs of that user based on Safe System principles taking into account vehicle speed. Five-star roads come as close as can be to Safe System infrastructure as we understand it.

Experience from around the world suggests that crash rates per distance travelled reduce between 33 and 50% for each additional star awarded (see Figure 5.2). In other words, the risk of death or serious injury risk per kilometre travelled on a five-star road is approximately 10% the risk a user faces on a single-star road. The potential for Safe System road infrastructure to be defined in a five-star standard for each relevant road user is currently being investigated by iRAP as part of seeking to understand the more complex interactions between vehicle types, speeds, infrastructure design and road users for safe outcomes.

The star-rating model includes more than 60 road attributes, including the core elements of Safe System design. They include road features that create a self-explaining environment (cross-section, line marking, signage and functional design) and thus minimise the potential for human error, as well as elements that mitigate the consequences of human mistakes when they occur so that crashes do not result in serious outcomes.

Figure 5.2. **Crash cost reduction per improved road safety rating**



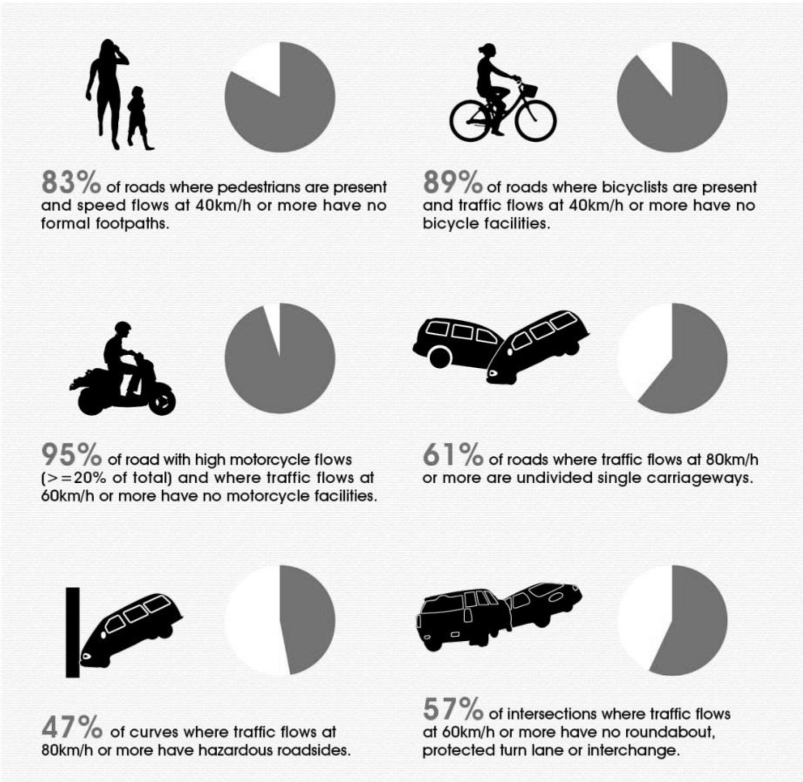
Source: iRAP.

As the speed and volume of traffic increases, higher-standard features are needed to maintain the same level of star-rated protection for road users. This may include physical separation of vulnerable road users, protection from roadside hazards, enhanced intersection design and separation of high-speed oncoming traffic. Figure 5.3 presents the summary findings from the assessment of almost 250 000 kilometres of roads in 60 countries at all levels of development. Linked to the relationship between speed and fatality risk, the analysis highlights the degree to which basic infrastructure features contribute to a Safe System and the management of crash forces that exceed biomechanical tolerance levels.

Safe System Infrastructure Assessment framework

A framework for assessing how infrastructure rates in terms of a Safe System has recently been developed by the association of Australasian road transport and traffic agencies known as Austroads (Austroads, 2015). Based on a review of literature on Safe System infrastructure and existing risk assessment frameworks, the framework considers typical crash types resulting in fatal and serious injury outcomes, and the risks of these crashes (exposure, likelihood and severity). It provides useful prompts to ensure each pillar of a Safe System is considered. The tool uses a matrix and multiplicative model to score and rate infrastructure projects on a 448-point scale, with 0 being low risk and 448 being very high risk.

Figure 5.3. **Levels of exposure to potentially non-survivable forces in the event of crash conflicts**



Source: iRAP.

While the scoring is to some extent subjective, guidance is provided in an attempt to make it as consistent and objective as possible. In the future, more tools such as this will become available and assist in embedding Safe System thinking into infrastructure projects. Such assessment frameworks could be helpful not only for new road projects, but could also potentially be applied to existing corridors and town planning proposals.

Figure 5.4. **Example of Austroads Safe System Assessment Framework**

	Run-off road	**Head-on**	**Intersec-tion**	**Other**	**Pedestrian**	**Cyclist**	**Motor-cyclist**	Total
Exposure	High volume	High volume	High volume on Burwood Hwy Moderate volume on Terrara Road	High volume	Low pedestrian volumes	Low cyclist volumes	Low motor-cyclist volumes	
	$\frac{4}{4}$	$\frac{4}{4}$	$\frac{4}{4}$	$\frac{4}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	
Likelihood	Steep grade Decelera-tion lane Presence of intersection No shoulders Moderate clear zone No barriers	Divided, wide/raised median Intersection movements /conflict points minimal for head-on crash	% turning movements No. of lanes and conflict points High speed Poor sight distance Protected turn lanes	High no. of lanes Protected turn lanes Short de-celeration lanes Buses stopping	Service lane with footpath No crossing facilities at intersection Many lanes to cross	Service lane some separation No crossing facilities at intersection	No delineation Well surfaced Straight road	
	$\frac{3}{4}$	$\frac{1}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{4}{4}$	$\frac{4}{4}$	$\frac{3}{4}$	
Severity	High speed No barriers Steep grade Poles and trees to hit	High speed Low speed in side road	High speed Bad conflict angles	High speed	High speed No crossing facilities	High speed	High speed Some roadside hazards	
	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{4}{4}$	$\frac{3}{4}$	$\frac{4}{4}$	$\frac{4}{4}$	$\frac{4}{4}$	
Product	$\frac{4}{4}x\frac{3}{4}x\frac{3}{4} = \frac{36}{64}$	$\frac{4}{4}x\frac{1}{4}x\frac{3}{4} = \frac{12}{64}$	$\frac{4}{4}x\frac{3}{4}x\frac{4}{4} = \frac{48}{64}$	$\frac{4}{4}x\frac{3}{4}x\frac{3}{4} = \frac{36}{64}$	$\frac{1}{4}x\frac{4}{4}x\frac{4}{4} = \frac{16}{64}$	$\frac{1}{4}x\frac{4}{4}x\frac{4}{4} = \frac{16}{64}$	$\frac{1}{4}x\frac{3}{4}x\frac{4}{4} = \frac{12}{64}$	$\frac{176}{448}$

Source: Adapted from Austroads (2016).

The economic benefits of safe road infrastructure

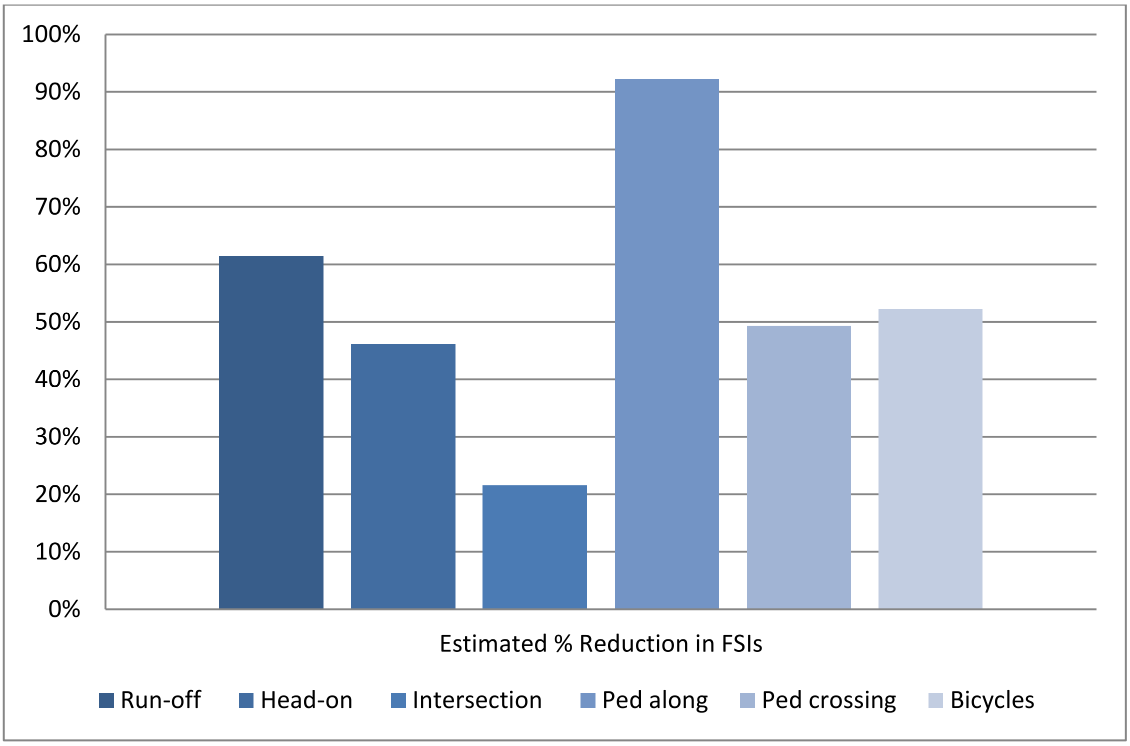
The economic cost of road crashes is estimated to be in the range between 2 and 5% of GDP per annum for many countries. Well-targeted investments in improved road infrastructure that achieve a reduction in fatalities and serious injuries thus offer potentially high returns.

An analysis by iRAP (2014) based on case studies from around the globe, investigated the proportion of fatal and serious injury outcomes that could be avoided or prevented with cost-effective engineering treatments. The study concluded that in total, 92% of pedestrian fatalities and serious injuries can be prevented among those walking along roads. Among pedestrians crossing the road, 49% of deaths can be avoided with cost-effective engineering treatments alone. Prevention of deaths and serious injuries among vehicle occupants in run-off-road crashes can be reduced by over 60% with simple but proven engineering treatments like barriers, shoulder sealing and rumble strips. The one area where cost-effective engineering solutions are more limited is at intersections. Here, treatment costs - for instance from installing roundabouts or grade-separated intersections - are typically high. The more affordable options, such as signalisation and turning lanes do not sufficiently manage road user behaviour, as to drastically reduce serious harm; for this conflict speeds and angles need to be more actively managed.

Safe vehicles

Motor vehicles in high-income countries are much safer than today than ever before, as the result of a combined effort to use mandatory standards and consumer information to advance the safety performance of motor vehicles. This model of regulatory “push” and demand “pull” has succeeded in contributing significantly to declining road fatality rates. The greatest contributor to vehicle safety over the last fifty years has been improved occupant protection or crashworthiness (also referred to as passive safety). Crash test standards and independent consumer rating by New Car Assessment Programmes (NCAPs) have helped to secure significant reductions in crash fatalities even as the exposure to injury through rising vehicle use climbed substantially.

Figure 5.5. **Estimated reduction in fatal and serious injury crashes with cost-effective infrastructure improvements**



Source: iRAP.

NCAPs provide transparency regarding the safety features of vehicle models by testing them and rating their safety performance using a star system analogous to that of Road Assessment Programmes. The star ratings are intended to encourage consumers to purchase vehicles with higher levels of safety, and, in turn, encourage manufacturers to produce and sell safer vehicles. The first NCAP was launched in 1978 in the United States, followed by the Australasian NCAP in 1993, Japan NCAP in 1995, and European NCAP in 1997. There are now nine NCAPs or similar bodies active in Asia, Australia, Europe, Latin America and the USA.

In 2015 the US National Highway Traffic Safety Administration (NHTSA) released a report estimating that between 1960 and 2012 more than 600 000 lives were saved in the United States by automotive safety technologies required by Federal Motor Vehicle Safety Standards (Kahane, 2015). Similar progress has been achieved in the European Union (EU), where between 2001 and 2012 there was a 55% reduction in car occupant fatalities (ETSC, 2014). An analysis of vehicle-based crash rates in the Australian state of New South Wales estimates that occupant fatality risk of cars built in 2010 are 75% lower than for ones built in 1995 (Anderson, 2014). The gains derived from improved crashworthiness are now being supplemented by active safety systems which can reduce potential impact speeds or avoid a crash entirely and will sustain the positive contribution that vehicle technology has made to reducing road fatalities.

Crash avoidance technology

The earliest crash avoidance technology was anti-lock brakes (ABS) and this has been followed more recently by electronic stability control (ESC) which prevents loss-of-control skidding incidents. ESC detects whether the steering inputs of the driver are consistent with the vehicle's direction of travel. If this is not the case, ESC applies the brake to one of the wheels (using the ABS) to correct the slide. Seventeen different studies undertaken between 2001 and 2007 have shown ESC to be highly effective, reducing single-vehicle crashes by approximately 30% as well as reducing the risk of opposing-traffic crashes and roll-over crashes, especially for Sport Utility Vehicles (Fitzharris, 2010). ESC is now mandatory in Australia, Canada, the European Union, Japan, New Zealand, South Korea, and the United States. In the European Union, where ESC became a mandatory requirement in all new cars from November 2014, it is estimated that it prevented at least188 500 injury crashes saved and more than 6 100 lives since 1995.

Originally developed in the mid-1990s, ESC was first introduced into the market by premium brand car makers. Gradually all major manufacturers adopted ESC and offered it across their product range, though as an additional rather than standard feature. Fitment rates grew steadily but remained low in the highly competitive small car segment - ironically the type of vehicle where the crash avoidance capabilities offered by ESC is most needed. The stalling ESC penetration in this high-volume but low-margin segment is a classic example of a market failure, making regulatory action necessary to achieve full penetration of ESC in all vehicle segments and realise the full safety potential. As a result most high-income countries have made ESC mandatory, albeit some twenty years after it was first introduced. ESC is now fitted to about 60% of new passenger cars worldwide, benefitting from economies of scale that have lowered unit costs to less than USD 50.

The follow-on technology from ESC is autonomous emergency braking (AEB). This uses laser/radar/camera systems to detect impending collisions and automatically brake if the driver does not react in time. A 2016 study by the Insurance Institute for Highway Safety (IIHS), using US police-reported crash data, shows that automatic braking reduced rear-end crashes by about 40% on average (IIHS, 2016). It estimates that if all vehicles had been equipped with auto-brakes that worked as well as the systems studied, there would have been at least 700 000 fewer police-reported rear-end crashes in the US in 2013.

AEB has also opened up significant further potential to avoid and mitigate pedestrian injuries. With sensors that detect pedestrians, AEB can reduce impact speeds by as much as 15 km/h and thereby contribute to less severe injuries. AEB will complement and maximise the benefit of softer, “forgiving” vehicle fronts that are already available. So the combined effect of improved pedestrian crashworthiness and crash avoidance promises further safety gains for pedestrians. If the infrastructure design keeps the vehicle speeds within the limits that can be sustained by the human body, the outcome would be a Safe System.

Given the central role of speed management within a Safe System, technologies that assist drivers to control vehicle speed are an area of significant importance. Intelligent Speed Assistance (ISA) systems can provide drivers with information about active speed limits warn them when the vehicle exceeds this maximum speed and, in the case of active ISA, assist the driver to stay below the speed limit. Citing evidence that ISA systems could cut collisions on all roads by one-fifth, the European Transport Safety Council (ETSC) supports the mandatory introduction of ISA in all new commercial vehicles by 2017 and for all vehicles by 2020 (ETSC, 2015).

ABS in motorbikes is another priority as studies of fatal crashes, insurance claims, and test track performance all confirm the system’s importance for powered two wheelers. In the United States the rate of fatal crashes has been estimated to be 37% lower for motorcycles equipped with optional ABS than for those same models without ABS (Teoh, 2011). Supporting this evidence of effectiveness are collision insurance claims for motorcycles with ABS which are filed 23% less frequently than for motorcycles without it (HLDI, 2012).

Co-operative Intelligent Transport Systems and Automated Vehicles

Vehicle technology is strongly connected to a Safe System both in terms of trauma reduction, but also supporting the driver in their behaviour. As vehicles are become increasingly smarter, Co-operative Intelligent Transport Systems (C-ITS) and automated vehicles (AV) will change the way in which drivers operate vehicles. Many of these are expected to address some of the existing system failures in today’s traffic and improve road safety.

C-ITS technologies use wireless communications to allow vehicles to exchange data co-operatively with other vehicles (V2V), infrastructure (V2I) or with multiple others at the same time including other vehicles, infrastructure, pedestrians, cloud-based services and smartphones (V2X). C-ITS could inform, warn or even override drivers in dangerous situations and reduce traffic congestion by optimising traffic management. Safety C-ITS applications include:

- **collision avoidance and hazard detection** (e.g. intersection movement assistance, right turn assistance)
- **vulnerable road user safety** (e.g. Motorcycle approaching indication, pedestrian detection)
- **in-vehicle signage** (e.g. speed zone warning, stop sign warning)
- **road weather alert systems** (e.g. spot weather impact warning)
- **post-crash notification systems** (e.g. eCall).

While only a handful of crash reduction results have been derived from large-scale C-ITS field operational tests to date, there is a high level of confidence that C-ITS applications have significant potential to reduce crash risk and the injury consequences of the road crashes.

In automated vehicles, one or more aspects of vehicle control - e.g. acceleration, braking, steering - are performed by vehicle computer, not the driver. The Society of Automotive Engineers (SAE, 2014) defines six levels of automation, with Level 0 indicating no vehicle automation, and the driver in full control to Level 5 describing full automation, i.e. the vehicle is completely in control of the driving task, with no requirement for the driver to monitor the system or road). Progression through the automation levels will not necessarily be linear, however, as a number of vehicle manufacturers considering avoiding intermediate Level 3 automation in their vehicles, as they are conscious of the challenges associated with complex human-machine interaction, notably the question of when and how human drivers should be able to regain manual control (see ITF, 2015c).

While automated vehicles will not be crash-free, they are generally expected to significantly benefit road safety, particularly as the level of automation increases. However, the crash reduction benefits of Level 3 and higher automated vehicles remain speculative, as highly automated vehicles have not yet travelled long-enough distances for accurate crash reduction estimates to be made.

Automated vehicles represent an exciting development and will ultimately improve mobility options for many, including the young and the elderly. Yet it will be some time before the anticipated safety benefits begin to flow and while countries may support the development of automated vehicles, that investment in the future should not come at the cost of continuing efforts in other areas to improve safety and implement a Safe System. The transition towards fully autonomous vehicles will bring new challenges with a mixture of automated and human controlled vehicles interacting in traffic and where some humans will take further risks assuming that the automated vehicle will see them and react to avoid potential collisions.

Realising the benefits from improved vehicle safety globally

The key determinant of the pace of improvements in motor vehicle safety is the fleet turnover cycle. In Europe it has taken a period of about twenty years for safer cars to fully penetrate the vehicle fleet. The EU originally introduced its front- and side-impact tests for new models in 1998, and in 2003 for all cars in production. Since then, millions of new safer cars have taken to Europe’s roads and several millions of older, non-compliant cars were de-registered. Today the overwhelming majority of passenger cars in the EU pass these crash tests.

The European experience – not least with ESC – illustrates why regulation is beneficial and ultimately necessary to secure the full benefits of new safety systems. The primary global body responsible for automotive safety standards is the World Forum for Harmonization of Vehicle Regulations (WP29) hosted by the United Nations Economic Commission for Europe (UNECE) in Geneva. Two agreements, adopted in 1958 and 1998[14], provide the legal framework for UN member states to voluntarily apply a wide range of motor vehicle standards.

The *Global Road Safety Status Report 2015* (WHO, 2015) notes, however, that only 40 of the 193 UN member states fully apply these safety regulations. Of those that do, almost all are high-income countries. The WHO report concludes that “there is an urgent need for minimum vehicle standards to be implemented by every country”.

Contributing to this low level of use is the limited engagement by entire world regions in the UN’s regulatory process, notably of Latin America, the Middle East and most of Africa. With middle-income countries now accounting for around 50% of the world's passenger car production, it becomes paramount that at least the most important of the UN safety standards for motor vehicles are applied universally. In this context two things are also worth noting: First, a large share of the unsafe cars withdrawn from circulation in high-income countries end up on the roads of middle- and low-income countries; of the 13.4 million cars de-registered in the EU in 2006, 7 million were scrapped while 6.6 million disappeared or were resold outside of the EU and now constitute a threat to road safety elsewhere. Secondly, many international car manufacturers that sell vehicles with high safety standards in in high-income countries offer the same cars with lowered safety - for example without seatbelts for back seats as standard fitting.

On 15 April 2016 the UN General Assembly adopted resolution A/RES/70/260 on "Improving global road safety" which includes strong commitments on vehicle safety. In recommendation number nine, the resolution "invites Member States that have not already done so to consider adopting policies and measures to implement United Nations vehicle safety regulations or equivalent national standards to ensure that all new motor vehicles, meet applicable minimum regulations for occupant and other road users protection, with seat belts, air bags and active safety systems fitted as standard." The resolution is an unprecedented call for standard fitment of vehicle safety technologies and is consistent with the vehicle safety actions proposed in the UN's Global Plan for the Decade of Action for Road Safety and also the Global New Car Assessment Programme's recommended road map for improved vehicle safety by 2020 (see Table 5.3).

Table 5.3. **Global NCAP Recommended Vehicle Regulatory Road Map 2020**

Road map for safe vehicles 2020 UN regulations* for:	All new vehicles produced or imported	All vehicles produced or imported
Frontal impact (No. 94) Side impact (No. 95)	2016	2018
Seatbelt and anchorages (No. 14 and 16)	2016	2018
Electronic stability control (No. 13H/GTR. 9)	2018	2020
Pedestrian protection (No. 127/GTR. 8)	2018	2020
Motorcycle anti-lock brakes (No. 78/GTR. 3)	2016	2018
Autonomous Emergency Braking systems	Highly recommended	Highly recommended

* or equivalent national standards such as US FMVSSs.

Generating more demand for safer vehicles for faster safety gains

Communities can realise greater safety benefits, faster from vehicle safety if more vehicles with improved levels of safety are purchased at a faster rate. Alongside regulatory action, there is considerable scope to promote stronger demand for safer vehicles. In this respect, the purchasing decisions of public and private fleet managers constitute an effective "demand-pull" lever. Motivated by a mixture of

Corporate Social Responsibility and cost control considerations, a growing number of organisations are introducing fleet safety policies which, for instance, require company cars to have a five-star NCAP rating.

Such a policy has been adopted by BHP Billiton, the world's largest resource-extraction company, and the governments of Australia and Sweden. Their policy decisions reflect the recommendation of the UN Global Plan for the Decade of Action for Road Safety, which encourages "managers of governments and private sector fleets to purchase, operate and maintain vehicles that offer advanced safety technologies and high levels of occupant protection". It is also in line with the ISO 39001 standard for road traffic safety management, which identifies vehicle safety as a significant factor for fleet operators seeking to reduce death and injury in road crashes.

Financial or fiscal incentives can also speed up the introduction of improved or new safety technologies, especially if they precede tougher regulatory requirements or are introduced in conjunction with them. This is common practice with regard to vehicle emissions and fuel-quality standards and is equally applicable to vehicle safety standards. Incentives might include reduced sales tax or registration tax for cars that meet advanced safety standards. In 1985, the government of Denmark decided to reduce the vehicle tax for vehicles equipped with anti-lock brakes (ABS). The reduction was relative to the purchase price of the vehicle and capped at EUR 1 000 (in today's prices). In 2003, the Danish government introduced a tax reduction of up to EUR 500 for vehicles equipped with electronic stability control (ESC). Today, a tax rebate of up to EUR 500 is offered for the purchase of vehicles with a five-star NCAP rating.

Last but not least, the insurance industry can play an important role, and indeed should take a lead, through reduced premiums for vehicles with the latest safety fittings. As crash avoidance systems prevent or mitigate crashes, they help directly to reduce insurance claims and insurers would serve their own as well as societal interests by passing some of these savings on to customers as discounts on premiums for vehicles fitted with state-of-the-art safety features.

Some insurers in the United Kingdom, for instance, are changing their group rating system to incentivise the purchase of cars equipped with AEB. In Australia, NRMA, a major insurance company, is offering discounts of between 10% and 15% on vehicles equipped with AEB as standard after it has been tested by the insurer for its effectiveness. Similarly, the Royal Automobile Club of Western Australia (RAC WA) is only insuring or financing cars which have been awarded an ANCAP safety rating of either four or five stars and manufactured from 2012.

Safe road users

Humans have always been the weak link in the safety of road transport safety, as in other complex socio-technical systems. The large and persistent variability in the performance of humans in traffic makes them the critical safety problem, while the other technical components can be designed to minimise variability. The fact that humans do not behave safely within the limits of the road transport system has usually been attributed to knowledge, information or attitude problems. It has long been considered that road users may not have enough knowledge and information in specific situations to be able to make rational, correct decisions. An incorrect decision may also be due to an inappropriate attitude towards the situation. Hence, much of the road safety effort has focused on improving the reliability of human behaviour by means of rules, training, monitoring and information. The idea has been to provide road users with sufficient information and knowledge, to ensure they have the right mind-set and follow rules and procedures for correct behaviour. If road users break rules they are sanctioned, so as to deter system-disrupting behaviour and encourage compliance (Read et al., 2013).

However, humans are not a mechanical component that can be conditioned to make objective, correct and consistent decisions in all situations; human beings are greatly affected by their surroundings and the context in which their decisions are made (Leveson, 2011). The technology, the social and organisational context, group affiliation, productivity requirements, time pressure, legislation, monitoring, the risk of discovery, consequences, the individual's level of knowledge, etc. are all examples of environmental factors which influence human behaviour.

Safe System thinking represents a new way of looking at and understanding road user behaviour. It considers the nature of human errors a Safe System goes even further in acknowledging human fallibility and frailty by making its very premise that human beings cannot always cope with the complex demands – be they physical, cognitive or psychological - that the road transport system confronts them with. The Safe System holds that, for this reason, there is a need to understand the human capabilities in relation to the system and how to adapt the properties of the system to these capabilities.

A comprehensive summary of case studies, facts and research on road user behaviour, including details on all of the major road user risk factors such as drink driving, helmet-wearing, seatbelts, speeding, distractions and child restraints is provided by The Global Road Safety Partnership Advocacy Resource Centre (GRSP, 2016). This also includes images, videos, news articles and information on tactical areas for advocacy activities.

Putting the road users at the centre of the system is the first and most important step towards a Safe System. Human-centric design (sometimes also called user-centric design or Human Factor Engineering) recognises that a system needs to explicitly acknowledge human strengths and weaknesses, and accommodate them in the solutions offered. This approach has been a central tenant of human-centric design for many years.

The initial objective of a Safe System in relation to people using the road transport system is to help and support them to comply with road rules, acknowledging their capabilities and limitations, so they can fulfil their part of the shared responsibility agreement that exists between the users and the designers in a Safe System. Such an approach helps to identify a range of initiatives and instruments to support humans and limit the incidence of critical errors. This requires thorough analyses are needed to understand the complex mechanisms behind human errors or non-compliance in different situations; otherwise the countermeasures might well turn out to be ineffective.

These analyses will show that non-behavioural measures, e.g. technical support, may be more effective (see Box 5.1). A range of initiatives and instruments may be used in a Safe System to guide and support road users to use roads safely. These include, infrastructure design that invites safe use, speed limits and road design that encourages safe speeds, road laws and traffic regulations for safety compliance, traffic safety education, training (and re-training), and assessment and, ultimately, licensing for safe road use. Both general and targeted enforcement are required to limit the incidence of the critical errors most commonly leading to serious injury. In a Safe System, there needs to be a greater recognition that human error will not be eliminated through safe road use (behavioural) measures alone and other parts of the systems need to be relied upon.

The way road user errors are currently categorised is another important factor that shapes what measures are taken. The underlying assumption has been that road user can make an intentional or conscious decision in all situations to act right or wrong, i.e. that ultimately errors are more or less intentional violations. In fact the patterns are more complex and human error can be distinguished as:

- **Slips:** Actions not carried out as intended or planned, e.g. misreading the road signs and exiting from a roundabout on the wrong road.

- **Lapses:** Missed actions or omissions, e.g. failing to do something due to lapses of memory or attention.

- **Mistakes:** Wrong actions carried out due to a faulty plan or action, e.g. someone believing something to be correct when it was, in fact, wrong.

- **Violations:** Deliberate illegal actions, i.e. somebody doing something knowing it to be against the rules.

There will always be errors that may not easily fit into one of these categories. Running a red light or trying to cross an intersection despite there being conflicting traffic are typical examples of serious traffic offences which are not necessarily intentional. Forgetting to put on the seat belt, not turning on headlamps, losing control on a road with invisible ice are other examples of traffic rule violations without real intention, which can have deadly consequences. The problem is that they are almost always regarded as violations and thus as intentional. But the remedies to address the issues vary with the category a given behaviour falls into. Thus intentional red-light running may be effectively addressed by red light cameras, but these will have only marginal effects on unintentional traffic-light violations. Similarly, speeding may sometimes be a violation but in other instances the result of mistake.

Box 5.1. **Case study: Seatbelt wearing in Sweden**

In the mid-1990s, Swedish road safety experts discovered that despite a generally high level of seatbelt use (approximately 90% in the front seats), the seatbelt wearing rate among car occupants who had been killed in crashes was only around 40%. For that reason a stakeholder coalition representing government, research, insurance companies, car manufacturers and suppliers of restraint systems addressed the problem. The initial inclination was to devise educational and informational measures and plan a public information campaign. However, the group decided to commission the Swedish National Road and Transport Research Institute (VTI) to carry out further analysis. A detailed study of road users who did not wear seat belts came to the following conclusions (Dahlstedt, 1999):

- Non-seat belt users had mostly positive or even very positive attitudes towards wearing seat belts.
- The most common arguments for not using a seat belt were "just a short trip" or "sheer forgetfulness".
- Only 2.5% of the non-users were genuinely opposed to seat belts, equalling 0.2% of Sweden's driver population.

These findings were later confirmed by studies from other countries. Based on these results, the group concluded that general behavioural measures would only have a marginal effect. Instead, car occupants needed a reminder every time they forgot to put on the seat belt. This led to a specification for a seatbelt reminder which was later included in the EuroNCAP protocol. For this reason seatbelt reminders are standard equipment in most car models in Europe today.

A 2008 study showed a seatbelt wearing rate of 97.5% in cars with seatbelt reminders and 85.8% in cars without (Lie et al., 2008). These results could not have been achieved with traditional behavioural measures, thus underlining the importance of analysing and understanding the mechanisms behind human behaviour in order to take targeted and hence effective measures.

One of the most common and critical errors made by drivers concerns speed choice. This is one of the oldest, most enduring and most difficult road safety issues. Excessive speed is perhaps the main element of risk in the entire road transport system. The relationship between speed and the risk of serious injury is well-documented. High speed increases both the risk of crashes and the severity of associated injuries. In particular, roads that have high rates of drivers exceeding the speed limits are the most dangerous. Yet speeding is common across all road types, and even in countries which have invested heavily in information, education and police surveillance (i.e. traditional behavioural shaping measures) the problem of speeding remains large. For this reason, other systemic measures - such as self-explaining roads and intelligent speed adaption - need to be taken into focus. The same is true for drink driving in many countries. While there is a clear social norm that drink driving is bad, set through traditional behavioural shaping measures, driving under the influence of alcohol remains a widespread problem. Addressing it with "more of the same" will likely only achieve marginally better results. Instead interventions in other parts of the road system may deliver real results, e.g. technical systems in vehicles that detect and stop drunk drivers ("Alco-locks").

One of the important understandings emerging in some countries pioneering a Safe System is the contribution of different levels of speeding on road trauma. The common belief that serious road trauma associated with speeding is mainly due to the actions of a relative few people exceeding the speed limit by large amounts is partially correct. Pioneering work is showing that speed-related road trauma on a population level is made up of a relative few people speeding by large amounts but also from the collective impact of a relatively large proportion of drivers exceeding the speed limit by a small amount of up to about 10 km/h over the speed limit.

This emerging understanding is reinforcing the need to ensure the speeding behaviour of the population as well as the few who speed by excessive amounts is being managed and responded to in a safe system.

It has been argued that a major factor in low rates of compliance with speed limits is that they are not credible to drivers. A "credible" speed limit is defined as one that matches drivers' expectations as evoked by the look and feel of the road or traffic situation. It has been shown that visual characteristics such as road markings, lane width and objects adjacent to the roadside can have significant effects on drivers' speeds, independently of the posted speed limits associated with the road. These effects appear to arise from a combination of drivers' perceptions of risk, their perceptions of how fast they are going, and expectations and habits formed from prior exposure to similar roads.

Roads that are "self-explaining" include such specific design elements which drivers will take as signal for a certain road type requiring a certain driving style. In this way, they act as built-in controls on driver behaviour. The "Sustainable Safety" programme in the Netherlands involves identifying a clear functional hierarchy of roads, then defining associated road designs that inherently promote the desired operating speeds for each road category, and finally applying those road designs consistently to all roads of the same function (see Safe speeds section below). The result is that roads with the same operating speed look very similar to one another, while roads with different operating speeds look quite different from one another. This approach has been trialled in an urban district in New Zealand with good results, leading to a 43% reduction in crashes and a 50% reduction in crash costs over five years (see Box 5.3).

Rural roads are associated with the highest risk of fatalities and serious injuries. This is due to a combination of a high variation in speeds (produced by both speeding and a diverse range of road users) and the presence of unforgiving roadsides. To address this issue there are two principal tactics to consider. The first, called error resistance, identifies ways of preventing users from making errors leading to serious injury or death. This approach relies heavily on changes to the infrastructure through improving road surfaces, re-engineering road layout to improve horizontal curvature, and installation of median barriers and guardrails to reduce the chance that drivers will leave their driving lane.

A second approach is to improve the error tolerance of rural roads. This approach often features changes to roadsides such as the removal of static hazards like ditches and poles. Improvements in this area, however, tend to be incremental rather than dramatic, in part because of the sheer multitude of ways people are injured in a crash. A complementary approach is to encourage fleet penetration of safer vehicles, with side impact air bags, antilock brakes, and stability control are seen as minimum standards. As the age of our driving population increases this will become an even more important consideration since older drivers are physically more fragile and thus more likely to be injured in a crash.

The focus of road safety efforts has been on drivers of private motor vehicles. This is understandable, given that occupants of private cars represent the greatest proportion of road deaths and serious injuries in most developed countries. However, there is an increasing appreciation of the road safety issues associated with other road users including motorcyclists, truck drivers, pedestrians and cyclists. This is in part due to the relatively high crash rates for these modes, but also a result of the many co-benefits that these modes bring through their daily road use. The safe distribution of goods is essential for the economy of any country, yet truck drivers are prone to fatigue due to long working hours and higher vehicle mass means that collisions with other road users, fault of the truck driver or not, is almost always severe or fatal. Walking and cycling have clear benefits for public health, the reduction of congestion, environment protection and social interaction; yet the requirements of these road users are often not fully integrated into road planning, funding and design. The vulnerability of pedestrians and cyclists means that the relatively high speeds in many existing road environments do not represent a safe environment for them.

A shift to a more holistic view of safety, well-being and economic productivity appears to be underway, however, and it may be that in future a more sophisticated understanding of the impacts of transport systems on the lives of humans, for better or worse, will provide better solutions – likely it will give greater weight to lower traffic speeds, enhanced vehicle safety features and greater separation of road users where pedestrians are cyclists are expected. It is likely that many of the Safe System principles that work for vehicle drivers - such as intuitive, “self-explaining” roads – are likely to be universally applicable.

Safe speeds

Speed is at the heart of a forgiving road transport system. It transcends all aspects of safety: Without speed there can be no movement, but with speed comes kinetic energy and with kinetic energy and human error come crashes, injury and even death. Speed strongly interacts with all pillars of a Safe System and is central to understanding the concept of a forgiving road transport system.

Speed is a factor in 100% of crashes and 100% of injuries. Speeding (which includes driving within the speed limit but at excessive speed for the prevailing conditions) is estimated to contribute to around 30% of fatal crashes (OECD/ECMT, 2006).[15] Travel speed affects the driver’s ability to accurately and reliably process information in the traffic environment. High-level information processing by drivers becomes critical to safe performance in cognitively demanding traffic settings, for instance in urban environments where pedestrians, cyclists and other highly vulnerable road users are common.

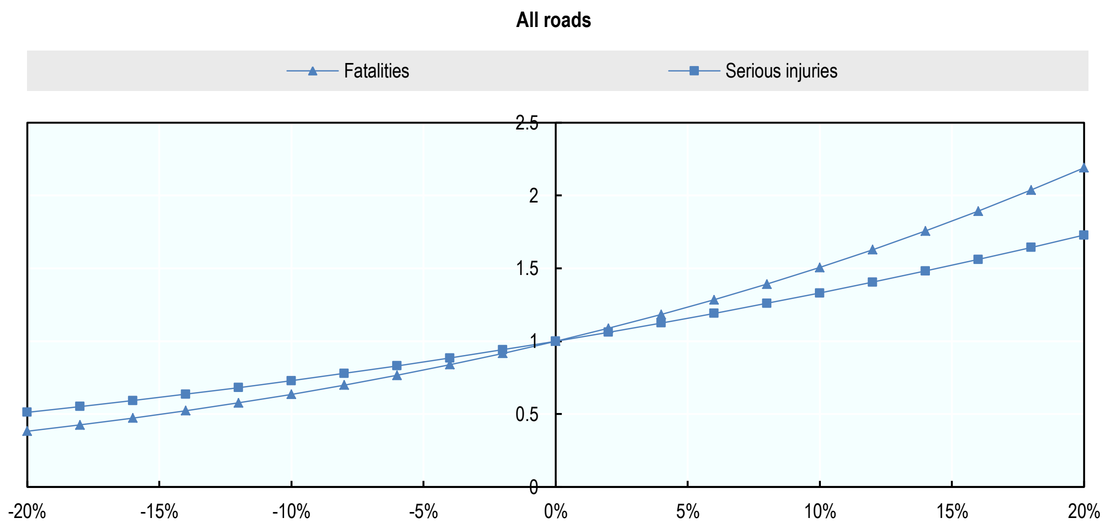
The relationship between speed, crash frequency and injury severity is well established. One of the most frequently referenced, the Nilsson power curves model shown in Figure 5.6, is an example derived for all road types. Curves by different road type and further discussion on these models can be found in Cameron (2010) and Elvik (2013).

The focus of speed management is not to universally lower speed limits. Its aim is to match the speed allowed with the mobility need, the environment, the infrastructure quality, the safety of the vehicle fleet and the risk of death and serious injury. If the infrastructure quality, combined with the vehicle types and standards, is insufficient to provide the level of protection required for the road users in that particular environment, however speed management is ultimately required that will set and enforce appropriate speed limits.

Managing speeds through speed limit setting and compliance

Speed limits should be set in accordance with scientifically robust findings on human behaviour and performance, as well as human biomechanical tolerance limits. Conversely, it is not acceptable, given the current state of knowledge about the critical role of speed, to set speed limits based on popular opinion or by adopting the 85-percentile speed at which drivers choose to travel.

Figure 5.6. **The relationship between change in mean speed and crash injuries**



X axis: Relative change in speed; Y axis: Relative change in number of crash injuries.
Source: Dr David Logan (MUARC). Derived from Cameron, M. and Elvik, R., (2010).

Around the globe, the experience for decades has been that speed limits are aligned primarily with driver attitudes and their personal preferences for high-speed travel. This philosophy of pleasing the public has not worked well in terms of safety. Optimum bias is the tendency of individuals to underestimate the likelihood that they will experience an adverse event that may cause harm and this can cause them to disregard precautions that may help them avoid or reduce the risk of these adverse events. Most drivers overestimate what speed is safe and also believe they are better drivers than the average. However, drivers are not good at perceiving many risks, for instance hazardous roadside objects. A new evidence-based philosophy centring on the “forgivingness” of the road system to characteristic crash problems is needed.

Notwithstanding the extent of speeding encountered on our roads, posted speed limits are still acknowledged as one of the most powerful mechanisms for influencing speed choice. Agencies with the authority to set speed limits have a duty of care to inform road users more effectively of the risks faced from driving in certain road environments, at particular speeds, including when complying with speed limits. It has proven inadequate to allow drivers to exercise their own judgement on speed choice. Yet this is effectively what is expected of drivers in many situations where the speed limit is substantially higher than a safe speed. Speed limit setting for a forgiving road transport system should take account of:

- the **types of road users**, their characteristic performance in traffic and their tolerance levels to foreseeable crash types
- the **safety quality of the infrastructure**, especially its capability to forgive foreseeable human errors, and so create low-risk conditions for all road users
- the **crashworthiness and crash avoidance capabilities** of vehicle fleets.

An example of inadequate speed limit setting is found in rural settings, where high speeds are often allowed on narrow, low standard roads with an unstable gravel shoulder as the only recovery space between the vehicle and endless lines of roadside trees, utility poles, drainage channels and myriad other hazards. In countries such as the Netherlands and Sweden, rural default speed limits in these environments are set at 70 or 80 km/h, whereas in countries such as Australia and New Zealand, where the terrain can be highly challenging, the default rural speed limit is 100 km/h regardless of road and roadside conditions. Should a vehicle leave the roadway at these higher speeds, the impact forces with unforgiving roadside objects would be well in excess of biomechanical tolerances.

Once appropriately set, speed limits must be adhered to be effective. For road users to fully comply, they must be supported through Safe System elements. Even low-level speeding results in disproportionately large increases in individual risk. If the speeding is frequent and a substantial share of road users in involved, the aggregate effect on system risk is considerable. The safety implications of low-level speeding are often underestimated and not well understood.

Speed cameras are an effective tool for assisting compliance with speed limits. Sweden has developed a general deterrence model of operating its national speed camera programme (comprising about 1 300 cameras as of December 2015) to improve general compliance amongst the motoring public over large lengths of the road network. The Swedish Transport Administration and the Swedish police have expanded the system to about 2 000 cameras. The cameras are located at about five-kilometre intervals on roads with high mean speeds and high risk of crashes. The installation of every new camera is made public through websites and media. Cameras are also clearly marked and they are sometimes active and sometimes inactive, but the actual state of operation is not discernible for road users. In this way, a high general deterrence effect can be achieved and the total number of infringements issued per year can be managed to not exceed the processing capacity of the police. Because the number of infringements per year is limited and the camera locations are signposted, accusations of using speed cameras for revenue raising are difficult to sustain.

The system has been carefully tailored to achieve maximum effectiveness through the unpredictable switching on and off of cameras to achieve a wide-ranging deterrence effect, with particular attention on the many thousands of kilometres of rural roads in Sweden which have no long-term prospect of receiving adequate funding for retrofitting the forgiving infrastructure required by “Vision Zero”. Real-time, central monitoring of speeds at each camera site provides data that is also used to determine the optimal strategy for camera activation. Sweden’s speed-compliance programme illustrates how a responsible driving culture in a Safe System can be fostered. Box 5.2 provides another example of an effective speed camera programme implemented in France.

A wide array of technologies is available to support drivers and riders to comply with speed limits. Technologies include Intelligent Speed Assistance (ISA), mobile and fixed-position speed cameras, point-to-point speed cameras, and advisory feedback displays, all of which are readily available and capable of being used to support drivers and riders to travel with low risk.

Speed management through infrastructure design

Speed limits should not only be safe, they also should be credible for road users. A speed limit is credible if it meets the expectations evoked by the characteristics of the road and its immediate surroundings. The Netherlands have developed a process for setting speed limits that are safe and credible (Aarts et al., 2009). Figure 5.7 below shows examples where speeds are not credible.

Figure 5.7. **Examples for non-credible speed limits**

Note: Both are urban roads with a speed limit of 50 km/h, but each with a completely different character.
Photo credit: Paul Voorham, Voorburg.

Credible speed limits are an important element of self-explaining roads. A Safe System road network with self-explaining roads meets the expectations of road users and evokes driving behaviour that is consistent with the legal rules and safety on the road. Ensuring appropriate speed should start with a clear road hierarchy which separate those roads with a flow function from those with access functions. In the Netherlands, which aim to make their roads self-explaining, three categories of road exist:

- **Through roads** enable travel between origin and destination as fast and as safely as possible (traffic has the highest priority).

- **Access roads** provide (direct) access to the buildings at the locations of origin and destination where residing is most important (traffic is a guest here).

- **Distributor roads** connect through roads and access roads (flow at road sections and exchange at intersections).

Each road category should have distinctive, different visual appearances and invoke different speed behaviours. Residential streets, for example, may well be lined with trees that serve to discourage speed and are unlikely to be a traffic hazard at speeds below 40 km/h. Research shows it is possible to identify specific characteristics of road and environment that influence credibility (SWOV, 2012). Table 5.4 describes five accelerators (road elements that intuitively elicit a higher speed) and “decelerators” (elements that intuitively elicit a lower speed) that provide guidance, also for retrofitting.

Box 5.2. **Case study: France's speed camera programme**

The French speed camera programme (SCP) represents one of the most important and effective innovations in the country's road safety policy over the decade. An estimated 16 000 fatalities were avoided due to the SPC over the 2003-10 period as well as more than 62 000 light and severe injuries (Carnis and Blais, 2013).

The programme was implemented in a particular institutional context marked by the interdepartmental dimension of road safety, specific governance arrangements and local government interventions The SCP represented a reaction to the relatively unfavourable road safety performance compared with other European countries and strong criticism of inefficient enforcement of traffic rules (Delorme and Lassarre, 2009; Carnis, 2007; Ternier, 2003). An important factor was the support from road accident victim advocacy groups (Carnis, 2012). Not least, the SCP was driven by the strong commitment of President Jacques Chirac, who publically declared road safety a top priority in his 14th of July speech, media support and the French public's strong reaction to a series of high-profile road crashes

The SCP can be considered as a core component of the French approach to a Safe System. It has contributed to a large reduction in the number of road casualties, as this is related directly to the significant decrease in operating speeds. This decrease occurred for each driver category and for all different road types of the networks. A large drop of speed violation rates was also observed in the 2002-12 period. The near complete automation of the speed enforcement process ended inefficient practices and put a stop to leniency hitherto shown by the police and judicial system. The SCP has thus improved enforcement operations and enabled a more stringent application of the law.

With more than 4 000 speed cameras in operation, the automation of traffic enforcement also expands the enforcement capacity of the police and has allowed a massively improved control of the road network. The number of speed tickets issued grew by a factor of ten over the 2003-10 period.

An enumeration of the institutional factors that explain the successful implementation of the French SCP must start with the crucial support provided by President Chirac at the top political level. This received complementary political back-up from the relevant ministries. The creation of dedicated lead authority, the Direction de Projet Interministériel Contrôle Automatisé (DPICA) in charge of the implementation process and the management of the programme (performance indicators, dedicated funding) was a third element. The French SCP is thus characterised by sustained collaboration between the different departments concerned (Carnis, 2009).

The SCP also faces some challenges that may hold lessons for other countries. Political commitment needs to be sustained and across political parties in order to fend off challenges from well-organised lobby groups and instrumentation during election campaigns. Interdepartmental collaboration must be safeguarded against capture by one single department which may result from administrative reorganisations. Evaluation is crucial, because it promotes transparency and improves the operation of the programme by making corrections and adjustments possible. Evaluation can help generate public support and increase the level of acceptance for speed limit enforcement in society. The revenue dimension remains an important issue for all speed camera programmes. The public often views cameras as a "cash cow" for government and a hidden tax on drivers. The authorities have to prove that such programmes are cost-effective and yield a positive return for society at large by reducing harm. Revenue generated by the SCPs can be also used for funding road safety measures and communication campaigns.

Independently of the speed camera programme, France has moved to gain a better balance between the quality of life and motorised traffic. In 2015, a bill was passed to allow local authorities to set general traffic speed limits at 30 km/h. Guidelines are now clearly expressing that 50 km/h should be restricted to urban roads where motor vehicle traffic is a priority. Grenoble has since chosen to adopt a 30 km/h speed limit except for a few main urban roads.

While it is not possible to reconstruct our road system overnight, it is possible to retrofit roads with engineering features such as road humps, road narrowing, angled slow points and mini-roundabouts on local residential streets. An example of creating a “self-explaining” road network through retrofitting from New Zealand is described in Box 5.3. Other methods of managing speed through infrastructure includes perceptual measures such as road markings or posts approaching hazardous locations, electronic speed feedback devices, and vertical displacements such as speed platforms at conflict situations such as pedestrian crossings and intersections.

Table 5.4. **Road infrastructure elements and their influence on speed**

Road elements	Accelerators (intuitively elicit a higher speed)	Decelerators (intuitively elicit a lower speed)
Tangents	Long tangents	Short tangents
Physical speed limiters	Physical speed limiters not present	Physical speed limiters present
Openness of the situation	Wide and open road surrounding	Narrow and closed road surrounding
Road width	Wide road	Narrow road
Road surface	Smooth road surface	Rough road surface

Post-crash response

Appropriate management of road casualties following the crash is a critical determinant of both the chance of survival and, on survival, the quality of life (ETSC, 1999; ETSC, 2001). Conversely, improper functioning of the post-crash care system leads to more fatalities and severe injuries, which could be avoided.

In many countries and cities road trauma can account for a significant proportion of trauma patients in hospitals and other treatment centres. In Victoria (Australia), 43% of major trauma in hospitals is transport related (Department of Health, 2014). Transport accounts for 70% of spinal cord injury in Africa (WHO, 2013a).

The system responsible for the medical treatment of injuries resulting from road crashes is referred to as trauma management (TM) or post-crash trauma care. It typically covers the initial medical treatment provided by Emergency Medical Services (EMS) at the scene of the crash and during the transport to a permanent medical facility, and further treatment by permanent medical facilities (hospital, trauma centres). Post-crash response is an important component of a Safe System, as it can help to avoid death and reduce the extent and severity of serious road trauma; it is also one of the pillars of the UN’s Global Plan for the Decade of Action for Road Safety.

The report *Safety Strategy for Rural Roads* (OECD, 1999) showed the importance of emergency services by indicating differences between the survival in severe (fatal and serious) crashes in rural versus urban areas. The study "Reducing the severity of road injuries through post-impact care" (ETSC, 1999) highlighted evidence-based actions for the organisation of optimal trauma care in the European Union (EU). The 2003 European action programme (CEC, 2003) stated that several thousands of lives could be saved in the EU by improving the response times of the emergency services and other elements of post impact care in the event of road traffic crashes. The World Report on Road Traffic Injury Prevention (Peden et al., 2004) indicated the importance of improving medical care delivered after crashes.

Post-crash response services

The term “post-crash response” is used to describe the broad range of services that may be available to crash survivors. These services have been divided into four sub-categories: legal support and legislation, research and Information, emergency responder training and equipment, injury care, and mental health care.

Thoughtful legislation can do a lot to improve the post-crash response, and in a variety of ways. Many countries – for example the UK with its Fire and Rescue Services Act 2004 – make it a statutory duty for emergency services’ intervention to save lives and to play a role in prevention. Other helpful supporting legislation may include recognition of a protection for those who offer help (Good Samaritan Laws) and duty to assist the injured; first aid training and equipment requirements for certain drivers or vehicles; protocols outlining minimum standards of pre-hospital and facility-based care; and financing mechanisms to ensure universal access to free emergency care.

Research is another lever that can be effectively employed to improve post-crash response. The collection of post-crash data and their scientific analysis in particular is critical for improving various aspects of how the post-crash phase is handled. Injury surveillance systems, trauma registries and quality improvement programmes all contribute to an increasing body of knowledge about injury and patient care that can be used to optimise post-crash services and inform injury prevention strategies.

Well-equipped and trained responders are the cornerstone of successful post-crash response. Yet in 28 of the 179 countries listed by the *Global Status Report on Road Safety*, fewer than 11% of seriously injured road victims are transported to hospital by ambulance (WHO, 2015). Many low- and middle-income countries lack the equipment to respond to road crashes in time to prevent fatalities or more serious injuries. Schemes to empower passers-by to respond are insufficient; emergency response services must be equipped to at least provide the backbone of a national post-crash response capacity. Training for emergency services and specialist equipment, such as extrication equipment, is often also lacking. Training should be interdisciplinary to enable effective multi-agency response to road crashes. Improvements in these areas can contribute to significant road casualty reductions as witnessed in the Republic of Moldova, where assistance by FIRE AID with equipment and training for emergency services has already saved many lives (see http://fire-aid.org/projects/republic-moldova).

Healthcare delivery should be organised and integrated through the entire spectrum, from injury prevention to pre-hospital, hospital and rehabilitative care. The effectiveness of such a chain and the outcomes for the injured depend upon the strength of each of its links. Survivors of road crashes may also experience Post Traumatic Stress Disorder (PTSD) which not only increased the their suffering (and that of their families) but may also affect their ability to be productive and thus further increase the economic impact of road traffic injury. Post-crash response should thus include acute stress and grief management, on-going professional psychosocial support, PTSD management and support groups.

Post-crash response process and benefits

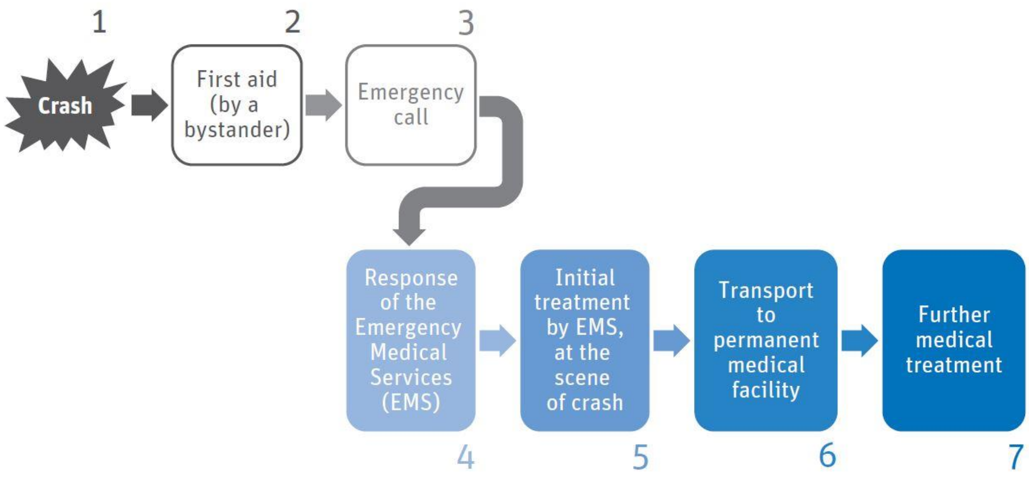
It is customary to distinguish between survivable and non-survivable injuries and to differentiate three phases in which death from road trauma can occur (OECD, 1999; Sasser et al., 2005). The first phase comes immediately in the seconds and minutes that follow the injury, when death occurs immediately or quickly as result of overwhelming injury. Death in this period is usually due to disruption of the brain, central nervous system, heart, aorta or other major blood vessels. Only few of those patients can be successfully treated, and typically only in large urban areas where very rapid emergency treatment and transport is available.

The second critical phase occurs one to two hours after the incident. Death in these instances results from major head injuries, chest injuries, abdominal injuries, fractured femur and pelvis, or multiple injuries associated with major blood loss. Survival rates during this period are clearly dependent on early and appropriate medical intervention (OECD, 1999).

The third phase where deaths from injuries typically occur is several days or weeks after the initial injury. Major causes of death in this phase include brain death, organ failure and overwhelming sepsis. Improved survival rates during this period mainly depend on the quality of hospital treatment. For example, a national evaluation study carried out in the United States found that the adjusted risk of death in trauma centres was significantly lower than in non-trauma centres (MacKenzie et al., 2006).

Thus, the potential to reduce fatalities by means of early and appropriate medical treatment exists, at least for the patients in the second and third post-crash phases. Summing up the published estimates, Hakkert et al. (2007) concluded that 35-50% of cases could be considered as “treatable”, i.e. occurring during phases two or three, and therefore, can be influenced (and partly reduced) by an improved TM system.

Figure 5.9. **Post-crash chain of events**



Source: Hakkert et al. (2007).

A typical post-crash chain of events is depicted in Figure 5.9. Risk factors in the pre-hospital phase include lack of effective and timely emergency services, lack of communication (e.g. mobile phones) and lack of health insurance in countries without basic universal health service provision. Hospital risk factors include the lack of suitably trained medical staff, particularly with respect to emergency medicine and trauma management, and lack of suitable medical equipment. While these factors vary between low- and high-income countries, they also vary within countries and between urban and rural areas.

“Mayday” systems aim to reduce the time between crash occurrence and the provision of medical services. By improving information transfer between the trauma-care physician and emergency medical service, they also aim for faster and more appropriate treatment. Automatic crash call notification, which is currently being implemented in Europe (see Box 5.4) extends the benefits of Mayday systems by providing emergency responders with data covering the location and the severity of the crash and the nature of injuries sustained (ERSO, 2006-4). This system has been estimated to reduce 4-8% of road deaths and 5-10% of vehicle occupant deaths in Finland (OECD, 2008).

Box 5.3. **Case study: Retrofitting self-explaining roads in New Zealand**

Point England, a suburb of Auckland (New Zealand) had a high crash rate. A lack of differentiation in the “look and feel” of local and collector roads caused speeding and the use of local streets for shortcuts. There were also substantial variations in speeds on all road types.

A Self Explaining Roads (SER) template for the area was developed through an extensive analysis, public engagement and design process. The aim was to create distinctly different local and collector roads (shown below) with 30 km/h speed limits on local roads and 40 km/h on collector roads. Less variation in traffic speed and more inviting environments for walking, cycling and socialising were also desired outcomes. Approximately 11 kilometres of roads were treated within the project area.

On local roads, mean speeds dropped considerably to around 30 km/h, while those on collector roads have remained at around 50 km/h. The variation in speed on all treated roads is now much lower, reflecting the different behaviour expected on each of the road types. On local roads, there is now less through traffic and more pedestrian movement. Video data reveals that pedestrians also appear to be to be less constrained, with vehicles often giving way to pedestrians. Residents now rate the look and feel of their street more highly than they did prior to SER construction. In the five years following the completion of the SER project, the number of crashes has fallen by 43% and crash costs by 50%, with only low-severity crashes occurring over this period.

Figure 5.8. **Self-explaining roads in Auckland, New Zealand**

Left, Local road; Right, Collector road.

A key benefit of the Point England SER project is that the scheme was delivered with comparable costs to traditional speed-hump treatments, which are generally less effective and are less favoured by residents. Further development of the SER process and its practical implementation is likely to yield further savings and even better designs. Building on the Point England experience, a new project called “Future Streets” is being implemented in Auckland, taking the SER concept further by making community streets safer and easier to walk and cycle. To understand the potential road safety, health and environmental benefits, a range of measures in treatment and control areas include casualties, traffic speed counts, walking and cycling counts, road user interactions, a resident survey (physical activity, travel patterns, perceptions of neighbourhood) and air pollution. The construction is currently underway and the short-term study will be completed by 2018.

Other effective countermeasures in the pre-hospital phase include trauma management training for emergency services personnel. Helicopter services in higher income countries are proving to be cost effective, particularly within a 200-km radius of major hospitals, as they provide rapid long-distance transport to specialised medical treatment and avoid delays associated with traffic congestion.

In-hospital care can be improved by training teams for trauma management with the Advanced Trauma Life Support course of the American College of Surgeons, widely recognised as the standard for this type of training. Adequate funding for physical resources, including equipment and consumable medical supplies and for training of medical staff is also essential. Advances in surgical technique, trauma management and technology, all informed by research, are also improving hospital care of road and other trauma victims; panel reviews indicate an average reduction of 50% in medically preventable deaths and trauma registry studies show around a 15-20% reduction (OECD, 2008).

Summarising the findings of specific trauma studies (presented in Hakkert et al., 2007) and additional evidence on changes in road traffic fatalities before and after introducing changes in trauma care (Chiara et al., 2002; McDermott et al., 2007), it can be stated that 5-10% of the fatalities can be determined as definitely preventable and a higher share of the fatalities - as possibly preventable due to improved trauma management.

Box 5.4. **Automatic crash notification via eCall in Europe**

On 28 April 2015 the European Parliament voted in favour of an eCall regulation which requires all new cars to be equipped with eCall technology from April 2018. By this time, eCall is planned to function seamlessly throughout the European Union (EU).

In the event of a crash, an eCall-equipped car automatically establishes a connection with the nearest emergency centre. Even if no passenger is able to speak, a “minimum set of data” is transmitted, including the location of the crash site. Emergency services are thus informed in real time that a vehicle has crashed and where. ECall can also be activated by pushing a button, i.e. used from an eCall-equipped car whose driver witnesses a crash.

ECall can thus reduce emergency service response times by 50% in rural areas and by 60% in built up areas. The fast response is expected to save hundreds of lives in the EU every year. The severity of injuries will be considerably reduced in tens of thousands of cases. eCall does not allow vehicle tracking under normal driving conditions.

Taking a system-wide approach to addressing the key crash types

People are typically killed and seriously injured in four main crash types: 1. vulnerable road users (including pedestrians, cyclists and motorcyclists) hit by motor vehicles, 2. intersection crashes (typically side impact), 3. run-off-road crashes (typically into hazardous roadside objects) and 4. head-on crashes. These crashes occur on road networks of all kinds from local residential roads to shopping streets, from city corridors to inter-urban routes. Targeting these priority crash types is central to the development of a Safe System and the following sections give an indication as to how different parts, and combinations of parts, of the system can be used to combat them.

Crashes with pedestrians and cyclists

Improving pedestrian and cyclist safety requires attention to vehicle design, road infrastructure, and speed management, the focus areas of a Safe System. Their safety should be researched from a system point of view to allow for consideration of the many factors that expose them to risk, such as vehicle speed, poor road design and lack of safe (segregated) facilities. Low- and middle-income countries also need to avoid the mistakes made by many high-income countries that designed roads mainly with motor vehicles in mind and without adequate attention to vulnerable road users. As countries witness increasing numbers of motor vehicles, improvements are needed to infrastructure for vulnerable road users as well as for vehicles, rather than focusing solely on behavioural measures. ITF/OECD (2012) and WHO (2013b) are comprehensive manuals for pedestrian safety and include reference to a Safe System and similarly good guides for cycle safety have been published (see for example ITF/OECD, 2013). Notwithstanding those, speed management in pedestrian and cyclist environments provides one of the greatest immediate opportunities for improving safety outcomes for these vulnerable road users.

In a driving simulator study that related driver workload, driver speed choice, road environment visual complexity and driver response times, Edquist, Rudin-Brown and Lenné (2012) found that drivers travelling in a 60 km/h speed zone attempted to compensate for the effects of increased complexity by lowering their speeds. However, the observed reductions in speed were insufficient to compensate for the reductions in driver response times needed to avoid an increase in crash (and injury) risk. This finding supports the case for reduced operating speeds to assist drivers in complex traffic environments, such as busy pedestrian/commercial areas, to make safe and timely decisions when their information processing abilities are being compromised.

Johansson found that drivers are less likely to give way to pedestrians using formal crossings when travel speeds are higher. The optimum driver give-way behaviour was found to occur at around 30 km/h. It was also noted in this research that at around 30 km/h travel speeds, there is more often a “social exchange” between driver and pedestrian, seemingly leading to safer driver behaviour around pedestrians. Corben (2006) found that fatal crash risk for pedestrians can be reduced by about 75% when a driver chooses to travel at 40 km/h instead of 50 km/h, and by over 90% when 30 km/h is chosen over 50 km/h. Further research from France (Dommes, 2013) showed that errors in judgement when crossing a street are similar for young adults and the elderly when traffic is travelling at 30 km/h but 19 times greater for the elderly when traffic is travelling at 50 km/h.

Hence for pedestrians and cyclists to safely mix with motorised traffic, speeds should be kept below 30 km/h. Even at this speed, crashes with larger mass vehicles such as trucks, buses and trams can result in death and a high likelihood of severe injury. In addition, vehicle pedestrian safety systems are most effective around 30-40 km/h.

Infrastructure designs measures such as speed humps and platforms, slow speed areas such as Woonerven (a name for “living streets” in the Netherlands, using traffic-calming techniques including shared streets and slow speed limits) and well-designed roundabouts can physically control speeds to within the limits of a Safe System. At speeds above 30 km/h pedestrians and cyclists should be physically separated from motorised traffic through provision of separated pedestrian and cycle ways. Time-separated facilities for pedestrians at signalised intersections and mid-block signalised pedestrian crossings can result in severe injuries to pedestrians or cyclists when road users make mistakes or drivers run red lights. Raised platforms at these at-grade crossing points can assist to manage speeds in these instances. In higher speed environments, grade separated crossings are required to improve effective separation.

Raised pedestrian platforms that significantly reduce traffic speed appear to be an effective infrastructure response to severe casualties at pedestrian crossings. In combination with systems that can brake a car automatically and pedestrian-friendly front ends, the safety effect can be even higher (see section on Safe Vehicles). In isolation, the effect of each measure may have some benefit, but when they work together they give each other preconditions to maximise the safety benefit.

Box 5.5. **Case study: Speed management in Japan**

In Japan, road sections with a 30 km/h speed limit are nothing unusual. Yet compared to other countries such as France or Germany these often encounter specific problems that reflect persistent patterns in the historical development of transport infrastructure in Japan. Notably, parts of Japan lack a functional distinction between trunk roads and community roads. Community areas and their roadways developed in a loose, random manner and this has made it more difficult to introduce zone regulations, including the 30 km/h speed zones ("Zone 30"), because through traffic and community traffic are often very much intermingled on the same road.

This mixing results in especially high traffic-death rates for pedestrians and cyclists that make up about 50% of total traffic fatalities in Japan. In response, the Japanese authorities in 2011 introduced the Zone 30 principle in 2011. By the end of March 2014, a total 1 110 such zones existed. They are being supplemented by zones with even lower speed limits. Reflecting the importance of this policy, implementation involved cooperation between police, road administrators, representatives of local residents and other stakeholders.

This bottom-up approach for improved road safety on community roads is supported by the use of Big Data. Through analysis of vehicle speeds, it is now possible to determine appropriate speed management measures, including speed humps and realistic speed limits for given routes.

A range of Co-operative Intelligent Transport System (C-ITS) applications have been developed to specifically meet the needs and transport issues faced by vulnerable road users, including pedestrians, cyclists and motorcyclists. This class of applications are aimed at improving the safety of vulnerable road users by alerting drivers to their presence, particularly if they are out of the driver's line of sight, and giving them priority at crossings so they are less likely to come into conflict with vehicles. These include:

- **Pedestrian detection** (a range of applications to detect vulnerable road users beyond the drivers line of sight).
- **Intelligent pedestrian traffic signals** (detects pedestrians, calls and adjusts crossing times).
- **Co-operative intersection safety for cyclists** (detects cyclists outside of view and sends message to driver about, position and speed of cyclist and warns of likely collision).

Crashes with motorcyclists

Crashes involving powered two-wheelers (PTW) can be divided into two main groups: those occurring in urban built-up environments and high-speed crashes on rural roads. In the urban environment, managing speeds below 30 km/h in potential conflict situations is likely to reduce the severity of injuries. Separated motorcycle lanes are now being provided in a number of countries with very high levels of motorcycle activity (see Box 5.6). Fully controlled turn phases at traffic-controlled intersections, roundabouts or other means of managing speed and angle of impact on intersections are other infrastructure initiatives. However, roundabouts remain as a major location for severe injuries for PTW riders, as they represent a complex environment where drivers fail to see PTWs (and cyclists). Signalised roundabouts offer an opportunity to improve this situation. Compulsory helmet-wearing and enforcement programmes, as well as protective clothing for PTW riders (and, again, cyclists) have been found to be effective in reducing injuries to these road users.

Motorcycles and other PTWs present a particular challenge in a Safe System where they use rural roads. This is largely because riders and pillion passengers do not have the level of protection of other motorised traffic and hence the typical Safe System energy transfers associated with side impact, object impact and head-on rarely apply. In high-speed environments, roadside barriers designed to improve safety for other motorised road users - whether impact absorbing, frangible or not - can be dangerous for motorcyclists who leave the roadway (albeit typically not more dangerous than the roadside objects that they are protecting). In high-risk locations, motorcycle-safe barriers should be considered. Median barriers help protect motorcyclists from head-on crashes and sealing gravel shoulders helps avoid loss of control. In many countries Safe System interventions for motorcyclists are likely to come from the Safer Vehicle, Safe Use and Safe Speed areas with particular emphasis on rider and passenger protection systems, and on anti-lock braking systems (ABS). C-ITS applications are also being developed for motorcyclists. These use vehicle-to-vehicle communication to warn the driver of a car or truck that a motorcycle is approaching from any direction.

The ITF has recently released a comprehensive research report on *Improving Safety for Motorcycle Scooter and Moped Riders* (ITF, 2015a). This study contains a specific section on safety of (PTW) in the context of a Safe System. PTWs provide some unique challenges, particularly that of providing sufficient protection in collisions with other vehicles or fixed objects. The recommended countermeasures take a system-wide approach addressing road use (behaviours and equipment) vehicles and infrastructure.

Box 5.6. **Case study: Exclusive motorcycle lanes safety in Malaysia**

Crash records in Malaysia for the period 2005-14 show that motorcycle fatalities made up 60% of all road fatalities, with an average of 3 975 motorcyclists and pillion riders killed each year. Moreover, motorcycle fatalities rose by approximately 16% over this period, from 3 591 fatalities in 2005 to 4 179 in 2014 (Royal Malaysia Police, 2014).

In a mixed traffic system, motorcyclists share the road with larger vehicles, resulting in differential cruising speeds and mixed-flow conflicts. One way of addressing the risks is to segregate motorcycles from other larger vehicles through the provision of exclusive motorcycle lanes (EMCL). In Malaysia, EMCL are completely separated from the carriageway and can be found on various highways. Egress (path of exiting from the motorcycle lane) and ingress (path of entering into the motorcycle lane) is one of the main elements of EMCL. It allows access into and out of the exclusive lane and thus provides mobility from one destination to another. An egress or ingress itself could also be seen as the most hazardous location of an EMCL as motorcyclists are required to make the critical decision whether to join or leave a traffic stream (Norfaizah et al., 2015).

The first EMCL was constructed along Federal Highway F02 between Kuala Lumpur and Klang in the early 1970s with support from World Bank. The total length of EMCL along F02 is approximately of 30 km per direction. Various studies were conducted to evaluate the effectiveness of the EMCL. A preliminary finding noted a significant overall reduction of crashes on the main carriageway by c. 34% and motorcycles accidents by 39% (Radin Umar, 1995; Radin Umar et al., 2000). Furthermore, Radin Umar and Barton (1997) have shown that the preliminary benefit-to-cost ratio of providing an exclusive motorcycle lane ranges between 3.3-5.2, depending on assumptions used in calculating the motorcycle crash costs and the capacity of the EMCL. The study indicated that even though the cost for provision of exclusive motorcycle lane is high, the benefit is at least three times higher than the construction cost and thus provides a cost-effective approach to tackle motorcycle safety problems in Malaysia.

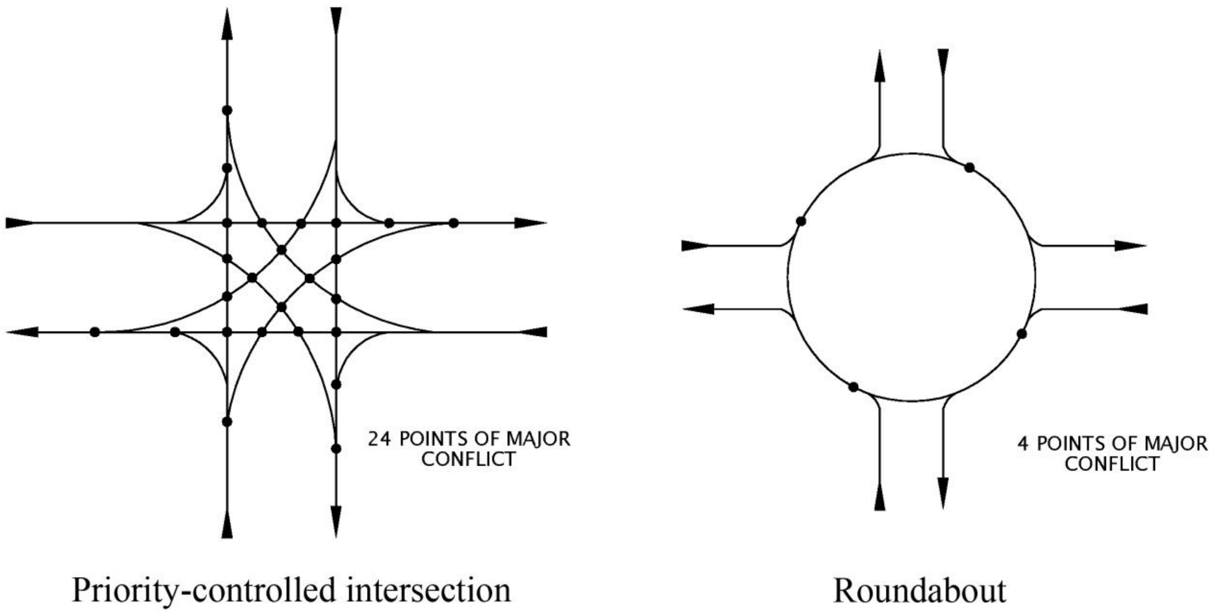
Intersection crashes

Crash locations in urban areas are often associated with the highest traffic volumes and often occur at intersections. This includes signalised intersections and thus often involves vulnerable road users in crashes. In this there is a certain irony: signalised intersections are the locations where traffic managers exert most control over road users, telling them when to go, when to stop and what manoeuvres can be performed. While they may have a relatively low crash rate on an exposure basis, they are nevertheless associated with a high injury risk when crashes do occur. Over a very long time, road authorities have seemingly been unable to address the core crash problems, often involving red-light running or unprotected turns.

Considerable scientific evidence and experience indicate that many of the existing intersection designs do not align with a Safe System. They rely on drivers' and riders' judgements in accepting appropriate gaps, they do not manage speed, do not account for dynamic visual obstructions, and allow side impacts, i.e. where vehicle protection systems are weakest.

A roundabout is an example of how to guide the road user to a safe form of behaviour and mitigate the consequences of common human errors (see Figure 5.10). It is an example of how the capabilities and limitations of the human being is, to a great extent, taken into consideration when designing the road transport system, both from a psychological and physiological point of view. However, even roundabouts can have safety implications related to single-vehicle loss of control, unless carefully designed. Multilane roundabouts have been found to be problematic for cyclists and motorcyclists. Signalised roundabouts offer potential for addressing some of these concerns. Managing speed through the intersection zone through raised platforms is one infrastructure response.

Figure 5.10. **Points of conflict at different intersection types**



A Safe System intersection is an intersection where road users will not get seriously or fatally injured even if they make a simple mistake. Most current intersections do not meet this ambition because the impact forces and kinetic energy levels are often beyond what a typical vehicle structure will resist, and far greater than the biomechanical tolerance of a human body. This mismatch between speed, human biomechanical tolerance and vehicle crashworthiness is especially challenging in rural areas where speed limits are usually set at high levels. Additionally, a Safe System intersection should aim to prevent a combination of mistakes or inappropriate behaviours occurring simultaneously. This can be achieved by providing intersection designs that are intuitively easy to understand and use i.e. self-explaining.

The fundamental constraints for a Safe System intersection design can be defined through the laws of physics (Corben et al., 2015; Candappa et al., 2015). Physics dictates the levels of kinetic energy of vehicles driving at speeds close to the posted speed limit, how quickly a driver can brake to avoid a collision, the impact forces that vehicles exert on each other, and the impact forces that they transfer to the human body in case of a collision. The angle of the intersecting roads and the angle at which vehicles collide is one of the core factors determining the severity of the injury (see Figure 5.11).

Candappa describes the following Safe Intersection Design Principles (SIDPs) defined in the MUARC Intersection Study (Corben et al., 2010):

- **Principle 1**: limit travel speeds through intersections to 50 km/h (key principle)
- **Principle 2**: avoid 90-degree impact angles (important principle)
- **Principle 3**: physically separate vulnerable road users or provide travel speeds below 30 km/h (important principle)
- **Principle 4**: limit points of conflict (supporting principle)
- **Principle 5**: promote active mutual responsibility at intersections (supporting principle).

A number of countries are starting to investigate alternative, innovative Safe System intersection designs. Future designs also need to recognise the human factor issues associated with an ageing population. ITS-type systems such as variable speed limits that are activated by vehicles approaching on side roads, or variable speed limits activated by vehicles turning across oncoming traffic at the intersection, warning systems and red-light cameras are other initiatives that can successfully reduce high severity crashes at intersections. Vehicle to vehicle technologies that detect vehicles entering the potential collision zones and alerting the road users or taking action, such as braking, also offer potential for reduced collisions.

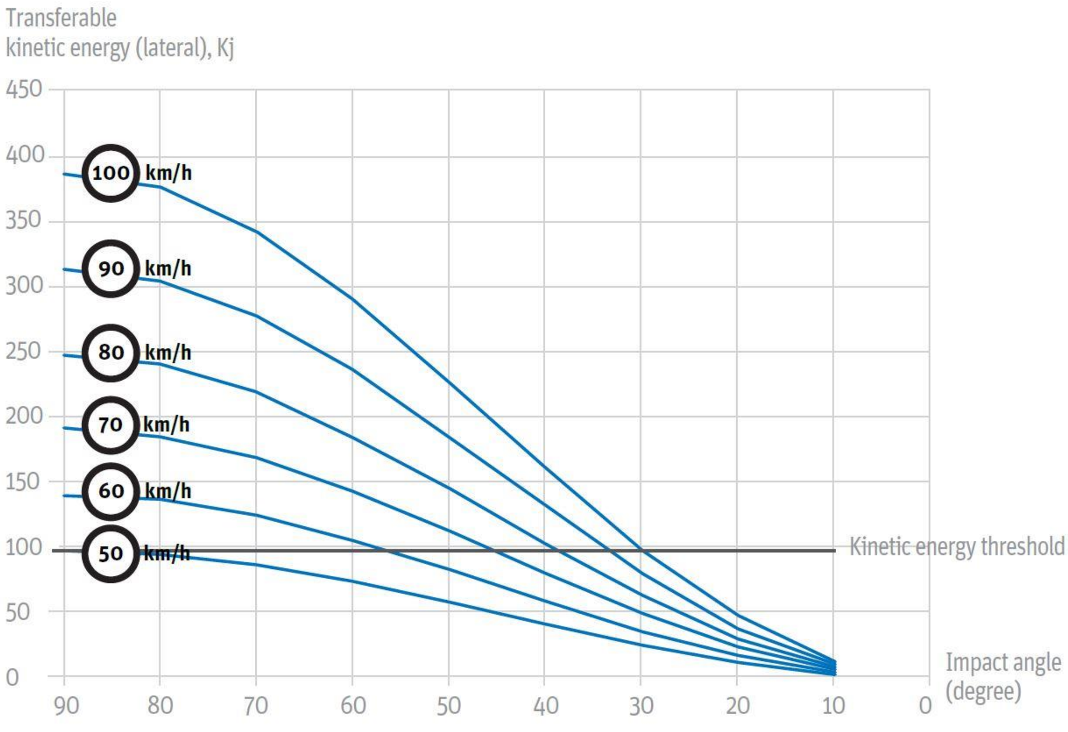
Run-off-road crashes

Historically road managers have focussed on keeping vehicles on the road through geometric road design (alignment and cross-fall). However, many vehicles still leave the road for all sorts of reasons, including driver fatigue and inattention. Even on very good quality roads, run-off-road crashes with single vehicles remain the main cause of serious injuries. This is due, to a large extent, to roadsides not being designed to accommodate the common occurrence of vehicle departures, often at legal speeds. Over the last 50 odd years, approaches to reduce the severity of these incidents have focussed on roadside design, roadside hazard management, and an ever-increasing clear-zone width.

Recent research, particularly in Australia (Doecke et al., 2010; 2011) and the report *Improving Roadside Safety* (Austroads, 2014) challenge the effectiveness of this approach. Indeed, they show that other than for very low-angle departures, some vehicles will travel well beyond the designed clear-zone widths. Speeds at the typical design clear-zone boundaries would exceed Safe System impact speeds. In wide clear zones, vehicles also tend to roll, still resulting in serious injuries. The Austroads report found that the lowest Fatal and Serious Injury (FSI) ratio per crash came from impacts into flexible wire-rope barrier systems. The flexible barrier system was found to come closest to aligning with a Safe System, primarily through its ability to capture vehicles, even well beyond the systems design speeds and mass, and minimise overturning. However, these findings relate to countries with high ratios of cars and trucks and may not relate to countries with a large share of motorcycles. European studies into run-off-road crashes on the Naples-Candela motorway in Italy and 2 000 kilometres of French motorways also support that well-designed barrier systems produce lower rates of injury and serious injury than unprotected roadsides.

Vehicle systems are now also playing an increasing role in assisting with keeping vehicles on the road. Electronic Stability Control (ESC) is a driver assistance system which reduces the risk of loss of traction of a vehicle. Although ESC cannot always prevent skidding from developing into a crash, it can limit the risk of an injury in some crash configurations by reducing the amount of energy that is exchanged in the crash. This is achieved by a more favourable crash configuration since the risk of the side of the vehicle hitting oncoming traffic or other obstacles is minimised. Speed management, through either infrastructure design or appropriate speed limits, offers huge opportunities for reducing the number and severity of run-off-road crashes. Charlton (2013) found that drivers significantly underestimate the risk of many roadside hazards and hence fail to modify their speed accordingly.

Figure 5.11. **Influenced impact angle on transferable kinetic energy**



Head-on crashes

The likelihood of severe injury from head-on crashes increases significantly beyond speeds of 70 km/h, suggesting that in a Safe System all undivided roads should have operating speeds below this threshold. Analyses from Sweden, Australia and New Zealand suggest that severe casualty numbers from head-on crashes are a major issue at traffic volumes well below typical thresholds for installing median barriers, often as low as 4 000 to 7 000 vehicles per day.

A Safe System infrastructure response to head-on crashes on roads above 70 km/h is to introduce single direction carriageways, very wide median separation or a forgiving median barrier system. Stigson (2009) found divided roads to be the strongest factor in eliminating fatalities among car occupants. The issues with wide median designs are often the same as clear zone designs referred to in run-off-road crashes above, with high speed, high departure angle vehicles travelling beyond the median-width or rolling over. Once an errant vehicle has traversed the median and reached the opposite carriageway, arriving even at very low speeds, severe injury can ensue, due to the high speeds and volume of approaching vehicles. As such, well-designed barrier systems are invariably more effective.

Sweden is one country that is leading the way in addressing head-on crashes in high-speed environments with a strategy of flexible wire-rope barrier systems installed on 13-metre wide undivided carriageways with alternating passing lanes (2+1 system) and more recently on its nine-metre carriageways with a 1+1 system. It is the erection of the mid-barrier that is critical to achieving a Safe System performance, rather than the need to have the alternating three-lane cross-section. However, a number of other countries have also successfully retrofitted median barriers within a relatively narrow space to address head-on crash risk. An example from New Zealand is described in Box 5.7. The safety gains from wire rope median barriers are likely to be greatest from countries with lower PTW usage. Alternative forgiving barrier systems are being developed and installed where concerns for wire rope barriers in respect to PTW and heavy vehicle use, maintenance costs from nuisance strikes, road worker safety etc.

Many countries have developed three-lane carriageways to enable safer overtaking also with the objective of reducing head-on collisions. Over time, the need for physical separation between opposing lanes on higher volume roads is recognised. With concerns around the potential risks for motorcycles, the need to maintain heavy vehicles and to minimise maintenance costs, other less flexible barrier systems are adopted such as semi-rigid steel beams or rigid concrete barriers.

The business case for investment in a Safe System

Approximate spending on land transport is about 0.7% of GDP annually in most countries (OECD, 2013). Assuming a similar global spend and world GDP equal to USD 75 592 billion (World Bank, 2015), a rough approximate estimate of the world road industry is USD 530 billion a year. Assuming targeted road safety interventions equate to 2-5% of total budgets, the investment in targeted road infrastructure safety is in the region of approximately USD 10 to 26 billion a year. This means that total world road infrastructure safety investment amounts to approximately 0.5% to 1.4% of the estimated global cost of fatal and serious crashes (USD 1 851 billion), or one US cent of investment for every dollar of road trauma costs (McInerney et al., 2015).

With this base funding as a starting point, road agencies have typically set design standards, warrants and investment levels to work within these funding constraints. This approach has led to undivided high-speed roads, dangerous roadsides, high-speed cross roads and urban settlements without footpaths all being considered as in accordance with the standards at certain volumes of traffic and therefore deemed acceptable by road agencies and engineers. In many cases the belief that road crashes are the road users' fault has provided a convenient excuse by funding agencies, politicians and engineers for maintaining the status quo. That is, within the constraints of available budgets, road authorities have had to compromise on road safety performance – and accept a level of death and injury on the road network.

Box 5.7. **Case study: Median barrier installation in New Zealand**

In the nine years prior to the installation of a median barrier on New Zealand's Centennial Highway in 2005, there had been eight fatal crashes and four serious head-on crashes. Since the construction of the wire-rope median barrier and the reduction of the speed limit from 100 km/h to 80 km/h, no fatalities or serious injuries have occurred. Since the installation of the wire rope median barrier there have been no fatal or serious crashes, nor any head-on collisions.

Camera surveillance of the median barrier showed that vehicles generally sustained relatively little damage when they struck the barrier and were often observed to drive away after the impact. Drivers also tended to travel more centrally within their lane with the barrier in place. Camera footage shows numerous situations where vehicles had collided with the barrier in the face of opposing traffic, including opposing motorcyclists, avoiding what would almost certainly have been head-on collisions.

Figure 5.12. **Rope-wire median barrier on the Centennial Highway, New Zealand**

Source: Marsh F et al. (2010).

Linked to the ethical, health and community benefits of road trauma reduction, the business case for investment in a Safe System is compelling. Based on actual estimates of cost-effective investments in safer roads and the expected reduction in road trauma and economic costs determined as part of iRAP assessments worldwide, a global business case for road investment has been developed. The analysis suggests that an additional investment of USD 681 billion (or less than 0.1% of global GDP per year for ten years) could prevent an estimated 40 million deaths and serious injuries over 20 years, with a return on investment of eight US dollars for every dollar invested (see Table 5.5). While not specifically measuring the cost to deliver Safe System outcomes, the analysis highlights the opportunity for a win-win investment in road trauma reduction.

Table 5.5. **The business case for investing in road safety**

What could be achieved	Low-income countries	Lower-middle income countries	Upper-middle income countries	High-income countries	All
Improve 10% of highest risk roads	108 000 km	610 000 km	992 000 km	1 546 000 km	3 255 000 km
Build viable countermeasures (USD)	8 billion	61 billion	149 billion	464 billion	681 billion
Reduction in fatalities over 20 years	384 000	1 483 000	1 528 000	283 000	3 678 000
Reduction in fatalities and serious injuries over 20 years	4 224 000	16 313 000	16 808 000	3 113 000	40 458 000
Economic benefit over 20 years (USD)	83 billion	663 billion	2 766 billion	2 202 billion	5 715 billion
Benefit cost ratio	11	11	19	5	8

Source: iRAP (2014): Business Case for Safer Roads.

The key to an appropriate level of investment in improved road safety is the recognition of those who benefit from reductions in road trauma (emergency services, hospitals, health and welfare systems, insurers, business and treasury) as opposed to the traditional organisations involved in funding and managing the road network (road agencies).

The potential for so-called Social Impact Bonds or other “impact investing” products to provide the mechanism to close this gap are being actively explored worldwide. A pilot study is currently being undertaken by the FIA Foundation, iRAP, the Traffic Accident Commission (TAC) of Victoria, VicRoads, the Australian Road Research Board (ARRB), and the Royal Automobile Club of Victoria (RACV) in Victoria, Australia, to develop a social impact bond calculator to measure the financial savings to all stakeholders from an investment in safer roads (McInerney et al., 2015). The approach has the potential to initiate a step change in resource mobilisation for combatting the biggest killer of young people worldwide. It would also lift an enormous burden from health systems and individuals everywhere and thus create a win-win-win. Further examples for developing business cases for investment in a Safe System are TAC’s Safe System Road Infrastructure Programme (see Box 5.8) and the business plan for “Sustainable Safety” programme in the Netherlands (see Box 5.9)

It is worth noting in this context that specific or additional Safe System funding is not needed when Safe System principles are integrated in the process of building new infrastructure from the outset. This will actually save money in the long term, both in the health system and in the transport system through avoiding retrofitting.

Challenges to implementing a Safe System

Implementing a Safe System has many challenges which countries that are already on that path can attest to. They centre around the paradigm shift away from driver blame, the debate and trade-off between safety and efficiency, the lack of guidelines and standards, and the fear of higher costs.

The case of Sweden, a leader in Safe System thinking and implementation, provides an illustrative example. After the Swedish Parliament had unanimously adopted “Vision Zero” and the executive was thus tasked with implementing the new vision, many road safety professionals remained sceptical and hesitant, which manifested itself in three main lines of resistance.

First of all, the engrained focus on cost-benefit analysis made that the notion of achieving zero deaths almost ridiculous to many road safety professionals. It was considered more or less absurd to suggest that making this a national policy objective could be sound policy from an economic point of view, as surely the marginal cost for reducing road deaths beyond a certain level would be extremely costly and hence prohibitive. This line of resistance was countered in part with ethical arguments and the rhetorical question how many dead and injured people would, in that traditional view, be “optimal” and most “beneficial” for society. But the criticism was also addressed with hard figures showing the actual economic cost of the unsafe roads. A final pillar in the case made by the proponents of “Vision Zero” were pilot projects, which demonstrated that significant reductions in road fatalities did not necessarily require costly investments. Rather, the coherent application of Safe System thinking could lead to straightforward, easy-to-implement solutions, and even where large investments were needed, they could be shown to be cost effective.

Box 5.8. **Case study: Victoria’s Safe System Road Infrastructure Program (SSRIP)**

Victoria’s Transport Accident Commission (TAC) is the state’s single insurer for transport injury compensation claims. In partnership with VicRoads, the state’s roads authority, TAC has a strong record of effective and cost-effective investment in programs which retrofit safety to the existing road network. In response to Australia’s formal adoption of a Safe System and the growing global commitment to a Safe System vision in general, the former Safer Road Infrastructure Program (SRIP) has been evolved into the Safe System Road Infrastructure Program (SSRIP). SSRIP focuses on three main crash types that continue to dominate severe road trauma in Victoria:

- intersection crashes (44% of all serious casualties)
- lane departure crashes (over 33% of all serious casualties)
- crashes involving pedestrians and cyclists (19% of all serious casualties).

The strategic investment focus of the SSRIP is on:

- Safe System transformation of intersections: mass action construction of roundabouts; innovative Safe System designs for signalised intersections.
- Safe System Transformation for eradicating lane departure casualties: freeways and divided major rural highways, through the erection of continuous, forgiving roadside and median barriers; undivided rural highways, initially through the trial of Safe System-aligned treatments, such as 2+1 designs and like-solutions; minor rural highways, through localised safety treatments and improved management of speeds, given the existing default, 100 km/h rural speed limits.
- Safe System Transformation for pedestrians and cyclists: popular cycling routes; commercial areas and routes for pedestrians and cyclists.

To maintain current benefits during the transition to Safe System investment, a steadily declining proportion of resources will be directed to conventional, cost-effective forms of safety investment (benefit-to-cost ratios of at least three) during the early years of SSRIP funding. However, consideration is now being given to halving this to 1.5 for treatments that align with a Safe System.

Box 5.9. **Case study: Making the business case for sustainable safety in the Netherlands**

Work towards the implementation of a Safe System in the Netherlands began in 1998 with the Start-up Programme Sustainable Safety. Ten years after the launch, the Dutch Institute for Road Safety Research (SWOV) assessed how implementation of measures in support of the Sustainable Safety vision has progressed and what their impact on road safety performance had been. Among the host of road safety measures implemented under the Start-up Programme, many aimed at improving infrastructure safety, the most important being categorisation of road networks and construction of 30- and 60-km/h areas. Furthermore, more than 2 300 roundabouts were constructed from 1998 through 2007. Together, these infrastructure measures have since prevented an estimated 120 to 145 fatalities per year.

Under the Start-up Programme, traffic enforcement also improved, due to the introduction of regional traffic enforcement teams. These teams consist of about 30 full-time equivalents per police region or 750 full-time equivalents in total, who work exclusively on enforcement in the following priority areas: helmet use on powered two-wheelers, seat-belt use, red light violations, driving under the influence of alcohol, and speeding. The increased traffic enforcement in combination with public information campaigns, probably contributed to a decrease in the percentage of alcohol offenders and an increase in seat belt use. These improvements in behaviour in turn resulted in preventing an estimated 65 and 55 fatalities per year respectively.

Vehicle safety also improved during the Start-up Programme, but this is largely attributable to European regulations and initiatives of the car industry (encouraged by the European New Car Assessment Program EuroNCAP). However, they align well with the “Sustainable Safety” vision.

On an aggregate level, the measures launched under the Start-up Programme showed positive effects. The overall fatality rate from road crashes in the Netherlands decreased from 7.3 deaths per billion kilometres travelled in 1998 to 4.7 deaths in 2007. The average annual decrease almost more than tripled compared to the preceding ten years; while between 1989 and 1998 the number of road fatalities had fallen by 1.8% per year on average, it fell by an annual average of 5.3% between 1998 and 2007. From a cost-benefit perspective, the measures were also effective, with monetarised benefits approximately four times the costs (Weijemars and Wegmann, 2011).

A second challenge to “Vision Zero” came from behavioural scientists within the road safety community who argued that approach was technocratic and ignored the importance of human behaviour. Their main contention was that 90% of all road crashes were caused by human behaviour and that the solution was to eradicate such “bad” behaviour. The Safe System supporters replied that in fact “Vision Zero” was very much human centric: it acknowledged human frailty and fallibility, building its entire approach around the notion that human beings cannot be expected to at all times cope with the complex demands of road traffic - be they physical, cognitive or psychological. Research results highlighting that speed management, infrastructure and vehicle solutions can prevent the majority of road deaths also helped to explain the role of Safe System in the context of human behaviour.

Thirdly, among road engineers a prevalent belief was that the only way to build a safe road was to construct large and expensive motorways. They also tended to be of the opinion that they designed and built high-quality roads and that it was up to the road users to behave correctly on them. This mind-set was challenged through a demonstration project, Sweden’s first 2+1 road. It showed that for a fraction of the cost of a motorway, it was possible to achieve a very high level of safety with enough capacity. At the same time the project provided clear evidence that the traditional roads in the class below motorways (13-metres wide roads without median separation) were very unsafe compared to these roads.

Conclusion

When implementing a Safe System, the professionals or practitioners responsible often ask questions along the lines of “what do we need to do differently?” or “show me what a Safe System looks like”. Although we all still have a lot to learn in this regard, this chapter shows how parts of the road system can be strengthened individually, but more importantly managed collectively, to help work towards a Safe System. This chapter does not repeat the significant array of well proven road safety interventions that can be found in manuals such as the PIARC Road Safety Manual (2015), Elvik (2012), or online in tools such as the CMF clearinghouse (www.cmfclearinghouse.org), or the iRAP road safety toolkit (www.toolkit.irap.org). Instead it focuses on the primary system treatments that, if effectively managed, will help make significant steps towards a Safe System.

The starting point for all Safe System practices is to understand the system failure points and how to work backwards from these to intervene at the earliest possible time in a way that avoids crashes, managing a crash to minimise any harmful impacts if it occurs, and to optimise the post-crash response. A Safe System requires an understanding of the forces involved in the event of a crash, and how to manage these forces within human tolerance for death and serious injury. These crash forces are typically best explained through Safe System speed thresholds for the most common crash types.

The avoidance of system failures and the management of crash forces can be achieved through a combination of encouraging safe use, providing self-explaining and forgiving roads and roadsides, improving vehicle crash-avoidance and occupant-protection systems, and – critically - managing speed. Should one part of the system fail, other parts must step in, including post-crash response.

Over time, road and vehicle design, and new technologies that promote and support safe driver behaviour will play an even greater role in creating a Safe System. In the meantime, the importance of managing speed to manage the kinetic energies should a crash occur cannot be overemphasised. While it can be challenging to build public acceptance and find political support, speed management is quick to implement at low cost and is highly effective.

While the fundamental principles of the Safe System are straightforward and should be simple to implement, this is not always the case. Many traditional design guides, processes and funding frameworks are not aligned with this approach and need to be updated or challenged. Business cases that clearly demonstrate the unquestionable benefits of a Safe System can help with this.

The Safe System is still developing and there are a number of areas, in particular with vulnerable road users, where further research, development and innovation is required. However, in many areas a lot is already known about what works and what does not. The practices and tools pro-actively move towards creating a Safe System are there to use.

References

Aarts, L. et al. (2009), *Safe Speeds and Credible Speed Limits*, Compendium of papers, 88th Annual Meeting of Transportation Research Board (TRB), Washington DC, 11-15 January 2009.

Austroads (2014), *Improving Roadside Safety, Summary Report*, AP-R437-14, Austroads, Sydney, Australia.

Austroads (2015), *Safe System Assessment Framework*, AP-R509-16, Austroads, Sydney, Australia.

BITRE (2012), *Evaluation of National Black Spot Program*, Bureau of Infrastructure, Transport and Regional Economics, Canberra, Australia.

Brennan, P.W., E.R. Everest an W. M. Griggs (2002), "Risk of death among cases attending South Australian major trauma services after severe trauma", in: *Journal of Trauma – Injury Infection and Critical Care*, Vol. 53, pp. 333-339.

Cameron, M.H. and R. Elvik (2010), "Nilsson's Power Model connecting speed and road trauma: Applicability by road type and alternative models for urban roads", in *Accident Analysis and Prevention*, Vol. 42, pp. 1908-1915.

Candappa, N., D. Logan, N. Van Nes and B. Corben B. (2015), "An exploration of alternative intersection designs in the context of Safe System" in *Accident Analysis and Prevention*, 74, pp. 314-332.

Carnis, L. and E. Blais (2013), "An assessment of the safety effects of the French speed camera program" in *Accident Analysis and Prevention*, Vol. 51, pp. 301-309. DOI: http://dx.doi.org/10.1016/j.aap.2012.11.022

Carnis, L. (ed) (2012), *International Comparison of Automated Speed Enforcement Systems (*ICASES), Grant n° 09 MT CV 04, Ministère de l'écologie, du développement durable, des transports et du logement, PREDIT, Operational Group 2.

Carnis, L. (2009), "Une analyse économique du dispositif de contrôle automatisé de la vitesse en France", *Proceedings of the 19th Canadian Multidisciplinary Road Safety Conference*, Saskatoon, Saskatchewan, 8-10 June 2009, Peer-Reviewed Paper, pp. 1-17.

Carnis, L. (2007), "The French Automated Speed Enforcement Programme: First Results and Analysis", *Proceedings of the 2007 Australasian Road Safety Conference Research Policing Education Conference*, 17-19 October, Peer-Reviewed Paper, Crown Promenade, Melbourne, Victoria, Australia, www.roadsafetyconference2007.com.au/finalpapers.php.

CEC (2003), "European road safety action programme: Halving the number of road accident victims in the European Union by 2010: A shared responsibility". Commission of the European Communities (CEC), Communication from the Commission (2003) 311 final.

Charlton, S.G., N.J. Starkey, J.A. Perrone and R.B. Isler (2013), *Reading the Risk of New Zealand Roads: A Comparison of Actual and Perceived Driving Risk*. TARS Research Report, Centre for Road Safety, University of Waikato. Hamilton.

Chiara, O., J. Scott J. and S. Cimbanassi (2002), "Trauma deaths in an Italian urban area: an audit of prehospital and in-hospital trauma care", in *Injury*, Vol. 33, pp. 553-562.

Corben, B., N. van Nes, N. Candappa, D. Logan, D. and J. Archer, J. (2010), Intersection Study Task 3 Report: Development of the kinetic energy management model and safe intersection design principles.

Corben, B., A. D’Elia, and D. J. Healy (2006), “Estimating Pedestrian Fatal Crash Risk” in *Proceedings of the 2006 Australasian Road Safety Research, Policing and Education Conference,* October 2006. Gold Coast, Australia.

Dahlstedt, S. (1999), “Icke-användares motiv för att inte använda bilbältet”, in *VTI rapport 417*. Linköping. Sweden.

Delorme, R. and S. Lassarre (2009), “Les régimes français et britannique de régulation du risque routier, La vitesse d’abord”, in Les collections de l’INRETS, n°57, pp.201-232, Institut national de recherche sur les transports et leur sécurité (INRETS)

Department of Health (2014), *Victorian State Trauma Registry,* Summary Report, Victoria, Australia.

Doeke, S., and J. Woolley (2011), “Further investigation into the effective use of clear zones and barriers in a Safe System context”, in: *Proceedings of the 2011Australian Road Safety Research, Policing and Education Conference*, Perth, Australia.

Doeke, S., and J. Woolley (2010), “Effective use of clear zones and barriers in a Safe System context.” : *Proceedings of the 2010 Australian Road Safety Research, Policing and Education Conference*, Canberra, Australia.

Dommes, A., V. Cavallo and J. A. Oxley (2013), “Functional deadlines as predictors of risky street crossing decisions in older pedestrians” in *Accident Analysis and Prevention*, Vol. 59, pp. 135-143.

ECMT (2006), *Speed Management*, OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/9789282103784-en.

Edquist, J., C. M. Rudin-Brown and M.G. Lenne (2012), “The effects of on-street parking and road environment visual complexity on travel speed and reaction time”, in *Accident Analysis and Prevention,* Vol. 45, pp. 759-765.

Elvik, R. (2013), “A re-parameterisation of the Power Model of the relationship between the speed of traffic and the number of accidents and accident victims” in *Accident Analysis and Prevention*, Vol. 50, pp. 854-860.

Elvik, R., A. Hoye, T. Vaa and M. Sorenson (2009), *The Handbook of Road Safety Measures*, second edition, Emerald Group, Bingley, UK,

ETSC (2015), “Position paper in revision of the General Safety Regulation”, European Transport Safety Council, Brussles

ETSC (2014), *Ranking EU Progress on Car Occupant Safety*, PIN Flash Report 27, European Transport Safety Council, Brussels http://etsc.eu/ranking-eu-progress-on-car-occupant-safety-pin-flash-27/

ETSC (2001), *Transport Safety Performance Indicators*. European Transport Safety Council, Brussels.

ETSC (1999), *Reducing the Severity of Road Injuries through Post Impact Care*. European Transport Safety Council, Brussels.

Eugensson, A. et al. (2011), “Cars are driven on road, joint visions and modern technologies stress the need for co-operation” in *22nd International Technical Conference on the Enhanced Safety of Vehicles (ESV),* www-nrd.nhtsa.dot.gov/pdf/esv/esv22/22ESV-000352.pdf

EuroRAP (2011), "Roads that Cars can Read: a Consultation Paper", www.eurorap.org/wp-content/uploads/2015/04/20110629-Roads-That-Cars-Can-Read-June-2011.pdf

European Road Safety Observatory (ERSO) (2006-04), *Post impact care*, www.erso.eu

Fitzharris et al. (2010), "ESC Effectiveness summary: Regulation impact statement for the control of light commercial vehicle stability", Department of Infrastructure and Transport, Canberra, Australia.

Hakkert, A.S., V. Gitelman and M.A. Vis, M.A. (eds.) (2007),*"Road Safety Performance Indicators: Theory*, Deliverable D3.6 of the EU FP6 project SafetyNet.

Highway Loss Data Institute (2012), "Predicted availability of safety features in registered vehicles", in *Bulletin*, Vol 28/26.

Highways England (2014), *5-Year Strategy Business Plan 2015-2020*.

IIHS (2016), "Crashes avoided: front crash protection clashes police reported rear end crashes", Insurance Institute for Highway Safety, Status Report Vol. 51/1.

iRAP (2015), *Vaccine for Roads*, third edition, International Road Assessment Programme. www.irap.org/vaccine_for_roads_3.pdf .

iRAP (2014), *Business Case for Safer Roads*, International Road Assessment Programme www.irap.org/en/about-irap-2/a-business-case-for-safer-roads

ITF (2015a), *Improving Safety for Motorcycle, Scooter and Moped Riders*, OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/9789282107942-en

ITF (2015b), *Automated and Autonomous Driving: Regulation Under Uncertainty*, Corporate Partnership Board Report, www.itf-oecd.org/sites/default/files/docs/15cpb_autonomousdriving.pdf.

ITF (2015c), *Road Safety Annual Report 2015*, OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/irtad-2015-en

ITF (2013), *Cycling, Health and Safety*, OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/9789282105955-en

ITF (2013), *Spending on Transport Infrastructures*, 1995-2011, International Transport Forum, Paris.

ITF (2012), *Pedestrian Safety, Urban Space and Health*, OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/9789282103654-en

ITF (2008), *Towards Zero: Ambitious Road Safety Targets and the Safe System Approach*, OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/9789282101964-en

Johansson, C. (2006), "Safe pedestrian crossings for children and elderly", in *Accident Analysis and Prevention* 38(2), pp. 289-94, DOI: 10.1016/j.aap.2005.09.012.

Jurewicz, C., A. Sobhani J. Woolley, J. Dutschke and B. Corben (2016), "Exploration of Vehicle Impact Speed - Injury Severity Relationships for Application to Safer Road Design", in *Transport Research Arena, Science Direct*, pp. 4247-4256.

Kahane, C.J. (2015), "Lives Saved by Vehicle Safety Technologies and Associated Federal Motor Vehicle Safety Standards, 1960 to 2012: Passenger Cars and LTVs, with Reviews of 26 FMVSS and the Effectiveness of Their Associated Safety Technologies in Reducing Fatalities, Injuries, and Crashes", Report No. DOT HS 812 069, National Highway Traffic Safety Administration, Washington, DC.

Kroyer, H.R., T. Jonsson and A. Varhelyi (2014), "Relative risk curve to describe the effect of change in the impact speed on fatality risk pedestrians struck by a motor vehicle", in *Accident Analysis and Prevention*, Vol. 62, pp. 143-152.

Larsson M., N. Candappa and B. Corbin (2003), "Flexible barrier systems along high speed roads", Monash University.

Leveson, N.G. (2011), "Applying systems thinking to analyze and learn from events", in: *Safety Science*, Vol. 49, pp. 55-64.

Lie, A., M. Krafft, A. Kullgren and C. Tingvall, C. (2008), "Intelligent seat belt reminders – do they change driver seat belt use in Europe?", in *Traffic Injury Prevention*, Oct. 2008, Vol. 9/5, pp. 446-449.

MacKenzie, E.J., F.P. Rivara, G. J. Jurkovich et al. (2006), "A National Evaluation of the Effect of Trauma Center Care on Mortality." In *New England Journal of Medicine*, Vol. 354/4, pp. 366-378.

Mann N., and R. Mullins (1999), "Population-based research assessing the effectiveness of trauma systems", in *Journal of Trauma*, Vol. 47, pp. 59-66.

Marsh, F. and M. Pilgrim (2010), "Evaluation of a narrow median wire rope barrier installation on Centennial Highway, New Zealand", in: *Journal of the Australasian College of Road Safety*, May 2010, pp. 34-41.

Martin J.-L., C. Mintsa-Eya and Goubel C. (2013), "Long-term analysis of the impact of longitudinal barriers on motorway safety", in *Accident Analysis and Prevention*, Vol. 59, pp. 443-451.

McDermott, F., S. Cordner S., D. Cooper and V. Winship (2007), "Management deficiencies and death preventability of road traffic fatalities before and after a new trauma care system in Victoria, Australia", in *Journal of Trauma*, Vol. 63/2, pp. 331-338.

McInerney, R., H. Alavi and B. Bui (2015), "Road Safety Impact Bonds – A financial business case." PIARC Congress, Korea.

Norfaizah, M.K., M. J. Nusayba, A. M. Muhammad Marizwan, and J. S. Ho (no date), Safety Evaluation of Egress and Ingress of Exclusive Motorcycle Lane at Federal Road 2, Kajang, Selangor.

OECD (1999), *Safety Strategy forRrural Roads*. OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/9789264172913-en

Peden, M. et al. (2004), *World Health Report on Road Traffic Injury Prevention*, World Health Organization, Geneva, Switzerland.

PIARC (2015), *Road Safety Manual* (Second edition).

Radin Umar, R. S. (2006), "Motorcycle safety programmes in Malaysia: How effective are they?" *International Journal of Injury Control and Safety Promotion*, Vol. 13/2, pp. 71–79. DOI: http://doi.org/10.1080/17457300500249632

Radin Umar, R.S., M.G. Mackay and B.L.Hills (2000), "Multivariate Analysis of Motorcycle Accidents and the Effects of Exclusive Motorcycle Lanes in Malaysia." In *Journal of Crash Prevention and Injury Control*, Vol. 2, pp. 11-17. http://doi.org/10.1080/10286580008902549

Radin Umar, R. S. and E. V. Barton (1997), "Preliminary Cost Benefit Analysis of the Exclusive Motorcycle Lane in Malaysia", in *Journal of the Road Engineering Association of Asia and Australasia* (REAAA), pp. 1-6.

Radin Umar, R.S., M.G. Mackay and B.L. Hills (1995), “Preliminary Analysis of Exclusive Motorcycle Lanes along the Federal Highway F02, Shah Alam, Malaysia”, in *International Association of Traffic and Safety Sciences* (*IATSS) Research*, Vol. 19/2, pp. 93-98.

Read, G., P. Salmon and M. Lenné (2013), “Sounding the warning bells: The need for a systems approach to understanding behaviour at rail level crossings”, in *Applied Ergonomics*, Vol. 44/5, pp. 764-774.

Rosen, E., H. Stigson H. and U. Sander (2011), “Literature Review of Pedestrian Fatality Risk as a Function of car impact speed”, in: *Accident Analysis and Prevention*, Vol. 43.

Royal Malaysia Police (2014), *Laporan Tahunan PDRM 2014*. Kuala Lumpur.

SAE (2014), J3016 Taxonomy and Definitions for terms related to on-road Motor Vehicle Automated Driving Systems, Society of Automotive Engineers,

Sasser, S., M. Varghese, A. Kellermann and J.D. Lormand (2005), *Prehospital Trauma Care Systems*. Geneva, World Health Organization.

Stigson, H., A. Kullgren and M. Kraft (2011), “Use of Car Crashes Resulting in Injuries to Identify System Weaknesses”, 22nd International Conference on the Enhanced Safety Vehicles, Washington DC.

Stigson, H., M. Kraft and C. Tingvell (2008), “Use of fatal real-life crashes to analyse a safe road transport system model, including the road user, the vehicle and the road”, in *Traffic Injury Prevention*, 9.

SWOV (2012), “Towards Credible Speed Limits”, fact sheet, Dutch Institute for Road Safety Research (SWOV) www.swov.nl/rapport/Factsheets/UK/FS_Credible_limits.pdf

Teoh, E. (2011), “Effectiveness of antilock braking systems in reducing motorcycle fatal crash rates”, in *Traffic Injury* Prevention, Vol. 12, pp. 169-73.

Ternier, M. (2003), *La politique de sécurité routière, les systèmes locaux de contrôle-sanction*, rapport de l’instance d’évaluation, Conseil national de l’évaluation, Commissariat général du plan.

Transport and Mobility Leuven (2014), *Study on the effectiveness and on the improvement of the EU legislative framework on road infrastructure safety management (Directive 2008/96/EC) - Ex-Post Evaluation*, http://www.tmleuven.com/project/roadinfrastructuresafetymngt/home.htm (accessed 26 July 2016).

Turner, B., M. Tziotis, P. Carney and C. Jurewicz (2009), *Safe System Infrastructure – National Roundtable Report*, Research Report ARR 370, ARRB Group, Victoria, Australia.

Weijermars, W. and F. Wegman (2011), “Ten Years of Sustainable Safety in the Netherlands. An Assessment”, in *Transportation Research Record*, 2213, pp 1-8.

WHO (2013a), *International Perspectives on Spinal Cord Injury*, http://apps.who.int/iris/bitstream/10665/94192/1/WHO_NMH_VIP_13.03_eng.pdf

WHO (2013b), *Global Status Report on Road Safety 2015*, table A3, pp.272-275.

World Bank (2015), World Bank national accounts data and OECD National Accounts data files, http://data.worldbank.org/indicator/NY.GDP.MKTP.CD (accessed 27 July 2016).

Wramborg, P. (2005), “A new approach to a safe and sustainable Traffic Planning and Street Design for Urban Areas”, Paper presented at Road Safety for Four Continents Conference, Warsaw, Poland.

Notes

[14] The 1958 Agreement has 58 countries as Contracting Parties (CPs) and has established 128 UN Regulations. The 1998 Agreement has 33 countries as CPs and it has established 12 UN Global Technical Regulations (GTRs). See http://www.unece.org/trans/main/welcwp29.html.

[15] The 2006 OECD/ECMT Report is a comprehensive document on speed management outlining the effect of speed and the various mechanisms for managing it through infrastructure design, speed limits, education, enforcement, and vehicle technologies. Johnson (2014) provides more up-to-date information on the importance of speed management in a Safe System. It is not the intention in this report to repeat this information but to reconfirm the importance of managing speed in the pursuit of a Safe System.

Chapter 6. Safe System in cities

Cities present both a pressing challenge for sustainable mobility and a great opportunity for creating a Safe System of road traffic. Already, major world cities are becoming Safe System laboratories, testing the viability of designing, communicating, managing and living the Safe System approach in complex communities. With continuing urbanisation in high-income countries and rapid demographic growth and urbanisation in many middle- and low-income countries combined with unprecedented motorisation, there is an urgent need to establish a road safety paradigm in which pedestrians and cyclists can equitably and safely share the public space of cities with motor vehicles.

Why a Safe System is needed in cities

Almost half of global road traffic fatalities and a large proportion of serious injuries occur on city roads and streets. Because of the diversity of road users in urban areas and their close physical proximity in city traffic, vulnerable users - pedestrians, cyclists, children and the elderly – are at particular risk (WHO, 2015).Thus, many major cities are grappling with extremely high rates of road traffic fatalities (see Figure 6.1). In some developing cities, more than 60% of those killed on the roads are pedestrians or cyclists (Mohan et al., 2015). The exposure of vulnerable road users to road traffic injury is likely to increase as both the population of cities and the number of vehicles within them grow.

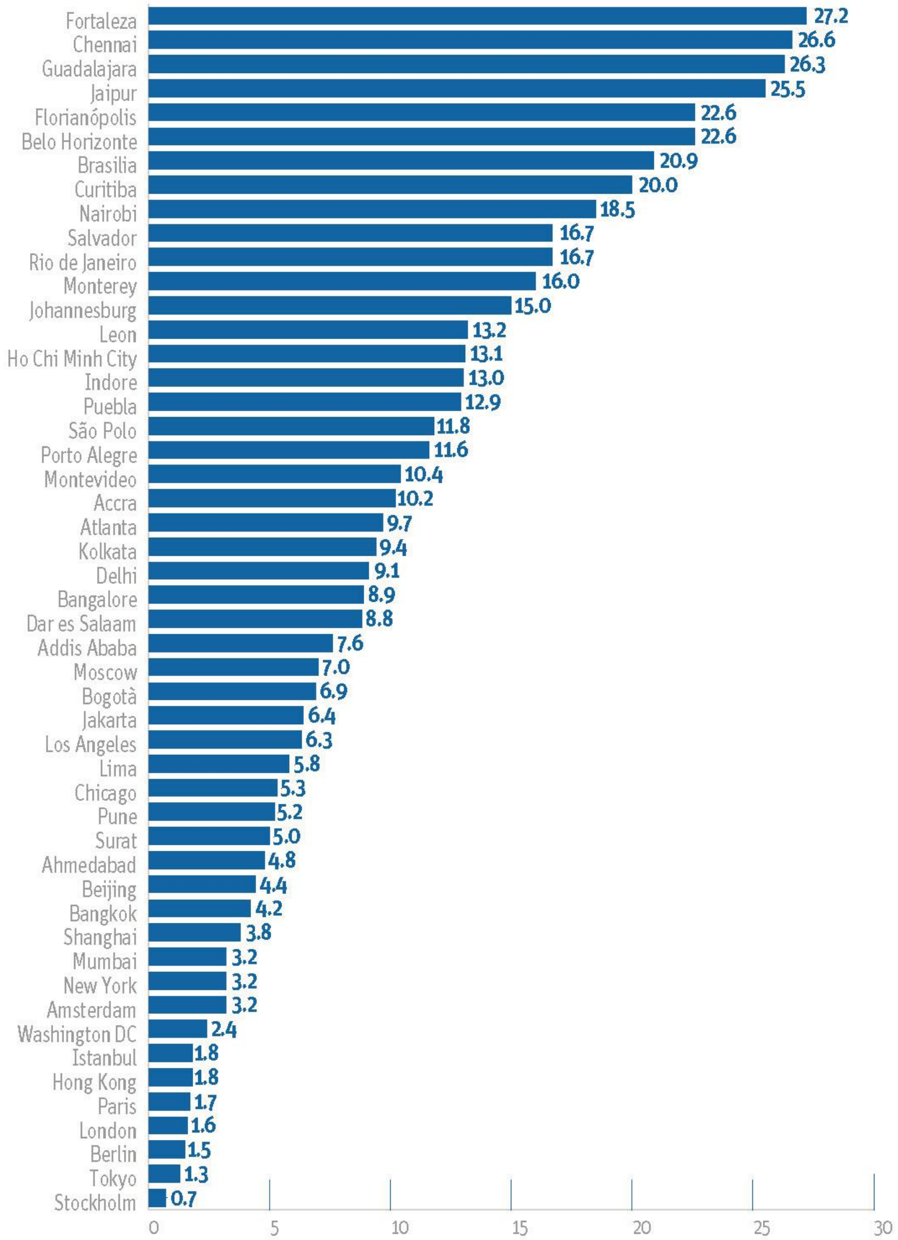
As a result of a mass migration that every week takes three million people from the countryside into cities in developing countries, the world's urban population of currently 3.7 billion is forecast to increase by another billion people by 2030 (WHO and UN Habitat, 2016). Even the population of major developed cities such as London or New York is still increasing steadily. Over the same period to 2030, global motorisation is predicted to grow from just over one billion vehicles today to 2.5 billion by 2030 (Sousanis, 2014) while land use taken up by urban development to accommodate these dramatic changes could double.

Shift in a society's age profile can also increase the number of vulnerable road users. Many high-income countries and cities are seeing a growing proportion of older residents with specific mobility requirements and exposed to specific risks. Meanwhile, urban sub-Saharan Africa is experiencing massive growth in its young population explosion. By 2050, the average age in Japan is expected to be 54 years, while in Nigeria it will be 21 years (PWC, 2015). The particular transport and road safety needs of both these age extremes call for Safe System policy and design solutions. In the words of former New York City Transport Commissioner, Janette Sadik-Khan: "Streets should be safe and simple to use no matter your age or ability. City residents should expect and demand streets safe for people who are eight or 80 years old."

For all these reasons there is increasing recognition that road safety needs to be a central focus when wider urban-planning decisions are being made. In addition to the road safety target included in the UN's Sustainable Development Goal (SDG) no. 3 (health), a specific target included the SDG no. 11 (cities): calls for "access to safe, affordable, accessible and sustainable transport systems for all, … with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons" (see https://sustainabledevelopment.un.org) by 2030. The Global Commission on the Economy and Climate (2014) has also highlighted the important role of policies for walkability and improving connections to mass transit for pedestrians and cyclists as part of a strategy for low-carbon cities, and warned of the negative impact for road traffic injuries when cities and their road networks are allowed to sprawl. This message is echoed by the Africa Progress Panel, led by former UN Secretary-General Kofi Annan, which has raised the alarm over rising road traffic deaths in sub-Saharan African cities.

Against this background, there is a growing recognition that Safe System thinking has an important role to play in urban land-use planning and mobility management. A major report on urban health published in March 2016 by the World Health Organization (WHO) and UN-Habitat as a contribution to the Habitat III process for a "New Urban Agenda", emphasised the Safe System as a strong framework for delivering lower speed limits, separated cycle lanes and improved pedestrian facilities. This call was echoed in a UN General Assembly resolution A/70/L.44 adopted in April 2016 which, "taking into account that the majority of road deaths and injuries take place in urban areas…", encouraged Habitat III negotiators "to give appropriate consideration to road safety and access to safe, affordable, accessible and sustainable public transport and non-motorised modes of transport, paying special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons in the future New Urban Agenda."

Figure 6.1. **Reported traffic fatalities per 100 000 inhabitants in selected world cities**

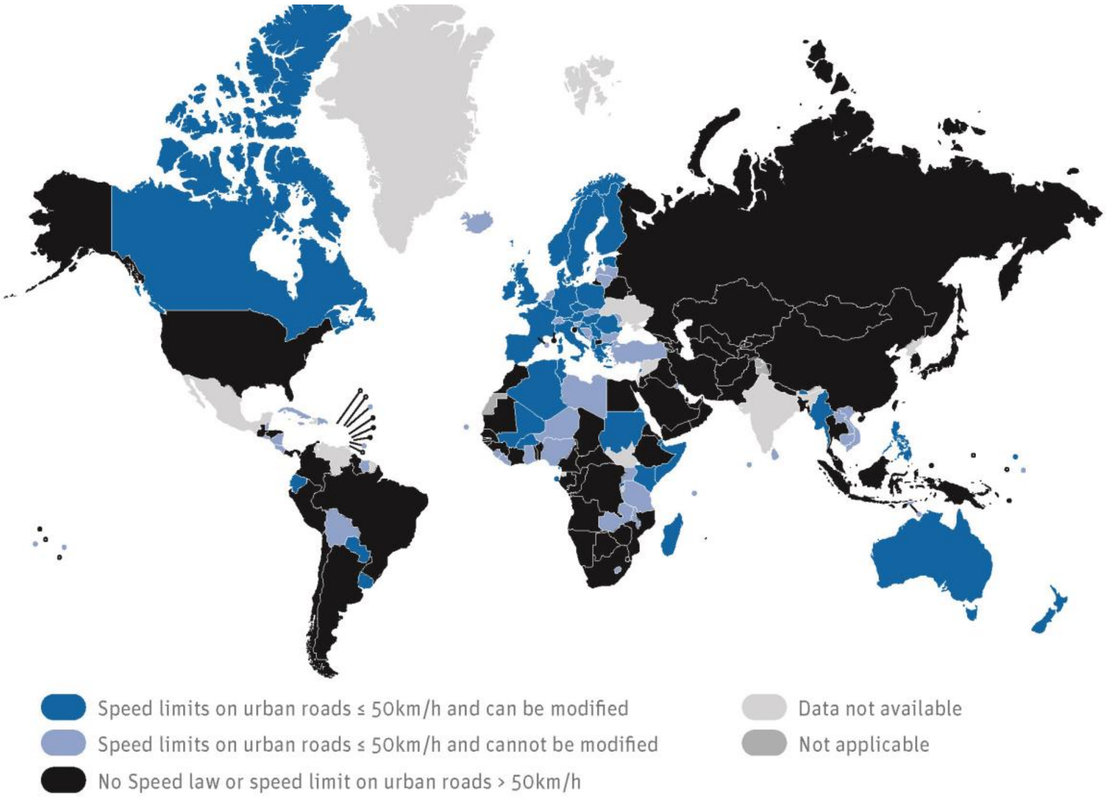


Key elements of an urban Safe System

Speed management, infrastructure and street design as well as vehicle regulations and technologies that protect occupants and pedestrians, can combine to deliver a Safe System in cities. Using speed policy to minimise the kinetic energy released in a road traffic collision is central to enabling a forgiving road environment. In urban areas, where motorised vehicles move in close proximity to pedestrians, cyclists and other vulnerable road users, this is particularly important.

The probability of an adult pedestrian being killed if struck by a car at less than 50 km/h is less than 20%, but this increases to almost a 60% if hit at 80 km/h. Yet, according to the WHO, only 47 countries (24 of them high-income), have currently meet best practice standards on urban speed management, which requires a national urban speed limit of 50 km/h and delegated power for local authorities to reduce the speed limit locally to ensure safe speeds. In developing countries, more than 80% of the roads surveyed by the International Road Assessment Programme (iRAP) that had a speed limit of 40 km/h or more and were used also by pedestrians do not have viable sidewalks. The combination of high vehicle speeds and inadequate pedestrian infrastructure is a recipe for disaster and high levels of urban traffic casualties - yet also pinpoints where huge improvements can be made, and quickly.

Figure 6.2. **Urban speed laws by country**



Source: World Health Organization, Global Status Report on Road Safety (2015).

Adopting a policy that inverts the traditional hierarchy of transport planning priorities (which placed motorists and their speed of movement at the top) and recognising the needs of non-motorised road users is a necessary first step to providing safety for all road users. This does not mean that Safe System policies are anti-car or anti-business. Rather they are “pro-people”, including the people in cars, who are often also walking, cycling, and travelling on a bus or metro. And they may find that improved street design and reduced overall speed actually can improve traffic flow, too. Most importantly these changes improve the urban form and the amenity of people living in these urban settings. Cities that are most effectively adopting a Safe System use speed management as the common denominator for a range of interventions.

Many cities are legislating for speed reductions. In the Americas, New York City campaigned for State approval to introduce a 25 mph (40 km/h) default speed limit as part of a holistic "Vision Zero" strategy (see Box 6.1), and São Paulo and Mexico City have recently adopted Safe System policies (see Box 6.2) with speed limit reduction as a core element. In Europe, London, Edinburgh and Cardiff are amongst other major British cities introducing widespread 20 mph (32 km/h) speed limits in urban residential areas that cover the homes of more than 15 million people. On the European continent, cities such as Paris or Barcelona have set 30 km/h speed limits for significant proportions of their streets.

Box 6.1. **Case study: The path to "Vision Zero" for New York City**

The evolution of road safety policy in New York City over a decade provides a case study of how a major and complex city builds support for and adopts the Safe System. Adoption of the PlaNYC strategic plan for sustainability by Mayor Michael Bloomberg in 2007 led to a fundamental reappraisal of traffic management, street design and road safety policy. In the NYC Department for Transport's 2008 strategic plan a target was set to halve road traffic deaths by 2030, from 270 to 135. A study by the city in 2010 reviewed 7 000 serious injuries and undertook an in-depth analysis of how, where, when and why these crashes and casualties had occurred. This study highlighted the need to improve safety along corridors rather than just at intersections (where it had always been assumed that most injuries occurred), and prompted re-design of streets up to block-length. As a result, fatalities fell by 34% in locations which had been remodelled. On streets redesigned to include protected cycle lanes, injuries for all road users fell by 43%. The Bloomberg administration thus demonstrated that safer street design is feasible at low cost, and that dangerous expanses of road space can be transformed into places for people complete with seating and tables, with a little paint and a few plant pots. Thus began a cultural change that went beyond simply road safety measures. In 2013, Mayor Bloomberg's successor Bill di Blasio took a further step by announcing that New York City would adopt a "Vision Zero" road safety strategy and aiming for zero fatalities on its streets by 2024. Mayor di Blasio set out his agenda as follows: "The fundamental message of Vision Zero is that death and injury on city streets is not acceptable, and that we will no longer regard serious crashes as inevitable."

A permanent Vision Zero task force was established. A successful legislative campaign at State level gave New York City the right to reduce the default speed limit to 25 mph (40 km/h). A co-ordinated multi-agency effort was launched with advertising campaigns and police activity targeting raising awareness and enforcement of risky driving behaviours. Further street modifications were also undertaken: By the end of 2014, fifty new street design improvements, 25 arterial slow zones, eight new neighbourhood slow zones, 250 speed bumps, 20 new speed cameras, and several miles of new cycle lanes. Going further, injury surveillance and data management was improved by, inter alia, closer collaboration between the Department of Transport and the city's Department of Health; and a review of available vehicle safety technologies launched. In the second year of Vision Zero the city added a further 80 street improvement projects. Of these, 60 targeted priority locations identified in the Vision Zero Borough Plans. At traffic lights, a total of 417 leading pedestrian intervals were installed to give pedestrians a head start crossing streets. An additional 12.4 miles of new protected bike lanes were built. On the enforcement front, New York police officers issued nearly 40 000 failure-to-yield penalties (nearly triple what had been issued annually in 2011 to 2013) and more than 134 000 speeding tickets (a 75% increase). In two years 2014 and 2015, almost 1.5 million speeding ticket were sent to drivers caught by speed cameras. In locations with fixed cameras, speeding declined by 50% on average.

While it is too early for definitive results confirming that New York is on a pathway towards zero road deaths, the signs are encouraging. Road traffic fatalities in the city fell to their lowest ever (231) in 2015. Pedestrian deaths in New York City fell by 27% compared with levels before the introduction of Vision Zero in 2013. The efforts of both the Bloomberg and di Blasio administrations have been characterised not least by intensive outreach to the city's different communities and broad consultation to explain policies, secure feedback and build sustained support. New York City's 2016 Vision Zero plan builds on this community support to maintain the momentum.

But many of these cities also recognise that while enforced speed limits are an important weapon in the armoury, a genuinely Safe System relies on more than education and enforcement to cut speed; it nudges, guides and leads road users into a self-explaining zone of safety where the physical parameters are designed to prevent serious injury. As Transport for London points out in its 2020 strategy document, "Safe Streets for London", which articulates an ambition "…to work together, towards roads free from death and serious injury" with an initial target of a 40% reduction in those killed and seriously injured. "Those responsible for delivering road safety in London must strive to accommodate and protect all road users from the impact of human error and unpredictability, as well as seek to minimise it […]. This requires innovative thinking about the full range of possible interventions, including developing a safe road infrastructure, improving vehicle safety and reviewing speed limits to reduce unacceptably high injury risk."

Box 6.2. **Case study: São Paulo and Mexico City - pioneer cities on the Safe System frontier**

Two Latin American megacities which have set ambitious goals to change urban mobility culture and dramatically reduce road traffic injuries are São Paulo in Brazil and Mexico City.

In 2013, Mayor Fernando Haddad of São Paulo introduced the Life Protection Programme (PPV), which focuses on making roads safer for all users, starting with the most vulnerable. As part of PPV, the city has reduced speed limits citywide, introduced diagonal pedestrian crossings, built new cycle lanes and created pedestrian-only zones. Besides reducing speed limits on major arterial roads, the city also implemented eleven "Areas 40" in quarters with high pedestrian and commercial activity. In an Area 40, the maximum speed is now 40 km/h on selected streets. The first Area 40 to be implemented, known as "Centro", recorded 71% fewer road fatalities and injuries after the new limits were adopted.

Road deaths in São Paulo have declined, by 20.6% overall from 2014 to 2015. This represents 257 lives saved. Cyclist fatalities dropped by 34% (from 47 to 31) and the number of pedestrian deaths by 24.5% (from 555 to 419). The number of fatally injured car occupants also declined, albeit less markedly, by 16.9% (from 207 to 172), as did the number of motorcycle deaths (-15.9%, from 440 to 370). Nevertheless, the measures introduced by Mayor Haddad have met significant opposition from businesses and motorists. They are supported by road safety and pedestrian NGOs, and these, in addition to international partners such as the World Resources Institute and the Institute for Transportation and Development Policy, are actively promoting positive results achieved under São Paulo's Safe System initiative.

Mexico City reports approximately 1 000 road traffic fatalities each year, which is around half the annual road deaths for all of the UK. Change is thus urgently needed. In 2015, Mayor Miguel Mancera announced a new Vision Zero policy aiming to improve safety for pedestrians across the city, following many years of advocacy by civil society organisations. Mexico City's Vision Zero establishes a range of road safety measures to protect and prioritise pedestrians and initially targets a reduction in pedestrian deaths by 35%.

The new policy is underpinned by a revision of traffic safety regulations, the "Law of Mobility", which formally establishes pedestrians at the top of the traffic system hierarchy. This translates into pedestrian now having the right of way at all intersections. Specific measures include reducing maximum speeds on primary urban roads from 70 km/h to 50 km/h, improving intersection design and introducing traffic-calming measures. The city's efforts are also being supported by international partners including the World Resources Institute and a partnership of the International Traffic Safety Data and Analysis Group and the International Automobile Federation (FIA) that supports traffic data management in Latin American cities.

Design of urban public space sends signals to users. Wide, multi-lane boulevards tell drivers that high speed is possible. Side streets with no traffic calming encourage their use as rat-runs. Re-allocating street space - for example by removing a lane of traffic to create a separated cycleway, providing wider sidewalks, introducing curb extensions or breaking up wide streets with pedestrian islands - reduces the encouragement and physical opportunity for high vehicle speed. Understanding how pedestrians and cyclists move, or would like to move, around cities is crucial to formulate policies that will harness design for safety and secure public acceptance and support. Observing and recognising the “desire lines” along which people intuitively make journeys and co-opting this reality into street re-design can create safer and more harmonious travel for all road users (Sadik-Khan, 2016).

Figure 6.3. **Space reallocation in a neighbourhood street**

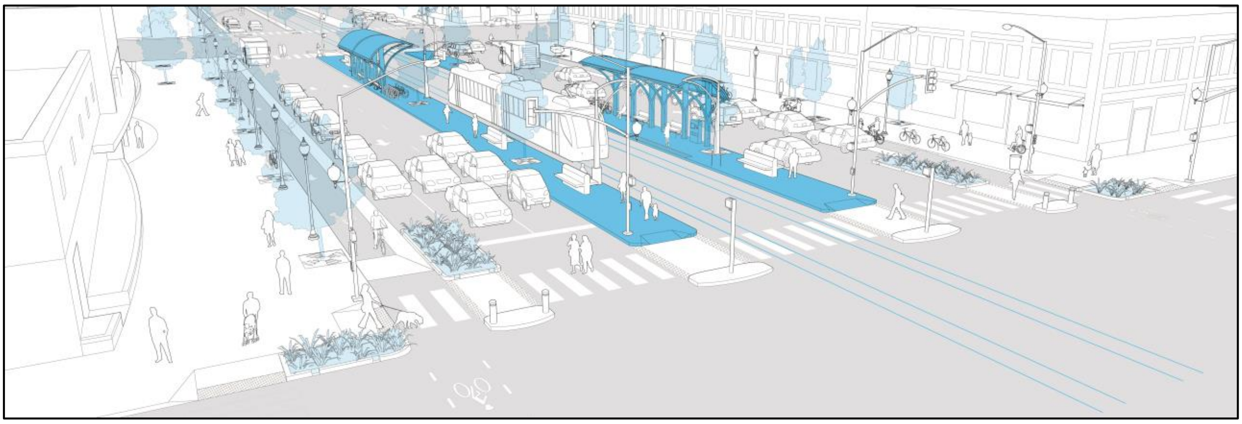
Space reallocation in a neighbourhood street adds facilities for walking/cycling and calms traffic.
Source: National Association of City Transportation Officials (NACTO).

Within the urban policy toolbox, design elements for safe urban travel include improving arterial roads through speed management, provision of pedestrian and cyclist facilities including traffic islands and cycle lanes, shorter blocks, frequent safe crossing points and consistent layout; traffic calming measures in side streets and residential streets such as speed humps, chicanes and chokers that reduce speed and enable safe pedestrian movement; a network of connected, separate cycle lanes; and safe access to mass transit (Welle, Lui et al., 2015). Many of these design changes are relatively cheap to implement and applicable for the streets and traffic situations of towns and cities across the world.

There is growing evidence that a city’s overall attitude to how public space is used, and in particular how pedestrian and cyclist access and movement is accommodated, can have a strong impact on road traffic casualties. Prioritising the provision of attractive and accessible pedestrian space, including parks and public plazas, large and small, and allocating street space alongside sidewalks to cycle lanes demonstrates that a city cares about its pedestrian visitors (including those who may have arrived by car) and can show that there are both safety and economic benefits to such an approach. In the United States, the National Association of City Transportation Officials (NACTO) is spearheading the practical adoption of new design approaches by city road engineers and advocating for urban street design as a core element of a Safe System. And an increasing number of cities in the US are re-visiting planning decisions from the 1950s and 1960s, for example by de-commissioning multi-lane flyovers or converting their use to walking and cycling.

Reducing the number and length of vehicle trips through city planning that brings shops and services closer to communities; and encouraging modal shift from the private car to mass transit or non-motorised travel, can reduce exposure to road traffic crashes. Yet a shift to public bus transport, bus rapid transit (BRT) or light rail is not in itself a panacea. Mass transit must be designed to be safely accessible to pedestrians – most mass transit journeys begin and end with walking – and service providers must be well-regulated and supervised. Target 11.2 of the UN Sustainable Development Goals can be an important driver for a holistic approach that encapsulates the provision of public transport as well as an emphasis on accessibility. Barriers to access of public transport, such as cost or security, particularly for women, must also be addressed.

Figure 6.4. **A redesigned transit corridor**



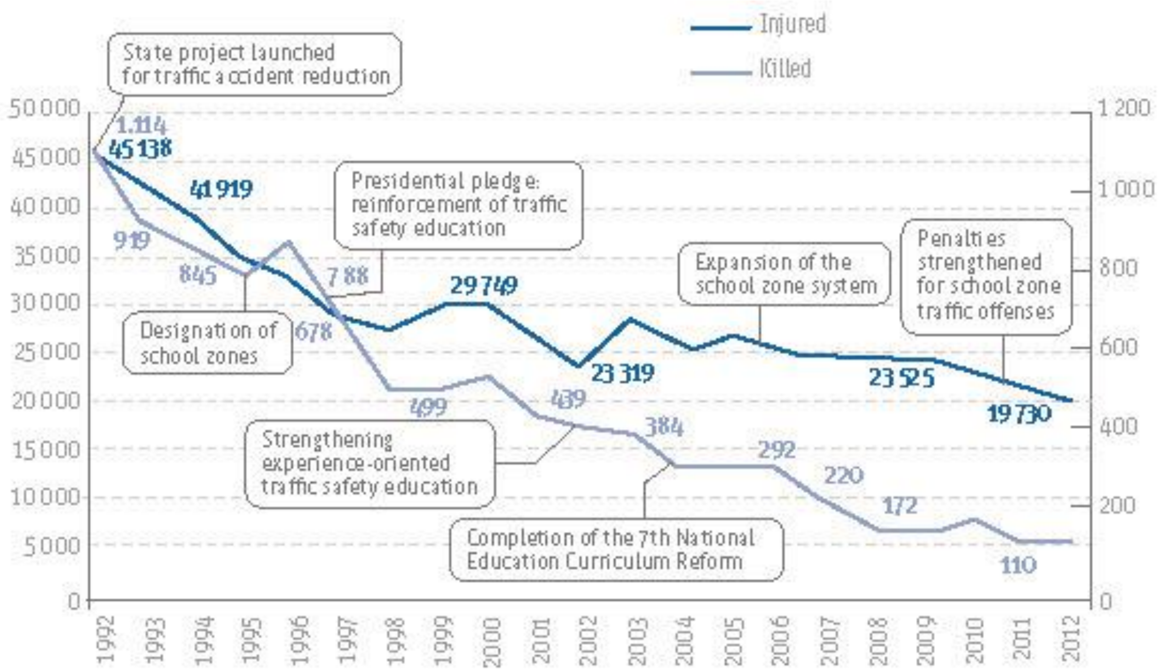
A redesigned transit corridor provides safe access to pedestrians and public transport users.
Source: National Association of City Transportation Officials (NACTO).

In an urban Safe System, vehicle safety has an important role to play. A combination of all vehicles meeting five-star NCAP safety performance and urban speed limits below 50 km/h would eliminate almost all fatalities and serious injuries for vehicle occupants in cities. In this context; governments should also adopt the UN technical regulations relating to pedestrian-friendly design of vehicle fronts, which can reduce injury severity for pedestrians at lower speeds. New active safety technologies, particularly Autonomous Emergency Braking (AEB), can take critical fractions of kinetic energy out of a collision or avoid the crash altogether. While many policy makers and commentators are mesmerised by a possible future urban utopia of autonomous self-driving vehicles, these life-saving technical regulations and technologies are available now and should be adopted much more widely and quickly. At city level large fleet procurement managers, such as city authorities and major employers, could take a lead in requiring purchase of vehicles that meet a pedestrian-friendly performance standard for both passive and active safety.

Ultimately, the test of a Safe System is how well it works for its youngest, oldest and most vulnerable users. Streets safe for children are a priority, and often a starting point, for cities embarking on the journey to a Safe System. Safe-routes-to-school programmes are localised micro-Safe Systems already existing in many cities. They are effective, widespread and popular, often well-funded, and can be a useful point of reference for urban authorities looking to establish a fully-fledged Safe System. For cities that are already implementing it, safe school zones remain an important part of the overall strategy.

The achievements of South Korea demonstrate how a focus on safe routes to school can drive wider change. The country managed to achieve a most remarkable 95% reduction in road traffic fatalities for children under the age of 14 between 1988 and 2012 (see Figure 6.5). At the core of this success is traffic speed reduction and management, through a combination of street redesign, traffic calming and strict enforcement of speed laws. The latter include mandatory prosecution of drivers involved in crashes within designated school zones and the doubling of fines for traffic violations within these zones. The strategy has also included regulatory interventions in school transport, support for civil society advocates, sustained awareness raising and adoption of new or expanded objectives as targets are reached. South Korea's results should provide an inspiration for other countries grappling with high road traffic injury rates.

Figure 6.5. **Child road casualty trends and related policies in Korea**



Source: KOTI.

As older people become a larger proportion of the population, particularly in developed economies, a Safe System must also be designed to anticipate and accommodate their needs. Because of physiological change associated with ageing, seniors are more likely to suffer serious injury (such as fractures) even in lower-impact crashes. Limiting vehicle speed, reducing the width of pedestrian crossings (e.g. through pedestrian islands) and extending crossing time through smart traffic signalling are all ways to make journeys on foot safer, less stressful and more enjoyable for elderly people. Safe, accessible and well-lit transit design is also vital.

Building political support and delivering a Safe System city

As a growing number of cities are adopting ambitious targets to reduce traffic casualties and seek to realise them with Safe System policies, what are the common ingredients that these agenda-setters share?

Firstly, political will and leadership is vital. Mayors who provide a clear statement of intent, who prioritise a Safe System within their administrations and who continue vocally to support and explain implementation even when measures run into fierce opposition, are the most important success factor.

Strong civil society pressure, particularly from NGOs representing road traffic victims, can help political leaders to take the step to adopting a Safe System and provide reinforcement as policies and strategies are rolled out. Former New York City's former Transport Commissioner Janette Sadik-Khan, for instance, acknowledges the important role played by pressure group Transportation Alternatives in both spurring and enabling sometimes controversial street design changes.

Secondly, data drove the decisions to adopt a Safe System, and is also proving integral to effective delivery – as illustrated by the example of New York City. Other cities have made the same experience. In Gothenburg, Sweden, it was data on pedestrian and cyclist crash injuries which kick-started a road safety step-change that resulted in a 75% reduction in such injuries (see Box 6.4). In Edmonton, Canada, it was also data on comparatively high fatalities that provided the motivation to act (see Box 6.5). On the implementation side, some cities for instance in the UK and Italy, are using data-driven tools such as the WHO's Health Economic Assessment Tool (HEAT) analysis to build a case for investment in walking and cycling infrastructure. In France, local road traffic injury data collection is an essential requirement of holistic Sustainable Urban Mobility Plans (SUMPs) and is guiding policy change which - while not necessarily explicitly adopting a Safe System vision, delivers Safe System objectives through speed reduction, prioritisation of pedestrians and cyclists, and investment in public transport (see Box 6.3).

Box 6.3. **Case study: Delivering Safe System policy through Sustainable Urban Mobility Plans in France**

In France, the provisions of the Solidarity and Urban Renewal Act (Loi SRU 2001) have made safety of transportation one of the main concerns of French Sustainable Urban Mobility Plans. The objective is to produce a well-balanced transport system placing particular emphasis on walking, cycling and public transport that is safe for all users. Taking account of safety in this way serves a dual objective of reducing the number and seriousness of road traffic crashes and of facilitating the introduction of other policies developed within the SUMP, such as equitable road-sharing and the development of active transport modes.

Initiatives to make motor vehicle traffic less aggressive for other users of the public space aim to change the role of cars and reduce crashes. In order to achieve this, the Urban Mobility Authority (AMU) must endeavour, through consultation, to understand safety problems within its jurisdiction, in particular by examining failures in the relationships between urban planning, transportation and development likely to lead to injury situations. In seeking greater coherence between town planning and transportation, local actors have a chance to tackle fundamental issues underlying safety problems in the whole of the urban area and to produce a transport system that is properly suited to the physical capabilities and vulnerabilities of all users.

In the SUMPs, French urban mobility authorities (conurbations of more than 100 000 inhabitants) are required to create a road accident observatory so that they integrate road safety under their field of responsibility. Knowing their own data, they can run studies, set road safety targets, take decisions on land use and changes in the transport system and evaluate performance (the SUMP is required to be updated every five years).

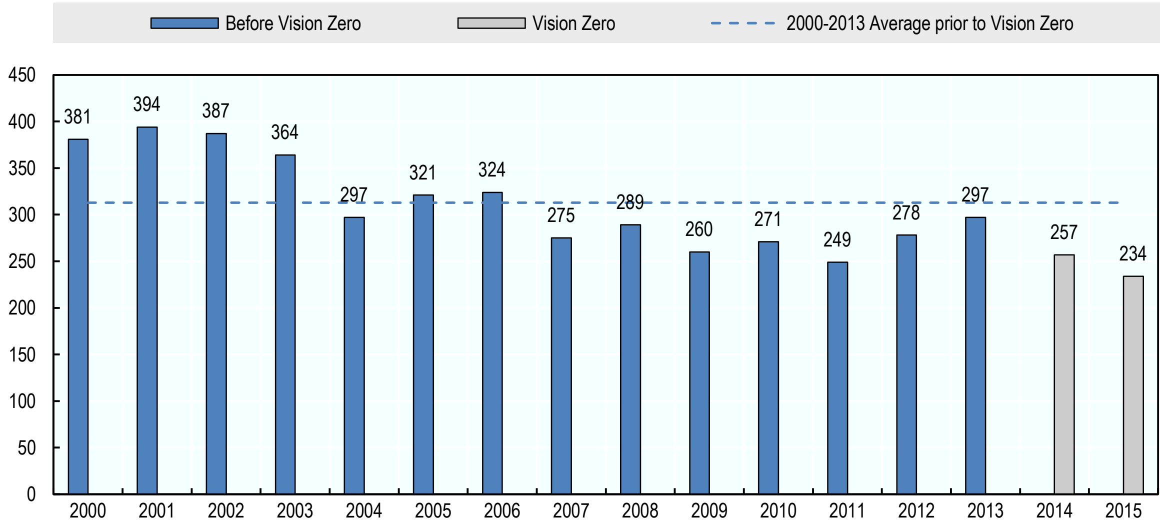
Lille Métropole, for example, included a target that no pedestrian should be killed by the end of its latest five year SUMP, and to achieve this has adopted many objectives common with the Safe System approach. Grenoble has implemented a default 30 km/h city speed limit as part of its SUMP. Many cities are using these urban mobility plans to effectively advance, step-by-step, towards a Safe System.

The use of star ratings for walking and cycling infrastructure awarded by Road Assessment Programmes (RAP) has proved useful to define targets as well as guide design concepts and speed management decisions in cities around the world. In Vietnam's capital Ho Chi Minh City, for example, pedestrian star ratings are guiding safety decisions around public transport hubs. In Mexico and South Africa, star ratings for schools are helping to ensure that school children's daily journeys are three-star or better in terms of road safety. The CycleRAP initiative being delivered in the Netherlands by the Dutch

Automobile Association ANWB and the Institute for Road Safety Research (SWOV) captures the needs and benefits of off-road facilities. Targeting five-star ratings for these user groups in urban environments provides one mechanism to deliver Safe System outcomes in cities.

Data about the impact of interventions is vital to prove the measures work and to lay the foundations for the next steps. With hard data, New York City was able to demonstrate significant reductions in casualties against the national trend as a result of its “Vision Zero” (see Table 6.1). In Colombia’s capital city Bogotá, policy makers and transport planners were able to show that twenty years of investment in bicycle lanes has increased the share of cycling from 0.6% to 6%, while at the same time reducing cycling fatalities by 47%. Similar stories can be told in cities from Copenhagen to Portland, Oregon. Success breeds success, encourages new political champions, and creates an environment in which establishing a Safe System becomes possible.

Table 6.1. **Annual road deaths in New York City before and after Vision Zero**



For cities seeking technical advice in establishing an urban Safe System there is a growing support community of practitioners providing technical advice and policy support. In the United States, NACTO is building on experiences in New York and other cities to provide mentoring and organisation across the country, and increasingly internationally. Its practical guides on urban street design, urban cycleway design and urban transit design will be complemented in 2016 with a *Global Street Design Guide*, part of the Global Designing Cities Initiative, supported by Bloomberg Philanthropies, which builds on experiences in more than 40 cities around the world. The handbook *Cities Safer by Design: Guidance and Examples to Promote Traffic Safety through Urban and Street design* from the World Resources Institute similarly provides practical advice on implementing Safe System street design, from arterial multi-lane carriageways to traffic-calmed home zones. The recommendations from these organisations are now being road-tested in low- and middle-income cities, both as part of the Bloomberg Global Road Safety Initiative and through the Global Initiative for Child Health and Mobility supported by the FIA Foundation.

National or regional governments that have adopted a Safe System are recognising that their cities are key proving grounds. In Sweden, for example, the national government is providing financial incentives to encourage cities to implement Safe System policies. Municipal authorities can receive up to 50% funding for Vision Zero projects. In Australia, the state of Victoria is working closely with a Melbourne metropolitan authority to deliver an ambitious plan to create Australia’s first “Towards Zero” municipality (see Box 6.6). Victoria is making a significant investment with the objective of inspiring other municipalities and cities to take on the challenge. And the goal is achievable.

A 2014 study analysing road deaths in towns and cities across Europe with populations of more than 50 000 found that 16 towns had experienced no road traffic fatalities over a period of five years (Dekra, 2014). Further analysis of even larger towns in Europe, Japan and the US found that many have gone a whole year without a single fatality. While these results may not be the consequence of deliberate Safe System policies, they do show that becoming a genuine "zero deaths" city is not science-fiction and is within reach for many urban areas. Such examples should provide inspiration to adopt the Safe System in town after town. Living next door to a "towards zero" district is the best encouragement to become one.

The best support networks for cities are cities themselves. Across the United States, other cities are following the lead of New York (see Figure 6.5) in adopting Vision Zero strategies and working together as part of a Vision Zero Network. Boston's Mayor Martin J. Walsh has committed his city to working towards eliminating death and serious injury by 2030. In Los Angeles, Mayor Eric Garcetti has set a target of achieving zero deaths by 2025. Both strategies are underpinned by detailed multi-agency plans, funding and regular progress reports to the public. These three cities and eight other Vision Zero "Focus Cities" have agreed to collaborate at senior management level, including representatives from Mayor's offices, police, transport and health departments, with regular engagement with advocacy groups. Although, at time of writing, there are questions about whether all of these cities are fully committed to implementation of a Safe System, there is certainly positive momentum coalescing around the principle that nobody should be killed or seriously injured in an urban road crash. The extent to which this principle is backed up by genuine and sustained Safe System policies will determine the effectiveness of the nascent US Vision Zero movement.

Box 6.4. **Case study: Building on data to create a Safe System for Gothenburg**

In the mid-1990s, Gothenburg was regarded one of the worst cities in Sweden in terms of its road safety. A particularly large number of car crashes incidents with trams filled the police reports. An investigation was launched by the city's road works department, largely driven by a single official. At the same time, a physician at a Gothenburg hospital noticed that many patients hospitalised after being hit by cars has sustained similar injuries. He started to systematically study and survey these injuries and their causes.

Then these two advocates learned about each other's preoccupation. They connected and started a unique co-operation to gather knowledge about traffic injuries and linking it to information from the police about where, when and how the crashes had occurred. The result was a map-based information system detailing traffic crashes and injuries in Gothenburg.

The hospital records added new and valuable data on who was injured and in what type of collision. This information showed a pattern of many single crashes involving pedestrians and bicyclists, which were mostly unknown to the police. The analysis also clearly revealed that speed was of great importance for the injury, thus laying the seeds of a strategy to reduce speeds on streets and at crossings where pedestrians and bicyclists interacted with cars, buses and trams.

With data on injury and crash types mapped across the city, it became possible to retrofit the sites where most crashes with injuries occurred. In some cases, the whole street was rebuilt to make it self-explaining and support the suitable speed. This was costly, and many streets needed to be retrofitted. As the data showed that many incidents occurred when pedestrians crossed to and from bus and tram stops, such sites could be prioritised, while on other streets simper speed calming measures, for example raised pedestrian- and bicycle passages, were implemented.

At the same time, Gothenburg put a lot of effort into expanding the network of bike paths. These were designed to separate bicyclists from cars and buses to increase safety. Furthermore the crossings between these bicycle paths and streets were speed-secured. The introduction of small, cost effective speed bumps in residential areas achieved low speeds in larger areas and not only in crossings.

Hospital records showed the success of these initiatives: over a period of 15 years, the number of injured pedestrians and cyclists on the streets of Gothenburg decreased by 75%. Evaluations have shown that speed calming measures have been the most important contributing factor to the injury reductions. Moreover, it has been shown that such measures are good investments, with a high return of investment of factor 22. Perhaps even more important is that children are much more likely to play outside in areas with speed calming measures.

In preparation of a new road safety programme for 2010-20, an analysis done over the past two decades identified the following success factors:

- **Take decisions based on reality**. Crash data from the police is valuable but the knowledge about injuries from hospitals is crucial.
- **City officials and politicians are knowledgeable and committed**.
- **Set targets to strive for.** Targets trigger resources, commitment and management.
- **Work systematically, monitor, measure, follow up and adjust** in order to use the resources effectively.

In the case of Gothenburg, a dramatic improvement in road safety began when two individual driving forces met and merged their knowledge. Additional important knowledge was obtained from the hospitals, which is used when developing Vision Zero treatments for implementation in current priority areas and then in new areas.

Box 6.5. **Case study: Edmonton's pathway to adopting a Safe System**

Driven by a Mayor's Task Force on Traffic Safety, the City of Edmonton established a municipal Office of Traffic Safety (OTS) in 2006 to address its rate of fatal and injury collisions, the highest of any major Canadian city. OTS works closely with traffic safety stakeholders in a collaborative, integrated process to reduce motor vehicle collisions in Edmonton. This approach resulted in a 55% reduction in injury collisions over the period 2006 to 2014.

The OTS utilises an evidence-based approach which identifies leading practices in traffic safety, supports research and evaluation, and drives continuous improvement through performance metrics such as lag and lead indicators (Tjandra and Shimko, 2016). Several ongoing initiatives support this approach including an annual International Urban Traffic Safety Conference, the establishment of an Urban Traffic Safety Engineering Research Chair and the extensive use of data, data analytics and predictive analytics. This progressive, systemic approach identified Vision Zero and the Safe Systems Approach as the next iteration of Edmonton's Road Safety Strategy, which was approved by Edmonton City Council in 2015.

Through the adoption of the Safe Systems Approach, Edmontonians immediately benefit from an ethical vision for traffic safety. The established, Safe Systems principles and practices take into consideration all road users, support targets, and a pathway to Vision Zero. As the first Canadian city to approve Vision Zero, Edmonton joins other major global cities in becoming the engine for Safe Systems implementation in an urban environment.

Box 6.6. **Case study: Creating Australia's first "Towards Zero" municipality**

Mornington Peninsula Shire (MPS), located in the outer metropolitan area of Melbourne, Australia, has made the commitment to becoming a "Towards Zero" municipality, as it strives to eliminate death and severe injury from its roads. In part, this entails endeavouring to become the safest municipality in Victoria. MPS constantly seeks new, improved ways of protecting residents and visitors from death or severe injuries when using the Mornington Peninsula roads.

The Shire's initiative enjoys a high level of in-principle support from Victoria's road safety agencies, including Victoria Police, VicRoads and the Transport Accident Commission, mainly because of the substantial safety benefits expected. Large, long-term reductions in deaths and serious injuries will be realised for all users of the Shire roads. Walking and cycling will be possible at much lower risk than today and the needs of youth, older residents and the mobility-impaired will be prioritised. A major thrust of the initiative will involve working in close partnership with Victoria's road safety agencies to implement Safe System-aligned infrastructure and speed management measures, as part of Victoria's AUD 1 billion Safe System Road Infrastructure Program (SSRIP). Demonstrations of innovative, best-practice traffic safety concepts will be a feature.

Residents, businesses and visitors to the Mornington Peninsula are expected to benefit in additional ways: strengthened strategic network planning and implementation processes; excellence in meeting community expectations; conditions for improved population health, by better supporting active transport; reduced carbon footprint; and townships to steadily become even better places to shop, conduct business, work, dine and simply enjoy. Overall, the initiative aims to create safer and more liveable urban and rural communities in the Mornington Peninsula. The "Towards Zero" commitment by MPS is believed to be the first of its kind in Australia. To initiate the process, collaboration with Victorian road safety partners is underway to:

- Ensure that future community consultation builds on Victoria's new Towards Zero vision and aligns well with state-wide communications on road safety.
- Identify problematic road environments, ranging from high- and low-density populations centres, with demand for local walking and cycling, to high-speed rural routes with a record of high severity crashes.
- Identify projects that can be implemented under SSRIP or other funding schemes. This involves a strong focus on trials and demonstrations of innovative design forms with the potential for widespread application in other parts of the municipality and elsewhere in Victoria.
- Share with other leading municipalities special expertise and experience in the same or similar safety challenges facing MPS.
- Review and strengthen MPS's fleet management practices as well as the delivering of transport services by the municipality
- Identify opportunities to enhance the effectiveness of local road policing.
- Identify obstacles to optimum post-crash response and opportunities to improve emergency response on the Peninsula.
- Embed the Safe System philosophy into all relevant areas of municipal business, in order to extend the potential safety gains.
- Develop a comprehensive MPS "Towards Zero" vision, to be reviewed periodically and continually strengthened with new ideas and opportunities.
- Identify and pilot new behavioural initiatives and strengthen existing behavioural programmes.

Last but not least, Mornington Peninsula Shire hopes that it will inspire other municipalities to also take up the challenge of eradicating road deaths in their area of responsibility.

Conclusion

The world's cities are where the 21st century will be defined. By 2050, fully 70% of the world's population will live in cities, and the economic, environmental and social future of the planet will be forged in the urban space.

It is in cities that the battle against climate change will be won or lost. This is why the urban liveability agenda is assuming such salience, and it is why – for transport and urban planning policy makers, even beyond the core road safety community – a Safe System is of growing relevance. A Safe System helps us answer important questions about how we live together in increasingly crowded and vibrant cities; how we better share limited public space and resources; how we rationalise our mobility and move towards lower or zero-carbon transport; how we care for the ever growing numbers of both elderly and young in the maelstrom of a rushing, fast-changing world.

Urbanisation, and the quality of life expectations of a growing middle class, provides an imperative for city authorities to re-imagine urban mobility and how we travel to essential or entertainment services, how city economies flourish, how our children grow to healthy independence. This re-imaging begins with our streets, the arteries and capillaries of the city. For advocates of a Safe System, it is a tremendous and exciting opportunity.

References

Africa Progress Panel (2015), *Power, People, Planet: Seizing Africa's Energy and Climate Opportunities. Africa Progress Report 2015*, accessible at: http://www.africaprogresspanel.org/wp-content/uploads/2015/06/APP_REPORT_2015_FINAL_low1.pdf

Ake-Belin, M. (2016), "Vision Zero Cities", in *International Journal of Traffic Safety Innovation*, Issue 1, March 2016. http://visionzerocities.org/

Dekra (2014), *European Road Safety Report 2014: Urban Mobility*, Stuttgart. Accessible at: www.dekra.pl/Content/Uploads/RSR_2014_Urban%20Mobility_ENG.pdf

Dimitriou, H. T., and R. Gakenheimer (2012), *Urban Transport in the Developing World*. Edward Elgar Publishing Ltd.

Global Commission on the Economy and Climate (2014), *The New Climate Economy: Better Growth, Better Climate*. http://newclimateeconomy.report/2014/

International Organization for Migration (2015), *World Migration Report 2015*. www.iom.int/world-migration-report-2015

Mohan, D., G. Tiwari and K. Bhalla (2015), *Road Safety in India: Status Report*, Indian Institute of Technology, Delhi. Accessible at: http://tripp.iitd.ernet.in/road_safety_in_India_status_report.pdf

NACTO (2013), *Urban Street Design Guide 2013*, National Association of City Transportation Officials, Island Press.

New York City Department of Transportation (2016), *Vision Zero Year Two Report*. Accessible at www.nyc.gov/html/visionzero/assets/downloads/pdf/vision-zero-year-two-report.pdf

Price Waterhouse Coopers (PWC) (2015), "Demographic and Social Change", http://www.pwc.co.uk/issues/megatrends/demographic-and-social-change.html (accessed 22 April 2016).

Sadik-Khan, J. and S. Solomonow. (2016), *Streetfight: Handbook for an Urban Revolution*, Viking.

Tjandra, S. and G. Shimko (2016), "Key Performance Lagging and Leading Indicators for Traffic Safety Improvement: Case Study of the City of Edmonton, Alberta, Canada", in *Journal of the Institution of Transportation Engineers* (ITE), Vol.86/4, April 2016.

Transport for London (2013), Safe Streets for London: The Road Safety Action Plan for London 2020. http://content.tfl.gov.uk/safe-streets-for-london.pdf

WHO and UN Habitat (2016), *Global Report on Urban Health: Equitable, Healthier Cities for Sustainable Development*. www.who.int/kobe_centre/measuring/urban-global-report/en/

WHO (2015), *Global Status Report on Road Safety,* 2015. www.who.int/violence_injury_prevention/road_safety_status/2015/en/

World Resources Institute (2015), *Cities Safer By Design: Guidance and Examples to Promote Traffic Safety through Urban and Street Design*. www.wri.org/sites/default/files/CitiesSaferByDesign_final.pdf

Chapter 7. Conclusions and recommendations for leaders

This chapter sums up the main lessons learned from the experience of pioneering countries on how to move from conventional road safety policies to a Safe System. It argues that the ambitious improvements in fatality reduction targeted by the international community can only be achieved with such a paradigm shift, which takes as its starting point the premise that no human being should have to lose his or her life in a road crash.

Leadership for a paradigm shift in road safety

In the history of human endeavour, substantial change has not come about without the vision and leadership of people who rallied others to make things happen. The paradigm shift in the way road safety is approached and the transformational changes in policy and practice necessary for a Safe System require visionary and sustained leadership.

In 2008, the International Transport Forum published *Towards Zero: Ambitious Road Safety Targets and the Safe System Approach.* This report was the first major international report to recommend “that all countries, regardless of their level of road safety performance, move to a Safe System approach to road safety”. It articulated the need for a fundamental shift in road safety policies based on the principle that any level of serious trauma from road crashes is unacceptable.

This report builds upon the *Towards Zero* report. It shares the experiences of countries that have embarked upon journeys using the principles for a Safe System to guide their thinking, their policies and their actions in pursuit of the ultimate prize of achieving zero road deaths and serious injuries. Most countries, cities, jurisdictions that have embarked on this journey are finding it difficult to shift the paradigm toward Safe System thinking and practice. They have learned that it is a transformational experience and a substantial change management challenge. Prevailing views on road safety are strongly established among road sector professionals and the wider community. There are persistent awareness and understanding deficits among professionals, in communities and the public at large that act as barriers. Specifically, there is:

- **A lack of public awareness of the magnitude of the road trauma problem**. The daily count of deaths and serious injuries on roads remains largely invisible. Only major incidents galvanise public opinion and political action from time to time.

- **A low perception of the real dangers and individual risk of crashes among road users.** “I am a good driver, it won’t happen to me” is the prevailing, and fallacious, mind-set.

- **A lack of appreciation of the fact that there are solutions available** that will substantially reduce crash risks.

- **A lack of support for initiatives seen as infringing on personal freedoms**, either because they are regarded as cumbersome interference (e.g. speed limits, seatbelts, helmet wearing) or work against engrained socio-cultural perceptions (often promoted in advertising) that equate motor vehicles with freedom and fun.

In combination these barriers contribute to a demand deficit for safe roads, which will only be overcome with strong and sustained leadership, commitment by those with a stake in road transport and sharing of information that will increase awareness among the public for the daily carnage on the world’s roads and the further solutions that are available. Two realisations must take hold before public and political support for bold action in road safety can reach the levels required. The first is that every year the equivalent of the population of a city the size of Dallas, Munich, Stockholm or Adelaide is wiped out in traffic crashes. The second is that this huge total results from a collation of risks taken and errors made by individuals during every trip, every day, every week, every month, every year - until one day a chain of circumstances causes the person to slip between the cracks of the protective system and a crash results in serious harm. In other words: the societal problem is huge, everyone is at risk, and the traffic system must support the solution.

With a wide range of individual and institutional actors involved in road safety, an agreed vision for a Safe System is critical. This vision must be supported by strong governance, effective management and broad co-ordination. The Safe System structures and networks will need to be able to:

- **Press the political system** to embrace and commit to a Safe System in its entirety.
- **Foster road safety leadership at all levels of society.** Strong change management leadership is required from leaders in government, the community and corporations to individually and collectively advocate for closing the gap between the current situation and the aspiration of moving towards zero fatalities and serious injuries through a Safe System. Mayors for example are providing clear statements of aspiration and intent for a safe city.
- **Ensure effective co-ordination** of road safety involving partners from a range of sectors under shared responsibility for actions that work together for a greater overall result.
- **Develop a road safety strategy based on a clear vision**, underpinned by interim and long-term targets and linked to Safety Performance Indicators.
- **Manage for results**. Monitor implementation and evaluate progress against Safety Performance Indicators and strategic objectives, and use the results to plan and act further.

Why act now?

The public health burden of road trauma worldwide is of epidemic proportions. The World Health Organisation (WHO) reports 1.25 million people killed. Low and middle income countries account for over 90% of total traffic deaths. And traffic fatalities, for all the human pain and economic cost they cause, represent only a small part of the global road trauma problem. Increasing evidence and improved data show that there is a huge but vastly underestimated global problem with serious injuries from traffic crashes. The WHO estimates that up to 50 million more people suffer non-fatal injuries, with many incurring a disability as a result of their injury. Underreporting of injuries is widespread

Progress in combatting the global menace of road trauma varies greatly between countries, between regions, between cities. Some jurisdictions are seeing increases in the number of crash victims, others experience a levelling-off, and still others can report improvements ranging from modest to substantial. In countries that motorised early, road fatality rates peaked in the 1970s. Now countries with growing populations, accelerating economic development and big increases in the numbers of vehicles on their roads are poised to become the victims of unprecedented levels of road trauma.

However, these countries have a singular opportunity to learn from the past mistakes of others and be proactive in providing safe roads. This is particularly true also for cities. They are among those seeing more and more people killed on their streets, many of them vulnerable road users like seniors and children. As the world's growing population is concentrating in cities (where 70% of the world's population are expected to be living by 2050), there is a pressing need to find sustainable approaches to improving urban traffic safety. At the same time, cities can also be laboratories of success for creating a Safe System in an urban traffic context. Knowledge-sharing among cities will help to amplify the positive impact; networks like Safer City Streets (www.itf-oecd.org/safer-city-streets), which links up cities around the world interested in improving their road safety performance, can play an important facilitating role.

The international community is reacting to the challenge. From 1 January 2016, the member states of the United Nations have committed to an unprecedented effort to reduce serious road trauma by adopting a target to halve road deaths and injuries by 2020, compared to 2010 levels. Road safety is part of the goals for health and cities in the new UN framework of Global Goals for Sustainable Development.

Unlike most areas of public health in developed countries where strong economic conditions are generally associated with improved levels of public health, there appears to be an inverse relationship with levels of road trauma, with strong economic conditions putting upward, negative pressure on road trauma results.

While serious crashes do occur from deliberate violations of traffic rules and risk-taking behaviours, the majority of serious road crashes result from a simple mistake or error of perception or judgement by otherwise generally law-abiding citizens. Relying on human beings to perform mistake-free in traffic for fifty plus years is unlikely to succeed and is not consistent with approaches in the airline, shipping and rail industries, nor in occupational health and safety where system approaches are made that include engineering the surrounding environment to support human behaviour. With growing populations, and expanding levels of motorisation, unless bold and different action is taken the road trauma epidemic worldwide will grow substantially before subsiding later.

Encouragingly, more and more countries and cities are committing to bold visions such as "Towards Zero", "Vision Zero", "Roads Free of Fatalities and Serious Injuries" "Zero Harm" and similar such public demonstrations of bold and ambitious intent for improvement are a positive step forward and will serve as a rallying point. However, bold visions must be accompanied by a shift in thinking and the adoption of new ways of working. Business as usual and incremental improvements to current practice will not achieve bold ambitions. There is a risk that if no substantial progress follows, support for a step-change may wane and visions could be abandoned.

A new and strategic effort is required to achieve and sustain substantial reductions in the number of road deaths and serious injuries. A paradigm shift to a Safe System fundamentally changes the way the road safety problems are viewed and responded to. This is opening up new thinking and new possibilities for responses.

What is a Safe System?

A Safe System is a holistic and proactive approach to road safety, managed so the elements of the road transport system combine and interact to guide users to act safely and to prevent crashes - and when crashes occur, ensure that impact forces do not exceed the limits that result in serious injury or death. If one part of the system fails, the other components act to prevent serious harm occurring when a crash occurs by keeping the transfer of kinetic energy into the human below levels known to cause serious physical harm.

A Safe System combines enforcement, education, safe road design, management of safe operating speeds and safe vehicles and post-crash response.

The four fundamental and non-negotiable principles of a Safe System are:

1. **People make mistakes that lead to road crashes**.

2. **The human body has a limited physical ability to tolerate crash forces before harm occurs**.

3. **There is shared responsibility amongst those who design, build, manage and use roads and vehicles** and provide post-crash care to prevent crashes resulting in serious injury or death

4. **All parts of the system must be strengthened in combination** to multiply their effects, and if one part fails, road users are still protected.

An effective Safe System policy package contains initiatives designed for immediate large-scale impact. This will include speed management initiatives, enhanced enforcement and education campaigns, together with measures such as improved vehicle standards and road and roadside infrastructure investments that will deliver sustained results over the medium to long term.

Why a Safe System?

Pioneering countries have experienced a variety of benefits from progressing implementation of a Safe System including:

- **Improved road safety performance:** The new thinking and innovative approaches stimulated by the paradigm shift to a Safe System are achieving results on the journey towards zero road deaths and serious injuries.

- **Focus on root causes:** A Safe System helps overcome the risk of a behavioural bias in the focus of road trauma responses and actions. Efforts were dominated by a belief and a desire to "correct" human errors in crashes and help make the human behave "perfectly" in traffic.

- **Gaining new insights** into the road safety problem and identifying new solutions by moving beyond approaches that continue to focus on correcting and managing human behaviour as the primary response to reducing road trauma are limited and constrain the necessary thinking and decision making to take a country to achieve ambitious results on the journey ultimately to zero deaths and serious injuries.

- **Universal applicability:** A Safe System is applicable in all contexts and jurisdictions, no matter the starting point. It enables those experiencing increasing rates of road trauma to leapfrog the mistakes of others.

- **Clear design guidance:** Using the Safe System principles as the basis for design guidance to underpin their approach to design and operation that goes beyond current conventional standards and guidelines.

- **Address perception gaps**: New approaches to data and needs analysis stimulated by Safe System thinking helps countries to identify types of crashes that remain yet to be addressed.

- **A fresh perspective:** The experience of countries implementing a Safe System is that it provides opportunities to think and act on road safety problems differently. A Safe System opens up new possibilities by working backwards from the ultimate vision to determine next steps, while previously this was based on incremental improvement upon current practice without a long-term vision.

- **Targeted resource allocation:** The new focus on root causes informs budget allocations towards proactive, innovative and successful measures particularly in road infrastructure investments.

- **An inclusive approach:** A Safe System caters for all road users and directly addresses the safety challenges for vulnerable road users that represent an increasing share of road crash victims, particularly in urban areas. Also, Safe System thinking is applicable in both developed nations and in low- or middle-income countries; it can enable the latter to leapfrog the peak in fatalities and injuries that usually accompanies increasing motorisation.

- **A flexible framework:** Today's world is rapidly changing, and so is the context for road safety work. New road safety challenges will emerge as the pace of technological progress increases, and different ways of working may be needed as traditional structures and processes might come into question. Building on four high-level principles rather than detailed specifications implemented through command-and-control, a Safe System offers high degrees of flexibility to adapt road safety policy to evolving circumstances.

- **Mainstreaming road safety work:** The holistic view of road safety in a Safe System creates new linkages with other policy areas and sectors such as public health, environment and public transport development, helping to create synergies and win-win situations, and leading to the inclusion of a road safety dimension.

How to start the journey to a Safe System

As political cycles come and go but the necessary changes take years, it is important that leaders set up policy and organisational structures and management systems in a way that the change process remains stable.

An important early step is to change the general mind-set about road safety and generate support for aspirational targets that aim beyond incremental reductions of crash fatalities. The adoption of a Safe System philosophy starts with the ethical imperative that the traffic system should be designed and used in such a way that no one is killed or seriously injured as a result of a road crash; this imperative needs to be established and become part of the public discourse. Complex social processes and interactions underlie the replacement of one prevailing paradigm with a new one. Policy formulation and social innovation more broadly are an ongoing process of exploration, error, trial, failure and success. The implementation of a Safe System can be seen as a journey with different individual paths that may have different starting points but ultimately seek to arrive at the destination of trauma-free roads.

The experience of pioneering Safe System countries offers lessons about common success factors:

- **Create a sense of urgency:** A paradigm shift requires a sense of urgency of taking action, and in a radically different way, out of a desire to achieve substantially better results.

- **Take a bottom-up approach:** A Safe System needs the involvement of an informed and committed community of stakeholders. In many countries it has been them who have demanded better road safety outcomes from system designers. The top down is needed in the sense that influential leaders can initiate institutional change, but a sustainable Safe System is built on shared responsibility among all stakeholders.

- **Try out new tools:** A Safe System way of looking at road safety gives birth to new ideas. Often these highlight the limitations of the traditional ways of viewing the road safety problem and lead to effective innovative solutions.

- **Create public demand for more road safety:** Convincing citizens of the potential of a Safe System can increase public demand for road safety, which can subsequently help to engage politicians, policy makers and system designers.

- **Make the four Safe System principles the foundation** to guide the development of road safety policy and strategy, and ensure that they are not negotiated away.

- **Let data drive road safety policy:** Road safety targets, benchmarking and in-depth studies of road safety crashes help to identify priority action areas and the measures that will most effectively deal with them. Collecting relevant data on road safety performance across the elements of a Safe System is thus critical.

- **Communicate road safety facts effectively:** Where information about road safety is shared effectively, different advocates, the media and community members begin to ask questions and demand safer roads, speeds and vehicles from system designers. Introducing relevant facts and questions into the public debate in a strategic manner can be an effective way for change leaders to build community demand for a Safe System.

- **Focus on outcomes by setting targets:** Road safety should be managed for results to drive change. Targets provide this focus on results and drive performance. They also help to communicate effectively around road safety.

- **Use Safety Performance Indicators:** Fully transparent and accountable monitoring of safety performance using valid and reliable indicators of outputs, intermediate outcomes and final crash outcomes across all the components of a Safe System is important.

- **Ensure effective governance and management structures:** Effective co-ordination contributes to successful implementation of shared responsibility. The ISO 39001 Road Traffic Safety Management standard provides a good basis for organisations to systematically identify safety risk and provides a "how to" implementation guide for organisations to implement a Safe System thus supporting the guiding principle of shared responsibility.

Policy makers seeking to achieve ambitious results in road safety are encouraged to recognise a paradigm shift to a Safe System is required to ultimately achieve and sustain transformational reductions in road deaths and serious injuries. Their strong and sustained leadership will be needed to establish that paradigm shift, change culture and then align current practice with a Safe System. The compass for the journey towards the eradication of road trauma is provided by Safe System principles, drawn from the practice developed in pioneering countries and cities. Leaders looking for a step-change in road safety can learn from the practices and tools used by the pioneers and translate those Safe System principles into on-the-ground action for their specific situations. They should, in turn, document, evaluate, publish and share their experiences to help create a knowledge base and a political dynamic around the world that will save millions of lives in the coming years and decades. The first step to achieve that is to act now.

Members of the Working Group

Chair: Iain Cameron (Australia)

Australia	Mr. Iain Cameron Austroads
Belgium	Ms. Emmanuelle Dupont Belgian Road Safety Institute
	Ms. An Volckaert Belgian Road Research Centre (BRRC)
Canada	Mr Gerry Shimko City of Edmonton
Chile	Mr Rodrigo Cruces Ministry of Transport
Denmark	Ms Rikke Rysgaard Danish Road Directorate
France	Mr Laurent Carnis Institut français des siences et technologies des transports, de l'aménagement et des réseaux (IFSTTAR)
	Mr Sylvain Lassarre Institut français des siences et technologies des transports, de l'aménagement et des réseaux (IFSTTAR)
	Mr Benoit Hiron Centre d'études et d'expertise sur les risques, l'environnement mobilité et l'aménagement (CEREMA)
Germany	Mr Jan-Andre Bühne Bundesanstalt für Strassenwesen (BASt)
Greece	Mr George Yannis National Technical University of Athens
Ireland	Ms Velma Burns Road Safety Authority

Israel	Mr Shalom Hakkert Technion. Israel Institute of Technology, Haifa
Italy	Mr Luca Persia La Sapienza University, Rome
Japan	Mr Katsuya Abe Ministry of Land, Infrastructure, Tourism and Transport
Malaysia	Mr Shaw Voon Wong Malaysian Institute of Road Safety Research (MIROS)
Mexico	Mr Alberto Mendoza Instituto Mexicano del Transporte (IMT)
Netherlands	Ms Wendy Weijermars Institute for Road Safety Research (SWOV)
New Zealand	Mr Colin Brodie New Zealand Transport Agency
Russian Federation	Mr Vadim Donchenko Scientific and Research Institute for Road Transport (NIIAT)
Serbia	Mr Dragoslav Kukic Road Traffic Safety Agency
Spain	Mr Alvaro Gomez Directorate General for Traffic
	Mr Roberto Llamas Ministry of Public Work and Transport
Sweden	Mr Peter Larsson Swedish Transport Agency
	Mr Johan Lindberg Swedish Transport Administration
Switzerland	Mr Stefan Siegrist Swiss Council For Accident Prevention (bfu)
United States	Ms Beth Alicandri Federal Highway Administration
	Ms Esther Wagner National Highway and Traffic Safety Administration (NHTSA)

World Bank	Ms Veronica Raffo
	Mr Marc Shotten
World Health Organization	Mr Meleckidzedeck Khayesi
Fédération Internationale de l'Automobile (FIA)	Mr Luca Pascotto
FIA Foundation	Mr Saul Billingsley
Global New Car Assessment Programme (NCAP)	Mr David Ward
World Road Association (PIARC)	Mr Matts Ake Belin
International Road Assessment Programme (iRAP)	Mr James Bradford
	Mr Rob McInerney

Members of the Editorial Committee

The report was drafted primarily by members of the editorial group: Mr Iain Cameron, Mr David Ward, Mr Shalom Hakkert, Ms Wendy Weijermars, Mr Peter Larsson, Mr Colin Brodie, Mr Saul Billingsley, Mr Gerry Shimko, Ms Emmanuelle Dupont and with support from the Secretariat of the International Transport Forum.