International Transport Forum

Road Safety in Cities
Street Design and Traffic Management Solutions

ROAD SAFETY GRANT PROGRAMME

Acknowledgements

The work for this booklet was carried out in the context of the Safer City Streets initiative of the International Transport Forum (ITF) and funded by the FIA Road Safety Grant Programme, supported by the FIA Foundation The author of the booklet is Dominic Streuber (ITF), who worked under the supervision of and in co-ordination with Alexandre Santacreu (ITF), the project lead of the Safer City Streets initiative.

This booklet presents measures that effectively reduce road traffic deaths and serious injuries in cities. It covers urban street design, traffic management and improving mobility options. Measures are illustrated with examples reported by cities collaborating in the ITF Safer City Streets network and include information on cost and effectiveness. The case studies draw on interviews held with city officials and Safer City Streets partners by telephone or email. The ITF would like to fully acknowledge their contributions and also take responsibility for any errors in representing the policies of their jurisdictions. The interviewees were:

Catherine Pérez, Agència de Salut Pública de Barcelona
Caio Assunção Torres, Departamento de Engenharia de Transportes, Fortaleza
Nathaly Milena Torregroza Vargas, Secretaría de Movilidad, Bogotá
Adriana Corssy Martínez, Secretaría de Movilidad, Bogotá
Claudia Mercado Velandia, Secretaría de Movilidad, Bogotá
Amy Pidwill, Transport for London
Nishma Mistry, Transport for London
Inês Castro Henriques, Câmara Municipal de Lisboa
Pedro Machado, Câmara Municipal de Lisboa
Rob Viola, New York City Department of Transportation
Selma van der Zwart, Gemeente Den Haag
Wernher Brucks, City of Zurich
Brian Deegan, Urban Movement
David Braunstein, Together For Safer Roads
Enrico Pagliari, Automobile Club d'Italia
Lucia Pennisi, Automobile Club d'Italia
Irene McAleese, See.Sense
Nikita Luke, World Resources Institute
Siba El-Samra, World Resources Institute

Other members and partners of the Safer City Streets network kindly provided comments through online workshop meetings organised on the 10th and 17th November 2021.

The booklet was reviewed internally by Alexandre Santacreu and Stephen Perkins at the ITF.
Christopher Marquardt (independent) copy-edited the draft and Hilary Gaboriau (ITF) co-ordinated production.
Layout by Ana Cuzovic (ITF).

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

The International Transport Forum

The International Transport Forum is an intergovernmental organisation with 63 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 Forum are: Albania, Armenia, Argentina, Australia, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Canada, Chile, China (People's Republic of), Colombia, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, India, Ireland, Israel, Italy, Japan, Kazakhstan, Korea, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Mexico, Republic of Moldova, Mongolia, Montenegro, Morocco, the Netherlands, New Zealand, North Macedonia, Norway, Poland, Portugal, Romania, Russian Federation, Serbia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Tunisia, Turkey, Ukraine, the United Arab Emirates, the United Kingdom, the United States and Uzbekistan.

Case-Specific Policy Analysis Reports

Cite this work as: ITF (2021), Road Safety in Cities: Street Design and Traffic Management Solutions, International Transport Forum Policy Papers, No. 99, OECD Publishing, Paris.

About Safer City Streets

The International Transport Forum (ITF) at the OECD launched the ITF Safer City Streets initiative at the UN Habitat III conference in 2016. It brings together road safety experts from 48 cities and explores the solutions developed at a local level. Cities in the network improve their urban road safety performance by sharing data, experience and knowledge and learning from each other. Safer City Streets replicates at city-level the International Road Traffic Safety Analysis and Data (IRTAD) group, a global road safety network of countries hosted by the ITF, which has run for more than 25 years. The IRTAD group has been commended by the World Health Organization as "a model of a multi-country effort".

Content

Introduction

Every minute, someone in the world dies in city traffic. In order to stop this epidemic of road deaths, cities worldwide have taken action to improve urban road safety and local authorities have adopted ambitious targets to make their streets safe. Cities are complex and there are many and competing demands placed on their transport systems. No single safety intervention will achieve all of the desired safety outcomes or achieve unanimous public support. Every intervention will come at a cost – to the city, to other users and to other transport modes. Finally, the mix of interventions that works in one city may not be sufficient in another. Cities must carefully analyse their own safety needs and decide on the most effective mix of interventions, together with mutually reinforcing measures, in line with the Safe System approach.

This booklet introduces measures for urban street design and traffic engineering, speed management and improved mobility options, three of the fundamental action areas of a Safe System approach to improving road safety (Figure 1). It presents nine groups of measures that have proven effective in reducing road traffic deaths and serious injuries in cities, outlining experience and case studies from some of the cities that are implementing such measures successfully. The focus is on infrastructure-related measures that contribute considerably to reductions in casualties (World Road Association, 2019). Technological measures and other action areas inspired by the Safe System approach are also briefly addressed, but remain to be covered in future Safer City Streets publications.

Street design in cities around the world has focussed on private motor vehicles, but policy makers are increasingly shifting the focus to making cities liveable for citizens and safe for all road users. Space is being reallocated and streets (re)designed to maximise safety and improve the environment for pedestrians and cyclists, and for safe access to public transport. Better traffic management and signalling systems are part of the improvements being made to infrastructure. Each specific measure discussed in this booklet is briefly reviewed in terms of costs and effectiveness.

A large range of measures are potentially available to address road safety problems, so it is important to consider the local context when selecting the most effective interventions. Most measures require skilled consultation with citizens and road users because they imply changes of behaviour and because benefits may be difficult to appreciate until they have been experienced. Building public and political support for intervention requires that effects on traffic flow, health, climate change and pollution are considered when selecting measures.
Policy makers should prioritise vulnerable road users, as they constitute the great majority of fatalities on urban roads. Policy makers need good information on the benefits and costs of measures so that they can maximise improvement with the limited budgets available. Costs depend on the scope and specific design of measures, but the costs described in this booklet provide an idea of the order of magnitude of the costs by category of measure.

Costs and effectiveness

This booklet provides examples of the reported effectiveness of some road safety measures. Such performance may, however, depend on the context in which the measures are applied. In other words, findings are not necessarily directly transferable from one city to another. The booklet thus provides case studies to help illustrate the order of magnitude of changes that one could expect. Road safety practitioners should develop trials, together with robust evaluation protocols, in order to make sure their actions reduce the number of traffic deaths and serious injuries. By doing so, they will also contribute to the global body of research on road safety measures.

The cost of a road safety measure depends on the local context in which it is implemented, and reflects the precise way in which a local authority chooses to deliver it. In addition, some high-cost measures, such as a bypass road or mass transit system, are typically funded outside of the road safety budget. With this in mind, the present booklet offers examples of the costs of road safety measures where this information is available. It does not, however, attempt to provide a framework comparing costs or cost-effectiveness across different measures.

The figures on road treatment costs and effectiveness presented in this booklet are taken mainly from The Handbook of Road Safety Measures published by Norway's Institute of Transport Economics (Elvik et al., 2009), a definitive compendium of international research on the effectiveness of safety interventions. Many of the other figures for costs and effectiveness are drawn from research undertaken for SafetyCube (the EU Road Safety Decision Support System) and from interviews with city officials (see the "Acknowledgements" and "Further reading" sections of this booklet). Other sources are cited in the text and listed in the References section.

The Safe System

A Safe System proactively and holistically reduces risks in all areas of a road safety system. It fosters safe behaviour while also addressing risks inherent in the design of the road network. Crashes are prevented by elements of the system that guide users to act safely. At the same time, measures are taken to try to ensure that the crashes that inevitably still occur do not result in serious injury or death.

Four guiding principles are central to a Safe System:

1. People make mistakes that can lead to crashes. The transport system needs to accommodate human error and unpredictability.

2. The human body has a known, limited physical ability to tolerate crash forces before harm occurs. The impact forces resulting from a collision must therefore be limited to prevent fatal or serious injury.

3. 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 effective post-crash care.

4. All parts of the system must be strengthened in combination to multiply their effects, and to ensure that road users are still protected if one part of the system fails.

Source: ITF (2016).

Figure 1. Principles, Core Elements and Action Areas of the Safe System Approach
Adapted from WRI (2018)

Measure 01

Allocation of protected space for walking and cycling

Vulnerable road users – i.e. people walking, cycling and using powered two-wheelers – make up the vast majority of urban traffic fatalities in the cities participating in the ITF's Safer City Streets initiative (Figure 2). Cities should therefore intensify their efforts to improve street design for vulnerable road users and provide better-protected infrastructure for walking and cycling.

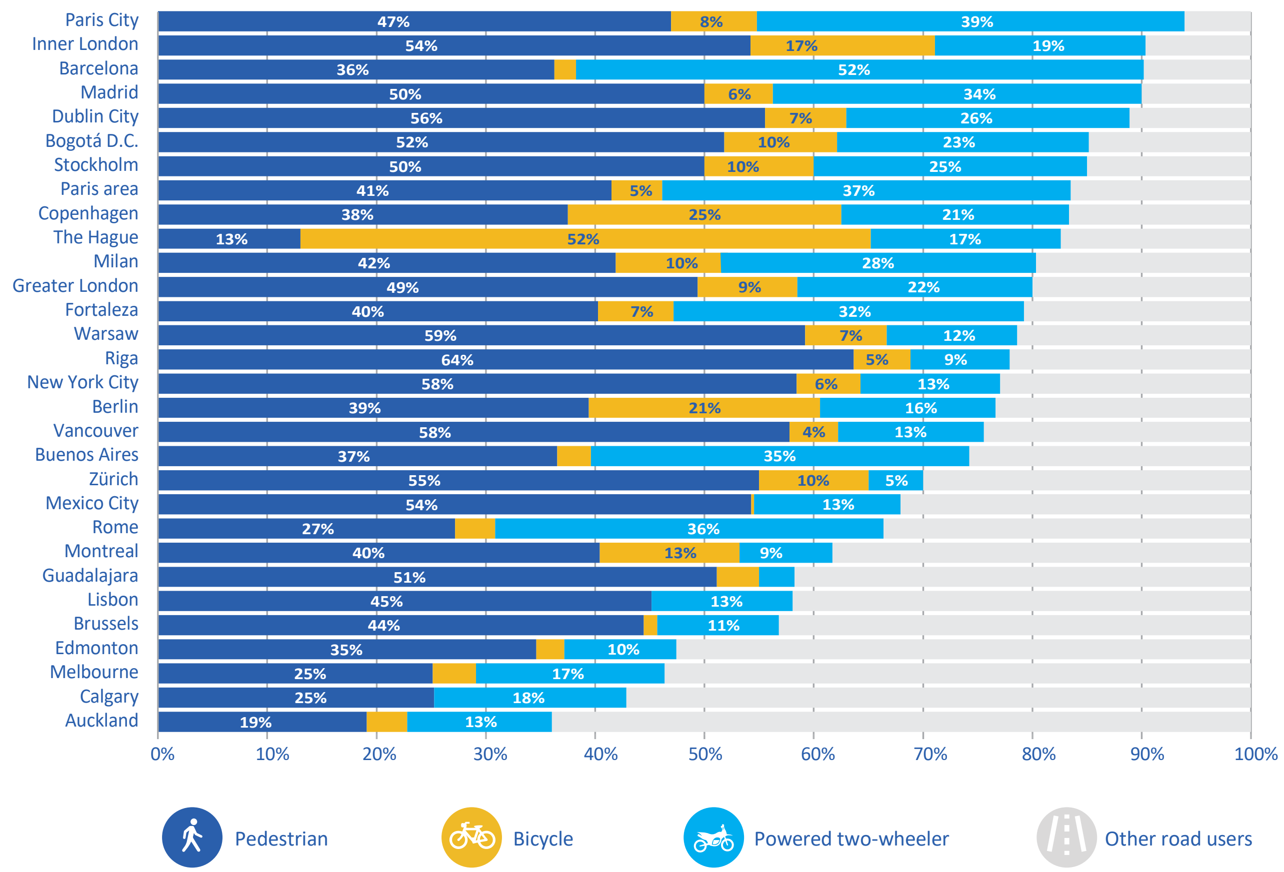
Sidewalks and cycle tracks protect the most vulnerable road users by physically separating them from motor vehicle traffic. Different degrees of separation are possible, defined in standard terms as follows. A **cycle track** provides a hard separation with curbs, vegetation, a parking lane or a combination of these barriers. A **cycle lane** is separated only by road markings, such as a solid white line. This creates clearly delineated space for cycling (when free of illegal parking) but, in practice, the markings can have the counter-productive effects of 1) reducing the passing distance between motor vehicles and cyclists (Harkey and Stewart, 1997) and 2) increasing overtaking speeds (Shackel and Parkin, 2014). Another measure to consider is **light protection of cycle lanes**. This consists of the use of physical objects intermittently placed alongside a cycle lane marking to give additional protection from motorised traffic. Light protection is adaptive and can be built quickly and cheaply. It also offers an improved sense of subjective safety that makes cycling more attractive (Deegan, 2018). Adding intermittent separators has proven effects on road user behaviour, with motor vehicles encroaching less into cycle lanes (Koorey, Wilke and Aussendorf, 2013).

The **treatment of road junctions** is critical to cycling safety and should be the starting point for allocating space to cycling rather than an afterthought to the introduction of cycle tracks or cycle lanes. Treatments include separate signal phases for cyclists and conspicuous road markings to guide cyclists on predictable routes through junctions and indicate priority (see the section on Junction treatment).

Inadequate sidewalk space can force pedestrians to walk on the carriageway and in cycle lanes. **Wider sidewalks** improve accessibility. **Physical barriers** can prevent the parking of motor vehicles on sidewalks and at crossings. **At-grade signalised pedestrian crossings** (crossings with traffic signals and road markings) help to increase pedestrian safety and promote walking and are therefore preferable to pedestrian bridges and tunnels in most circumstances. Safe and direct routes for walking and cycling facilitate a modal shift that of itself can significantly enhance road safety in dense urban areas and deliver public health benefits associated with increased physical activity and improved air quality. **Mixed use of space** by pedestrians and cyclists is common, but at the highest pedestrian densities this ceases to be an attractive solution for either group.

The construction of one kilometre of cycling lane in Europe costs around EUR 100 000 and a cycling track costs around EUR 760 000 per kilometre (Elvik et al., 2009). Light segregation brings the cost of developing a cycling network down to EUR 100 000-250 000 per kilometre (Deegan, 2018). Sidewalks cost between EUR 54 000 and EUR 188 000 per kilometre of 1.5- to 2-meter-wide shoulder (Pedestrian Safety Guide and Countermeasure Selection System, 2013). Maintenance costs should be factored into the choice of pavements as well as budget planning, as degraded surfaces are unsafe and unattractive. The implementation of protected sidewalks and cycle tracks and the widening of sidewalks can be controversial despite the low costs because they reduce the space allocated to motor vehicle traffic lanes and parking bays.

Figure 2. Modal shares of road fatalities, by city and by population density group, 2013-15



Lively squares and sidewalks programme in Fortaleza, Brazil

A rapidly growing number of cities are making radical improvements to pedestrian infrastructure that are transforming accessibility, improving safety and cutting congestion. In 2018, the Fortaleza City Council implemented a "Lively Sidewalk" programme at Barão da Rio Branco Street. Developed in consultation with the local population, the programme included the conversion of one traffic lane into an interim sidewalk extension. Before the implementation, many pedestrians were forced to walk on the road between motor vehicles. At the writing of this booklet they have a safe and accessible space to walk. In order to make the adjacent squares more lively, kiosks for street vendors, accessibility ramps, three new at-grade raised crossings and urban furniture were installed. The programme aimed to make walking more attractive and increase pedestrian mobility. It was developed in partnership with the Bloomberg Initiative for Global Road Safety and the National Association of City Transportation Officials.

Low-cost and fast-implementation materials – paint, benches, bollards and planters – made it possible to test the measure and evaluate its impact rapidly. The changes to the urban space reduced the number of pedestrians walking in the road by 92%. Vehicle speeds above 30 km/h and 40 km/h dropped by 65% and 84%, respectively. The programme was also successful at regenerating activity, with pedestrians taking advantage of the kiosks and public benches. Several other cities, attracted by the programme's success and low cost, have replicated it in several of their own neighbourhoods. As of the writing of this booklet, one kilometre of sidewalks have been widened, 2 100 square meters of public space have been reclaimed and 32 crosswalks have been improved permanently through the programme (Pompeo and Abdulsamad, 2021).

Light protection of cycle lanes in London, United Kingdom

The Camden district in the northwest of London introduced a cycle lane with light protection on Royal College Street as part of a wider policy to improve conditions for cycling. This project was the first one in the United Kingdom to use light protection to protect cyclists from traffic. Prior to the changes, a bi-directional cycle track was segregated from the general carriageway by a curb. However, traffic safety records were poor as drivers failed to notice the approaching contra-flow cyclists at intersections. The new project aimed to improve conditions for both cyclists and motorists and test the concept of light protection as a measure that can be implemented faster and at a lower cost than conventional cycle tracks.

The Council removed the bi-directional cycle track and replaced it with cycling routes, using light protection measures instead of curb separation. In addition to low profile “armadillo” separators, planters, flexible posts and vehicle parking were used on most of the route as protection from motor vehicle traffic. A before-and-after study revealed a 50% reduction in both the number of crashes involving cyclists and the severity of resulting injuries. This reduction was achieved while the total number of people cycling in both directions increased by 70%. Motor vehicle traffic levels and speeds dropped while 71% of cyclists said that Royal College Street offered a better experience than the rest of their route. The cost of the light protection measures amounted to EUR 80 000, bringing the cost per kilometre of the project to EUR 120 000. Maintenance costs of replacing damaged planters and “armadillo” separators were EUR 15 000 in 2014/15.

Measure 02

Speed management

Speed is a contributory factor in about 30% of fatal accidents in urban areas (European Commission, 2018). Consequently, speed management is one of the most effective urban road safety policies. Reducing speeds can reduce the risks and severity of crashes significantly. A 1% increase in average speed results in approximately a 2% increase in injury crash frequency, a 3% increase in severe crash frequency, and a 4% increase in fatal crash frequency. The risk of a pedestrian being killed in a collision with a car is almost five times higher at 50 km/h than at 30 km/h (Kröyer, Jonsson and Varhelyi, 2014). The benefits of lower speeds on urban streets have been documented in Safer City Streets Case Studies (ITF, 2020b). They were also highlighted in the Stockholm Declaration issued at the 2020 Global Ministerial Meeting on Road Safety, which recommends limiting speeds to 30 km/h wherever vulnerable road-users mix with motor vehicle traffic, and limiting all speeds on urban roads to 50 km/h (see also ITF, 2018).

Interventions limited to signposting **30 km/h limits** are not always successful at lowering speeds. More often, **30 km/h zones include engineering measures** to reduce speed, such as road narrowings, speed humps, curb extensions and raised pedestrian crossings and junctions. **Speed limiting devices** such as humps have to be designed carefully; otherwise, they can hinder emergency vehicles and cause discomfort, particularly for bus passengers. Lower limits have also been introduced in areas of some cities, for example, to create **urban play streets** where motor vehicle speed is limited to a walking speed of 10 km/h. For over a decade, 15 km/h and 20 km/h zones have been implemented in shared spaces of many cities, including Belgium, France and the Netherlands.

Several studies show clearly that speed limit reductions in combination with physical measures reduce casualties significantly (by around 25%) and conclude that 30 km/h speed limits should be combined with physical interventions (see, for example, Li and Graham, 2016; Seya, Yoshida and Inoue, 2021). Street design and traffic signals are also an important part of ensuring compliance, which can otherwise be challenging.

Signs that inform of the speed-reducing measure cost between EUR 200 and EUR 500 per sign; speed humps cost between EUR 1 000 and EUR 3 000 (Elvik et al., 2009). The implementation of speed limits is controversial. Engagement with the community is required to achieve acceptance of and adherence to reduced speed limits. Communities initially sceptical about the value of speed management are likely to demand interventions to reduce speeds when the benefits are demonstrated and communicated effectively, as experience in Bogotá shows (ITF, 2020b).

Speed management in Bogotá, Colombia

Bogotá developed a speed management programme, the Programa de Gestión de la Velocidad (PGV), after identifying the main factors contributing to crashes. The programme aims to improve the road environment and guarantee the safety of all road users. The city evaluated existing speed limits in relation to road function, infrastructure condition, land use and operational characteristics. An appropriate speed was then defined for each road type. The programme also provides guidelines to ensure compliance with speed limits.

The initiative first targeted the five corridors with the highest casualty rates. The speed limit was lowered from 60 km/h to 50 km/h, and speed cameras were installed to enforce compliance on five corridors. The programme took an incremental approach, testing the benefits of speed reduction and disseminating results before expanding to other roads. Fatal crashes were monitored corridor by corridor, and results were compared with the average for the preceding three years. Results were reported weekly to the public via social media, using headline indicators of the number of lives saved since implementation and days accumulated without recording a death. The demonstrated reduction in lives lost convinced many of the administration’s strongest critics to accept the speed management programme as effective.

Interventions were extended to ten arterial corridors, with forty-six lives saved in 2019 due to the programme. This represents a 21% decrease in traffic fatalities compared to the average for the three preceding years 201518. Data from speed cameras indicates an improvement in compliance, with lower excess speeds, although the rate of vehicles exceeding speed limits was unchanged at around 20%.

Curb extensions in Lisbon, Portugal

As part of efforts to enhance accessibility and safety, Lisbon has implemented curb extensions, including at the site illustrated in the photos below, at Alexandre Herculano Street. At first sight, this intervention is simply a junction treatment. However, curb extensions and other street design changes are also part of effective speed management and traffic calming. This intervention reduces the crossing distance for pedestrians and increases the curve radius on all corners, which slows cornering speeds. Shorter curves with better sightlines are particularly useful at intersections where cars are permitted to turn right at red lights. The shorter crossing distances for pedestrians bring the crossing into conformity with national legislation for the speed at which pedestrians have to walk to cross on a green pedestrian light (0.4 m/s – 1.4 km/h). The intervention has had a traffic-calming effect, with no reported increase in traffic congestion. Drivers approach the intersections at lower speeds, and pedestrians report feeling safer (+18%) with less pressure from drivers to walk faster (-14%).

Measure 03

Roadside safety treatment

In cities where speeds are limited to 50 km/h or less, out-of-control vehicles are unlikely to kill their drivers and occupants but represent a lethal threat to vulnerable road users. Roadside obstacles such as lamp posts, planters and parked vehicles can protect pedestrians and cyclists from vehicles that leave the carriageway. Safety barriers and guardrails at the roadside are designed to protect pedestrians from motor vehicles, to stop pedestrians from walking into the road, and to guide pedestrians towards designated crossings. However, although they are intended to reduce conflicts between pedestrians and drivers, they can be counter-productive depending on how they are deployed.

Well-designed **safety barriers** can reduce the number of severe crashes and increase the level of road safety. If properly designed, installed and maintained, the barriers should reduce the severity of crashes involving out-of-control vehicles (iRAP, 2010). **Guardrails** can be effective in channelling pedestrians towards dedicated crossings, and small sections of guardrail can prevent pedestrians (especially children) from inadvertently stepping onto the road, for example, at school entrances or park exits (City of Bristol, 2014).

However, excessive segregation of vulnerable road users and motor vehicles can create risks. Roadside barriers can encourage motor vehicle drivers to adopt higher vehicle speeds. They can cause drivers to perceive a reduced risk of conflict, leading to tunnel vision (Transport for London, 2017). They can also force pedestrians to make long detours to cross roads, which severs communities.

More accessible and open street design is increasingly recognised as more appropriate in most urban contexts (Transport for London, 2020). The removal of roadside barriers and pedestrian guardrails can have a positive safety impact by increasing the visibility of all road users and inducing more careful driving and slower speeds.

Removing pedestrian guard railings in London, United Kingdom

Removing pedestrian guard railings appears paradoxical at first thought. The railings are a common measure implemented in the United Kingdom and most other countries. A reduction of risk for vulnerable road users is the overriding result when installed at critical locations.

When over-used, however, railings can become more of a barrier to access than an aid to safety, limiting crossing points and increasing the time needed to cross roads. They can give an unintended visual message to drivers that they have priority over pedestrians, and they can result in pedestrians climbing railings or taking shortcuts across adjacent junctions where they are exposed to the greatest risk.

Transport for London has implemented a policy to remove sections of pedestrian railings along main roads where they are counter-productive. The removals have included a large number of staggered junctions. An evaluation of the project revealed that removing safety railings at pedestrian crossings can lead to a significant reduction in pedestrian deaths and injuries. In this case, removing the railings reduced the number of fatal and serious pedestrian collisions by 53%. Crashes for all road users decreased by 47% at junctions where barriers had been removed. Transport for London argues that the reduction is caused by a shift in driver attitudes toward giving way to pedestrians following the removal. Perhaps the conclusion of this experiment is that some roadside treatments perform better than others due to subconscious effects on driver behaviour (Transport for London, 2017). Authorities making changes to street design are encouraged to develop protocols for robust evaluation of the effects of such changes.

Measure 04

Traffic management

Traffic can be managed through many different approaches but is strongly dependent on street design. The first objective of traffic management is to prevent conflicts between road users. The management of both traffic volume and speed is important as they are fundamental determinants of the number and severity of crashes and injuries.

Traffic management measures include the implementation of **pedestrian streets**, **low-traffic neighbourhoods** and **traffic-calming** measures such as new **circulation plans**. Where streets are pedestrianised, most motorised traffic is prohibited. Typical exemptions enable motorised deliveries at certain times of the day. A spectrum of pedestrian prioritisation exists and access may be extended to cars for off-street resident and hotel parking, taxis and access for people with impaired mobility. Low-traffic neighbourhoods are residential areas with no through-route for motor vehicles; residents are still able to drive to their homes while profiting from improved air quality and reduced noise pollution. Traffic-calming measures and circulation plans unburden the city centre of traffic while providing more space for pedestrians and cyclists and for community or commercial use of public space. New **bypass roads** may be included in traffic circulation plans to relieve congestion in central areas, in conjunction with measures to avoid traffic induction.

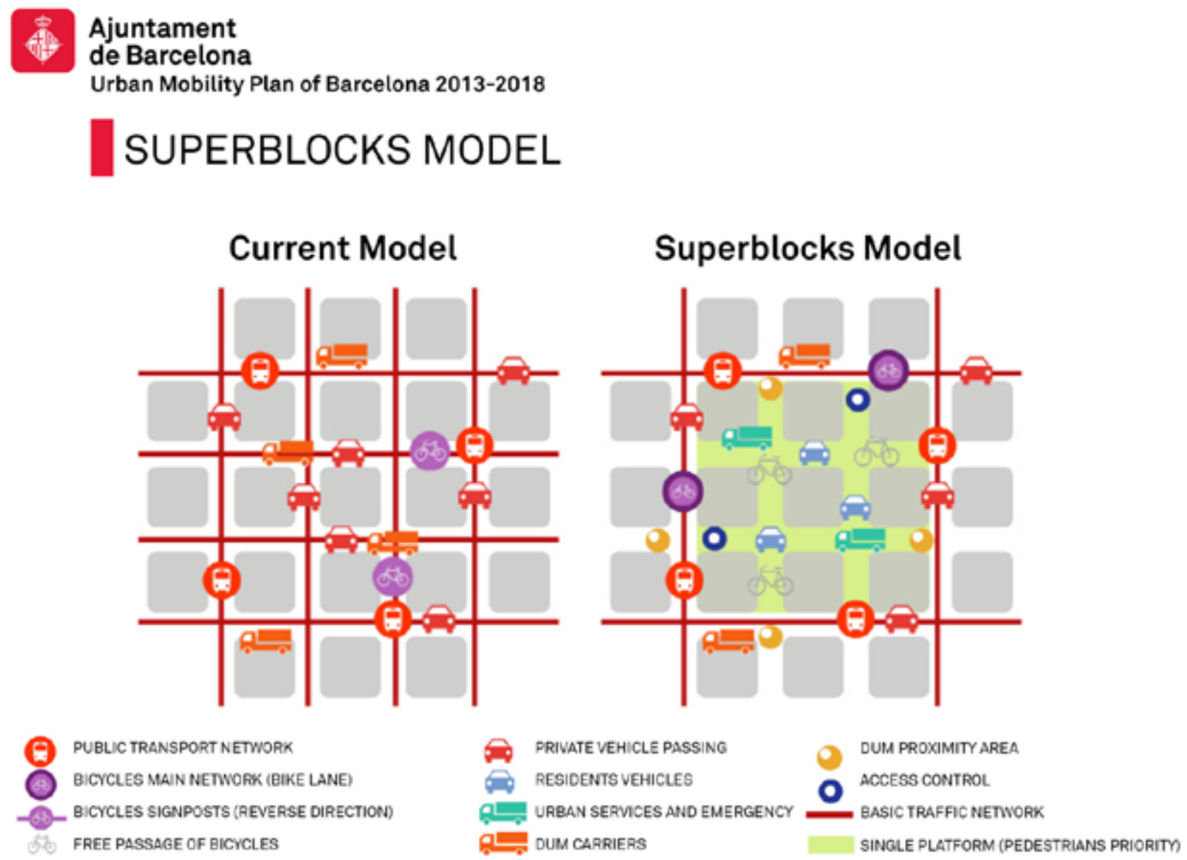
Traffic reduction measures can be highly effective. The *Handbook of Road Safety Measures* reports that on streets with high pedestrian traffic, a 60% reduction in the number of crashes can be expected from pedestrianisation, with a 25% drop on neighbouring streets (Elvik et al., 2009). The same source found that area-wide traffic calming reduces the number of crashes by 15% due to the overall reduction in traffic. Overall there is a strong correlation between traffic volume and crash rates. The bypasses evaluated in the *Handbook,* which are designed to high safety standards as part of integrated traffic-management plans, were found to reduce collisions on both new and existing roads, with results ranging from 19% to 66% (Goldenbeld and Schermers, 2017).

The main cost of creating pedestrian streets is that of renewing of street surface, which is estimated to be around EUR 750 000 for a 200-metre-long street. Costs for traffic calming vary depending on the individual measures. Building a bypass road costs around EUR 1.9 million per kilometre (Elvik et al., 2009).

Superblocks in Barcelona, Spain

The “superblock” model developed in Barcelona has proved an effective way of reprioritising access in central parts of the city, with clear safety benefits. Pedestrians and cyclists have priority in superblocks. Space that was formerly occupied by cars has been reallocated to pedestrians, playgrounds and public benches while preserving essential access by motor vehicles. Car traffic is redirected to the periphery of each block, with traffic inside the block allowed on one remaining one-way street, with speeds limited to 10-20 km/h, to serve local access and delivery. This is a very complete example of improving traffic management by combining new traffic circulation plans with traffic-calming measures. In creating superblocks, the city aims at recovering space for public use to foster social cohesion.

Since 2016, interventions have been carried out to implement superblocks in three neighbourhoods: Poblenou, Sant Antoni and Horta. The environmental and health effects of these urban transformations have been assessed by the Agència de Salut Pública de Barcelona (Public Health Agency). Road safety in these neighbourhoods improved due to the reduction in the number of motor vehicles. Residents reported better rest in a quieter, more comfortable and safer environment that encourages interaction between neighbours. A major expansion of the superblock initiative is estimated to cost EUR 37.8 million over the next ten years (Carey, 2020).



Traffic reduction in school zones in Lisbon, Portugal

Home-school trips in Lisbon are characterised by the use of cars (the modal split of cars in 2020 was 51.4%). “Mexe-te pela tua cidade!” (move for your city) is a municipal initiative promoting sustainable mobility and a change in habits for commuting from home to school. This initiative is part of an overall school-mobility programme and consists in limiting motor vehicle access to areas around schools, particularly at the beginning and end of the school day. During these periods, schools can be accessed only on foot or by public transport, bicycle, skateboard, rollerblades or scooter. Access to the area by car is reserved for residents only. The measure both encourages active mobility and improves safety by reducing exposure to motor vehicle traffic.

Lisbon launched the pilot programme in two areas of the city: every Tuesday in the surroundings of the Dona Filipa de Lencastre schools, in the Arco do Cego neighbourhood; and every Wednesday in Jardim-Escola João de Deus. Five bicycle lanes with light protection were also established to serve the Dona Filipa schools and one for Escola João de Deus. The pilot project started in December 2019 and included an awareness-raising campaign organised by members of the school community to explain the initiative to local residents. Since the beginning of the initiative, a considerable reduction of motor vehicles in school areas has been achieved, leading to safer conditions for children to walk and cycle to school. Although there is no clear data available yet, research from Edinburg University finds that perceived road safety increases on the surrounding streets of school-streets closures as well as on the closed streets themselves. This evidence suggests that there is an implied road safety benefit based on fewer motor vehicle movements (Davis, 2020).

Measure 05

14th Street Busway in New York City, United States

In October 2019, the New York City Department of Transportation (NYCDOT) implemented a pilot programme on 14th Street, a major connector road in Manhattan, with the goal of improving the bus service and increasing safety on this Vision Zero Priority Corridor. Within the pilot programme, only buses, trucks and emergency vehicles may travel along 14th Street from 3rd Avenue to 9th Avenue between 6 AM and 10 PM. All other vehicles may make local trips to access businesses, residences and garages along 14th Street, but drivers must exit at the next available right turn. Additional elements of the pilot include new pedestrian space, painted curb extensions to shorten pedestrian crossings, and bus boarding platforms.

The project has successfully reduced crashes with injuries by 42% in the study area (Schwartz, 2020). Meanwhile, bus travel times have increased by as much as 24% and ridership by as much as 30% (NYCDOT, 2021). After the successful pilot, the 14th Street Busway was made permanent in June 2020, with a plan to extend bus lanes further east.

Improved mobility options

One of the fundamental action areas of the Safe System approach is the provision of improved mobility options. Public transport is the safest mode of urban transport, and substituting transit for car traffic is central to road safety policy in an increasing number of cities (ITF, 2019; WRI, 2013). Good-quality public transportation systems, particularly late-night public transport, can significantly reduce crashes and enhance road safety (Lichtmann-Sadot, 2019; APTA, 2016). People who have access to an efficient public transport system are less likely to drive under the influence of alcohol, drugs or medicine, and to drive a car or ride a powered two-wheeler at a young age, when crash rates are highest.

A range of mobility options are available to improve road safety. Walking and cycling infrastructure reduces the risk of fatalities while promoting healthier modes of transport (Jacobsen, 2003; WRI, 2013). High-quality **public transport** outperforms all other choices of transportation in terms of safety. Besides urban bus and rail networks, other interventions such as **bus priority at junctions**, **bus priority lanes** and adequate protected pedestrian **infrastructure for stops and stations** can contribute to improved road safety.

The costs of providing and maintaining public transportation infrastructure are high. The cost of running a public transport system ranges from EUR 200 to EUR 1 000 per year, per inhabitant, in major European cities. Most of these cities cover 40-60% of this cost with fare revenues (EMTA, 2020). In 2018/19, Transport for London had a total budget of about EUR 11.5 billion, of which about EUR 5.6 billion was generated from fare income (Transport for London, 2018). However, the primary benefit of public transport systems is the very large number of daily trips they can accommodate. Existing public transport systems can be enhanced by investment in safe pedestrian access to stops and stations. Protected crossings, sidewalk widening and traffic calming represent very small costs in comparison with the overall public transport budget.

Bus Rapid Transit and cable cars in Bogotá, Colombia

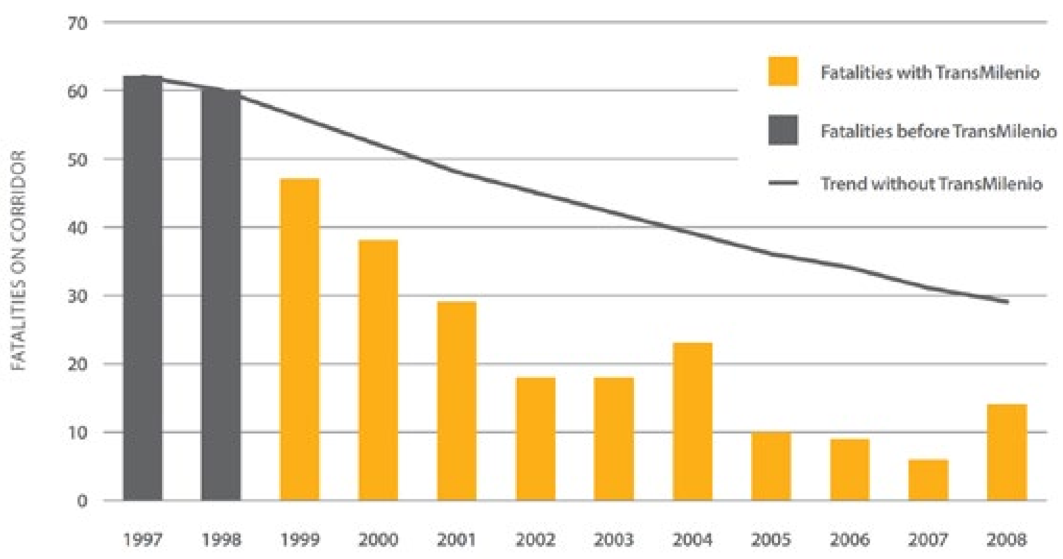
Bogotá provides a successful example of improving road safety by reorganising transit. The city's TransMilenio Bus Rapid Transit (BRT) system was developed to improve mobility and travel times and to cut crashes and emissions. The system started operation in December 2000. The first line saw a thorough reconfiguration of the major Avenida Caracas corridor, eliminating a series of poorly configured junctions with multiple traffic-conflict points. The introduction of BRT saw a reduction in traffic fatalities of more than 50% on the corridor (WRI, 2013; Duduta et al., 2012).

A before-and-after comparison shows that annual traffic fatalities on the corridor decreased from an average of 61 before the implementation of the transport system to an average of 21 during the first nine years of operation, with roughly half of the improvement attributed to the BRT system itself and half to other road safety policies (Figure 3). In the total area where TransMilenio operates, a reduction of 92% in road-related deaths, 75% in injuries and 79% in collisions was observed. According to more recent data, in 2015 the BRT system was involved in 34 fatalities compared to 21 in 2019, for a fatality reduction of 38%. Likewise, according to official fatality data registered during 2021, a projection shows that there will be a further reduction, contributing to increased road safety in Bogotá.

The total costs of the system from the year 2000 until now are estimated at USD 2.2 billion, with the national government covering 64% of investment costs and the District of Bogotá the remaining 36% (Urban Sustainability Exchange, n.d.).

The safety and capacity of BRT infrastructure have been improved by separating priority bus lanes and increasing the number of buses by 40%. Other major projects include the new cable car system TransMiCable, which was put in service in 2018. The new cable car line connects one of the lowest-income neighbourhoods in Bogotá, Ciudad Bolívar, directly to the BRT system. The cable car system has significantly reduced travel times in these inaccessible neighbourhoods.

Figure 3. TransMilenio's traffic safety impact on Avenida Caracas, Bogotá, before and after the implementation of the BRT system



Measure 06

Junction treatment

Most crashes occur at junctions, where different categories of road users cross paths (USDOT, 2020). Interventions to improve junctions, therefore, have the potential to reduce road fatalities substantially. Junction design must allow all road users to cross safely. Several different measures to improve road safety at junctions exist.

Channelling is a measure that separates certain flows of traffic from the overall traffic. **Converting junctions to roundabouts** slows traffic and alters the angle of collisions to reduce the severity of crashes. **Staggered junctions** replace crossroads with two T-intersections, reducing the complexity of conflict points and making crossing junctions easier. **Grade-separated junctions** segregate primary traffic streams from each other by placing them on separate levels; this measure is used for high-traffic-volume roads. Other treatments to **redesign junctions** include changes to the angle between roads and measures to improve lines of sight and eliminate objects that obscure approaches. **Daylighting** describes the removal of parking spaces in front of the curbs around an intersection, increasing visibility for pedestrians and drivers.

Evaluations by the European Road Safety Decision Support System indicate that these junction treatments are effective (Soteropoulos and Stadlbauer, 2017). Strong positive effects are reported for left- and right-turn channellisation, with the number of crashes reduced by 27% and 19%, respectively. Grade separation of intersecting roads is the most effective measure for preventing collisions at junctions, with reductions of between 15% and 45%, depending on the previous junction type (Botteghi, Ziakopoulos and Papadimitriou, 2017). However, this measure involves very high costs and can have several negative effects. Grade separation can cause a “halo effect” with drivers adopting higher speeds. It can also make junctions more difficult to cross for pedestrians and cyclists. Roundabouts and staggered junctions reduce the number of conflict points and lower the number and severity of crashes. Converting a conventional signalised 4-leg junction to a single-lane roundabout reduces crashes by 38% (Soteropoulos and Stadlbauer, 2017b). Roundabouts require minimal maintenance and reduce delays at lower traffic volumes. Daylighting and other sight-distance improvements have been found to reduce the number of collisions significantly by 12% (Soteropoulos and Stadlbauer, 2017c).

Daylighting involves very low costs. Depending on the type of channelisation, costs are estimated to lie between EUR 20 000 and EUR 160 000 (Elvik et al., 2009). By contrast, the cost of grade-separating a junction is estimated at EUR 3.8 million (Elvik et al., 2009). Despite its effectiveness, grade-separation is not always appropriate as it can dominate cityscapes and sever communities as ramps create physical barriers (Anciaes, Jones and Mindell, 2016).

Safe junctions in Fortaleza, Brazil

Fortaleza City Hall implemented a Safe Junctions Programme in 2017. The programme was designed to be easy to implement and to produce rapid results. Junctions were modified mainly with highly visible paint markings to channel traffic, shorten pedestrian crossing distances and widen pavements with some light protection. Other road marking were refreshed and signs added to alert motorists to the existing prohibition of parking near junctions. The interventions were supported by a realignment of communication and enforcement activities.

A before-and-after study of the measures implemented demonstrated the programme’s effectiveness. The main findings were a reduction of 53% in the total number of crashes and a reduction of 60% and 48% for crashes involving injury and property damage, respectively. Cost-benefit analysis using these results (and assuming systematic annual engineering maintenance at the treated intersections) estimated a return of USD 103 for every dollar invested. To date, 450 intersections have been improved with these treatments.

Turn Calming programme in New York City, United States

As part of its Vision Zero initiative, New York City is making efforts to reduce left and right turn speeds to increase safety at junctions. As of December 2020, its Turn Calming programme covered 468 intersections, with several types of treatment applied to redesign the junctions. “Slow turn wedges” combine daylighting and road markings with a raised plastic or rubber pad placed several metres out from the curb. This channels turning vehicles around a steeper turn, reducing speed. The humps can substitute for what would have to be very large curb extensions and can be driven over when necessary by long trucks that would not be able to make a turn around an extended curb. Drivers of light vehicles very rarely chose to mount the humps. “Hardened centrelines” are also used to slow down left-turning traffic and improve the visibility of pedestrians. The “hardened centreline” treatment consists of a hard rubber or plastic curb with bollards that are installed along a centreline at the intersection. (More recent installations omit the bollards as these have proved expensive to maintain and the treatment remains effective without them.) A “complete hardened centreline” combines a “hardened centreline” with a “slow turn wedge”. “Bike Island channelisation” is also used, consisting of a box (the “slow turn wedge”) with flexible plastic posts or rubber speed bump, separating cyclists from motor vehicles and allowing them to turn on the inside of the box. At these intersections, the city has documented reduced turning speeds and fewer incidents (NYCDOT, 2021b).

The implementation of the Turn Calming programme in New York City has led to a significant decrease of pedestrian injuries of 20%, declining faster than nearby comparable locations. Additionally, average left-turn speeds have decreased by 53% and average right-turn speeds have decreased by 34%. These measures have significantly increased vehicle turning safety at low cost (NYCDOT, 2021b).

Measure 07

Hot spot identification and treatment

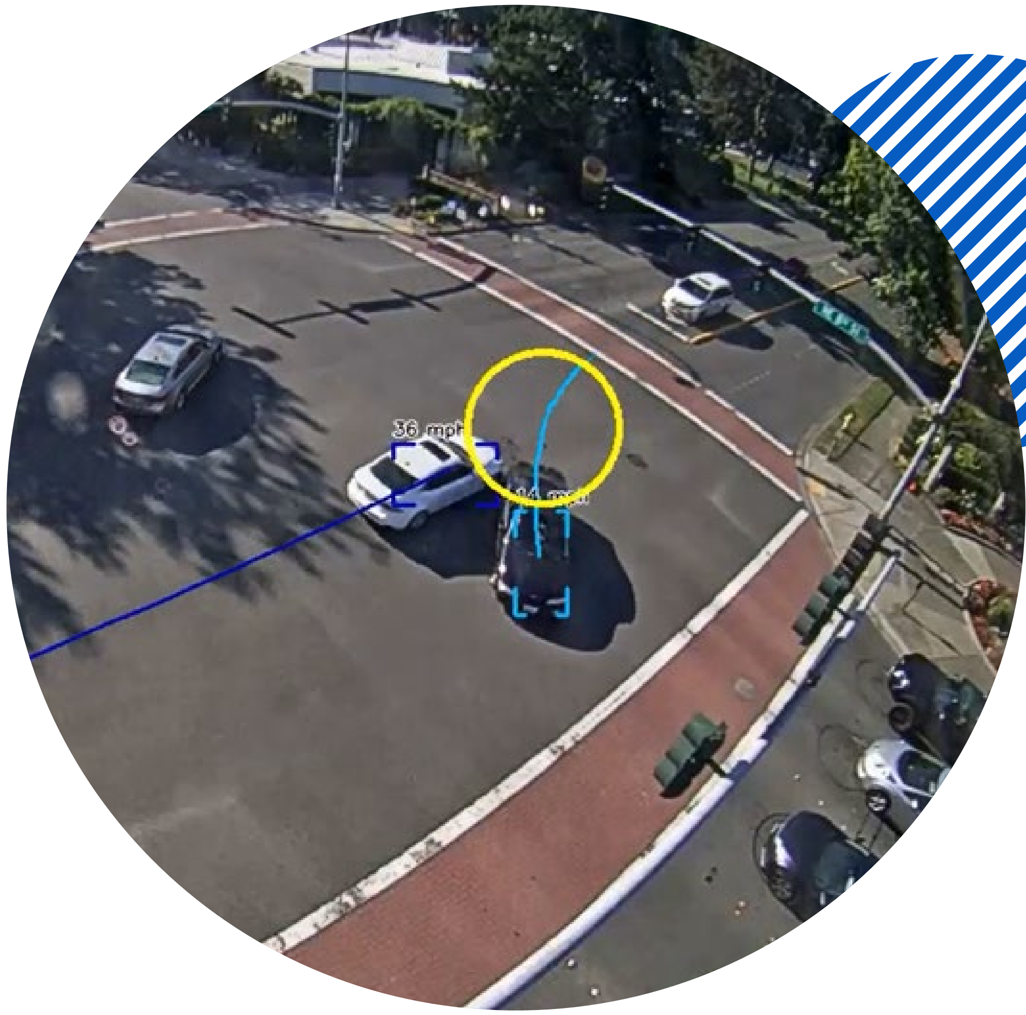
With a limited budget, authorities must identify dangerous locations, called “hot spots”, where injury risk should be addressed as a matter of priority and where road safety gains are maximum. Hot spot identification enables countermeasures to be deployed where they are most needed, contributing to enhanced road safety (Johnsson, Laureshyn and De Ceunynck, 2018).

Various tools and techniques exist to identify high-risk locations. **Crash data** can reveal an accumulation of serious injury and fatal crashes, which calls for immediate countermeasures. **Police crash reports** can reveal that crashes are caused by recurring factors such as road layout, road surface condition or vehicle manoeuvres; in locations where such factors contribute to a high crash risk, this information can help address risk in a proactive manner before casualties are reported. Such data may support the mapping of high-risk locations. **Surrogate safety metrics** are quantitative indicators that are designed to correlate with and predict the number of serious and fatal crashes. Many such metrics are derived from automated video analytics that assess the number and severity of events in which crashes are narrowly avoided.

Hot spot identification through video analytics in Bellevue, Washington State

A project was developed in Bellevue (WA), United States, to identify hot spots with the city’s network of 360degree, high-definition traffic cameras, which have been installed at 40 intersections. The video feeds were analysed to collect data on traffic volumes, road user speeds, and near-crash traffic conflict indicators. Through a public-private partnership, advanced artificial intelligence algorithms and video analytics were then developed to process, analyse and identify safety issues at the intersections. Based on over 5 000 hours of video footage, it was concluded that intersection conflicts and near-crash events are an accurate predictor of where crashes will occur.

Video-based monitoring was also successful in detecting speeding infractions and lane violations. Data collection from all road users and modes of transportation was better than with GPS or Bluetooth sensor data, which only capture some road users. The cameras are relatively easy to deploy and maintain, and videos are easy for people to review and understand, unlike many other data collection technologies that simply provide numerical outputs. The project shows that video analytics for hot spot identification, together with surrogate safety analysis, can assist practitioners in identifying problematic intersections. Video analytics can also help with diagnosing site-specific issues, selecting and implementing improvements, and evaluating outcomes.



Increasing safety of critical pedestrian crossings in Siena, Italy

In Siena, high-risk pedestrian crossings were first identified through the analysis of collision data, then assessed using the criteria of the European Pedestrian Crossings Assessment (EPCA) programme. EPCA is an independent assessment process aimed at highlighting better crossing solutions and at improving behaviour by road users. EPCA considers a broad range of safety factors. First, it conducts a general assessment, including factors such as crossing distance, pedestrian-vehicles conflict points, road surface, and maintenance of markings and signs. Day- and night-time visibility of pedestrian crossings is also assessed. Finally, accessibility for pedestrians is assessed, taking into account sidewalk width and accessibility for persons with disabilities.

Under the programme, six sites have been assigned for priority improvement, including a crossing on Via Armando Diaz that scored poorly on most of the safety assessment criteria. The crossing has no traffic light and crosses a sloping two-lane road to the city centre with high driving speeds. Its weaknesses include poor visibility for drivers and pedestrians (because of a bend in the road) and nearby parking spaces on both sides of the road that mask the crossing. Traffic signs are also hidden by trees. Following the assessment, several measures are being implemented. Sidewalk width will be extended to ensure good visibility for pedestrians and oncoming vehicles. Ramps will be created for wheelchairs on both sides of the pedestrian crossing. Horizontal traffic markings on both sides of the road will be installed to warn drivers of the pedestrian crossing ahead, with rumble strips installed to slow drivers down. Lastly, a vertical and horizontal lighting system will be installed, which is activated by a sensor detecting nearby pedestrians. Due to Covid-19, the planned safety works have been postponed and are scheduled for spring 2022.

Measure 08

Improving road surfaces

Road conditions are an important part of safe street design. Potholes can be a lethal hazard for cyclists and motorcyclists and poor surfaces discourage the use of bicycles. Regular maintenance is essential, and improved surfaces may be required for durability in difficult weather environments.

Maintenance of **road surface friction and control of unevenness and rutting** of the road surface is essential to the safety of all road users. Depending on the scale of degradation, defective road surfaces require **resurfacing or rehabilitation and reconstruction** that bring them up to current design standards. Regular surface maintenance extends the lifetime of pavements and should include maintenance of the quality and visibility of **road markings and signage**.

The *Handbook of Road Safety Measures* identifies road surface rehabilitation and reconstruction, resurfacing and regular winter maintenance as effective measures for reducing crashes. The costs of road surface treatments depend on the specific measures.

Improving the road surface for cyclists in Dublin, Ireland

Dublin City Council is using mobile data technology to improve road surfaces for cyclists following a project supported by the SynchroniCity initiative with support from an EU research grant. The Council collected data with the help of See.Sense's GPS tracking devices, which monitor braking, swerving, collisions, and road surface conditions as well as location. Data was also collected on speed, dwell time, collisions and near-miss events. Traditionally, the Council is dependent on physical observation and reporting from citizens to identify poor road conditions. The project transformed the quality and coverage of information available to the Council.

Anonymised data from See.Sense was shared with the city and allowed planners and engineers to improve the infrastructure where the road surface was found to be problematic. The data was gathered through the distribution of bicycle lights that record harsh movements due to road surface defects or emergency manoeuvres. Two hundred project participants received the tracker bicycle lights and agreed to share the data collected by the sensors. The project results showed which road surfaces were particularly challenging for cyclists. The information gathered from the project was used to plan the development of Dublin's most recent cycle infrastructure improvements (Smart Dublin, 2019).

Measure 09

Traffic signalling and intelligent transport systems

Technology plays an increasingly important role in road safety, and smart traffic signalling can contribute to improved road safety. Innovative solutions include traffic surveillance and control systems to provide speed control and warnings, lane departure warnings, and control and exchange of information with urban traffic control systems (ROSEBUD, 2006).

The timing and configuration of **traffic lights** are particularly important. For example, **leading pedestrian intervals** to indicate "walk" to pedestrians several seconds before turning traffic gets a green light improves pedestrian safety. This measure gives pedestrians a head start, which makes them more visible and decreases the risk of being hit by a car (Fayish and Gross, 2010).

Vehicles are becoming increasingly connected by devices that interact with each other and the road infrastructure. This interaction is captured by the term **Cooperative Intelligent Transport Systems (C-ITS)** and the data can be shared with traffic managers. Vehicle-to-vehicle communication and vehicle-to-infrastructure communication channels are used for emergency braking warning, distance sensing, improper-driving detection, collision-avoidance systems, weather-related skid warnings and optimised intersection management.

The introduction of **Intelligent Speed Assistance**, mandatory on new vehicles models in the EU from 2022, will facilitate intelligent use of speed limits on city streets. These systems use a GPS-linked speed-limit database, and sometimes sign-recognition video cameras, to help drivers keep to speed limits (ETSC, 2018). When speeds exceed regulated limits, the driver is alerted or the speed is automatically reduced, thereby reducing the exposure of road users to crash risks as well as the risk of speeding fines for drivers equipped with the system. Local governments have to digitise their speed limit maps and keep them up to date in order for these systems to deliver their full potential benefits. Stockholm's government earmarked funds in its 2020 budget to equip all municipal vehicles with intelligent speed adaptation and to use geofencing to prevent them from exceeding speed limits across the city (Closer, 2020).

Improved traffic signal timing, such as leading pedestrian intervals, can reduce the risk of pedestrian-vehicle crashes substantially, with some studies reporting up to 60% (Fayish and Gross, 2010). Traffic signal installation at uncontrolled junctions can also reduce collisions significantly by 29% (Ziakopoulos, Botteghi and Papadimitriou, 2017). The European Transport Safety Council (ETSC, 2018) expects that the mass adoption and use of intelligent speed assistance technology can reduce collisions by 30% and deaths by 20%; however, robust safety benefits need to be evaluated in the future.

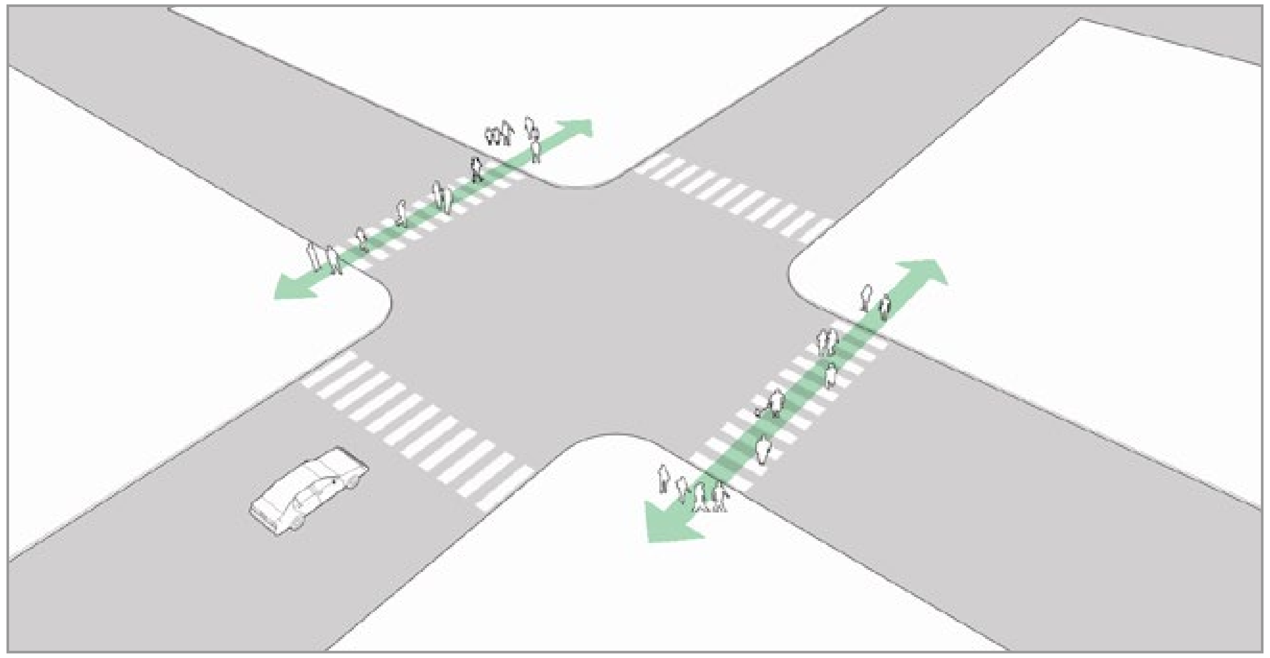
The purchase and installation of a traffic signal costs around EUR 215 000 to EUR 430 000 (WSDOT, 2021). Maintenance costs have to be considered. Costs for changing the signal timings are low.

Pedestrian head starts in New York City, United States

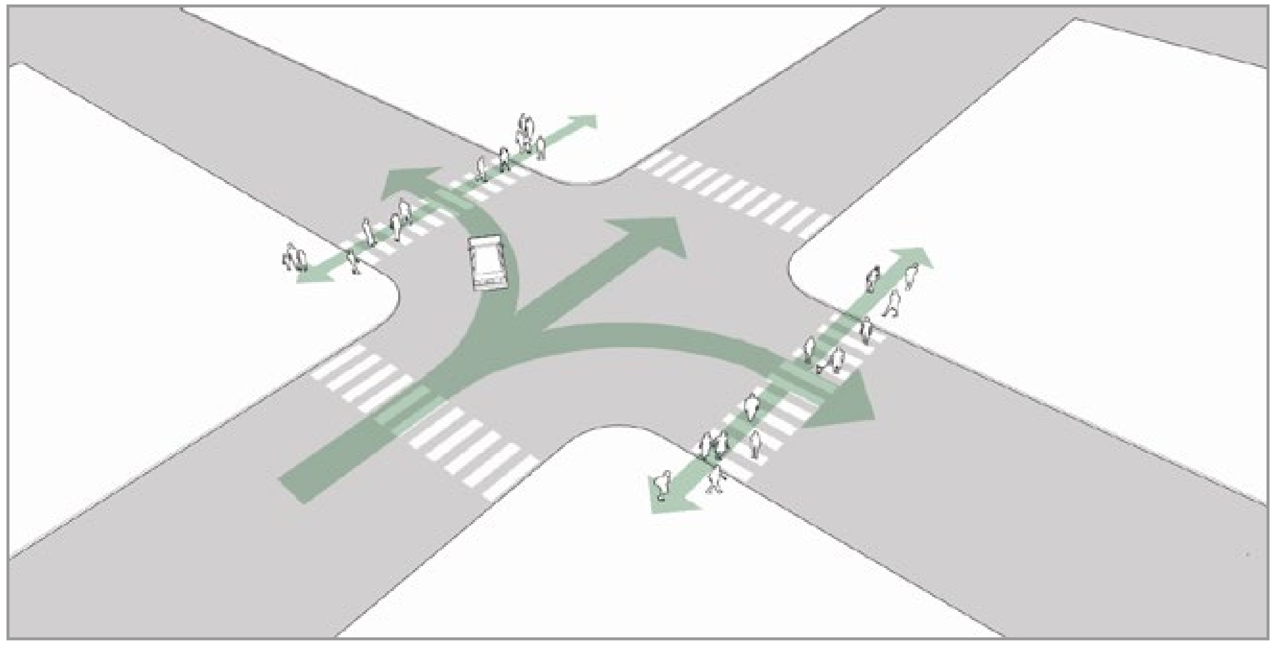
In New York City, left turns account for more than twice as many pedestrian and bicyclist fatalities as right turns, and over three times as many serious injuries and fatalities. As a result, The New York City Department of Transportation (NYCDOT) has prioritised the treatment of left-turn pedestrian and bicyclist injuries under its Vision Zero initiative. In 2015, the city started installing over 400 Leading Pedestrian Intervals (LPIs) at priority Intersections; since 2016, 800 LPIs have been installed every year. In total, almost 5 000 LPI crossings have been implemented in the city. These signals hold traffic for several seconds at the beginning of the pedestrian "Walk" phase, allowing pedestrians or cyclists to establish their presence in the intersection before turning traffic is permitted to proceed. Additionally, on major urban one-way arterial roads with high pedestrian and bicycle volumes, traffic signals have been modified to entirely separate left-turning traffic from the "walk" phase for pedestrians and cyclists. This measure provides pedestrians and bicyclists with a conflict-free crossing while turning traffic has to wait.

A before-and-after crash analysis of 104 intersections with LPIs found that left-turn pedestrian and bicycle injuries declined by 14% and the number of left-turning pedestrians and bicyclists killed and seriously injured declined by 56%. Intersections where green lights for motor vehicles and vulnerable road users have been split experienced a reduction of 33% for left-turn pedestrian and bicyclist injuries and a 25% reduction for total pedestrian and bicyclist injuries. This simple and invisible treatment is cheap and scalable and has delivered tangible road safety improvements.

Figure 4. Traffic signals with a leading pedestrian interval



Leading pedestrian intervals hold all through and turning traffic for a number of seconds after the pedestrian "Walk" signal begins (above). When the traffic signal turns green, turning vehicles must yield to pedestrians already in the crosswalk (below).



Source: NACTO (n.d)

Further reading

The resources below can support cities with evidence-based policy making for enhanced road safety. They provide detailed information on road safety measures that can be implemented in urban areas.

BIKESAFE, Bicycle Safety Guide and Countermeasure Selection System, http://www.pedbikesafe.org/BIKESAFE/index.cfm.

Elvik, R., Høye, A., Vaa, T. and Sørensen, M. (2009), The Handbook of Road Safety Measures, Second Edition, Emerald Group Publishing, Institute of Transport Economics, Oslo, Norway, https://doi.org/10.1108/9781848552517.

iRAP (2010), Road Safety Toolkit, http://toolkit.irap.org/.

National Association of City Transportation Officials, Urban Street Design Guide, https://nacto.org/publication/urban-street-design-guide/.

PIARC, WRA Road Safety Manual, https://roadsafety.piarc.org/en.

PEDSAFE, Pedestrian Safety Guide and Countermeasure Selection System, http://www.pedbikesafe.org/PEDSAFE/index.cfm.

SafetyCube, EU Road Safety Decision Support System, https://www.roadsafety-dss.eu/.

WRI Ross Center for Sustainable Cities, Cities Safer By Design, https://publications.wri.org/citiessafer/.

References

Anciaes, P.R., Jones, P. and Mindell, J.S. (2016), "Community Severance: Where Is It Found and at What Cost?", Transport Reviews, 36:3, 293-317, http://dx.doi.org/10.1080/01441647.2015.1077286.

APTA (2016), The Hidden Tra¬ffic Safety Solution: Public Transportation, American Public Transportation Association,https://www.apta.com/wp-content/uploads/Resources/resources/reportsandpublications/Documents/APTA-Hidden-Traffic-Safety-Solution-Public-Transportation.pdf (accessed 08 November 2021).

Botteghi, G., Ziakopoulos, A., Papadimitriou, E. (2017), Convert at-grade junction to interchange, European Road Safety Decision Support System, developed by the H2020 project SafetyCube, https://www.roadsafety-dss.eu/assets/data/pdf/synopses/Convert_atgrade_junction_to_interchange_20102017.pdf (accessed 08 November 2021).

Carey, C. (2020), "Barcelona to expand 'superblocks' to city centre district", https://cities-today.com/barcelona-to-expand-superblocks-to-city-centre-district (accessed 08 November 2021).

City of Bristol (2014), "Pedestrian Guardrails", https://www.trafficchoices.co.uk/traffic-schemes/guardrails.shtml (accessed 08 November 2021).

Closer (2020), "Speeders in Stockholm to be stopped with geofencing", https://closer.lindholmen.se/en/news/speeders-stockholm-be-stopped-geofencing (accessed 08 November 2021).

Davis, A. (2020), School Street Closures and Traffic Displacement: A literature review and semi-structured interviews, Transport Research Institute, Edinburgh Napier University, https://www.napier.ac.uk/~/media/images/news/school-street-closures/school-streets-closure-traffic-displacement-literature-review-final2.pdf.

Deegan, B (2018), "Light Protection of Cycle Lanes: Best Practices", Discussion Paper, International Transport Forum, Paris.

Duduta, N., Adriazola, C., Hidalgo, D., Lindau, L.A. and Jaffe, R. (2012), "Understanding the Road Safety Impact of High Performance BRT and Busway Design Characteristics",

Transportation Research Record 2317: 8–14, http://www.brt.cl/wp-content/uploads/2013/03/Duduna-et-al-2012.pdf.

EMTA (2020), "EMTA Barometer 2020", https://www.emta.com/IMG/pdf/2018_emta_barometer-200526.pdf (accessed 08 November 2021).

ETSC (2018), "Briefing: Intelligent Speed Assistance (ISA)", European Transport Security Council, https://etsc.eu/wp-content/uploads/2018-05-ISA-briefing_updated-Nov-18.pdf (accessed 08 November 2021).

European Commission (2018), “Speed and Speed Management”, European Road Safety Observatory, https://ec.europa.eu/transport/road_safety/sites/default/files/pdf/ersosynthesis2018-speedspeedmanagement.pdf (accessed 08 November 2021).

Fayish, A. C. and Gross, F. (2010), “Safety Effectiveness of Leading Pedestrian Intervals Evaluated by a Before–After Study with Comparison Groups”, Transportation Research Record, 2198(1), pp. 15–22, https://doi.org/10.3141%2F2198-03.

Goldenbeld, Ch. and Schermers, G. (2017), “Creation of bypass roads, European Road Safety Decision Support System”, developed by the H2020 project SafetyCube, https://www.roadsafety-dss.eu/assets/data/pdf/synopses/Creation_of_bypass_roads_24052017.pdf (accessed 08 November 2021).

Harkey, D.L. and Stewart, J.R. (1997), “Evaluation of shared-use facilities for bicycles and motor vehicles”, Transportation Research Record 1578, 111–118, Paper No. 970840, https://doi.org/10.3141%2F1578-14.

ITF (2016), Zero Road Deaths and Serious Injuries: Leading a Paradigm Shift to a Safe System, OECD Publishing, Paris, https://doi.org/10.1787/9789282108055-en

ITF (2018), “Speed and Crash Risk”, IRTAD,https://www.itf-oecd.org/sites/default/files/docs/speed-crash-risk.pdf.

ITF (2019), “Road Safety in European Cities: Performance Indicators and Governance Solutions”, International Transport Forum Policy Papers, No. 67, OECD Publishing, Paris, https://www.itf-oecd.org/sites/default/files/docs/road-safety-european-cities-performance-indicators.pdf.

ITF (2020a), “Monitoring Progress in Urban Road Safety”, International Transport Forum Policy Papers, No. 79, OECD Publishing, Paris, https://www.itf-oecd.org/sites/default/files/docs/monitoring-progress-urban-road-safety.pdf.

ITF (2020b), “Best Practice for Urban Road Safety: Case Studies”, International Transport Forum Policy Papers, No. 76, OECD Publishing, Paris, https://www.itf-oecd.org/sites/default/files/docs/best-practice-urban-road-safety.pdf.

Jacobsen, P.L. (2003), “Safety in Numbers: More Walkers and Bicyclists, Safer Walking and Bicycling”, Injury Prevention 9: 205–9, https://doi.org/10.1136/ip.9.3.205.

Johnsson, C., Laureshyn, A. and De Ceunynck, T. (2018), “In search of surrogate safety indicators for vulnerable road users: a review of surrogate safety indicators”, Transport

Reviews, 38:6, 765-785, https://doi.org/10.1080/01441647.2018.1442888.
Koorey, G., Wilke, A., Aussendorf, J. (2013), Assessment of the Effectiveness of Narrow Separators on Cycle Lanes, Dunedin, New Zealand: IPENZ Transportation Group Conference 2013.

Kröyer, H. R. G., Jonsson, T., Varhelyi, A. (2014), “Relative fatality risk curve to describe the effect of change in the impact speed on fatality risk of pedestrians struck by a motor vehicle”, Accident Analysis and Prevention, 62, pp. 143-152, https://doi.org/10.1016/j.aap.2013.09.007.

Li, H. and Graham, D. (2016), “Quantifying the causal effects of 20mph zones on road casualties in London via doubly robust estimation”, Accident Analysis and Prevention, Volume 93, pp. 65 74, https://doi.org/10.1016/j.aap.2016.04.007.

Lichtman-Sadot, S. (2019), “Can public transportation reduce accidents? Evidence from the introduction of late-night buses in Israeli cities”, Regional Science and Urban Economics, Vol. 74, https://doi.org/10.1016/j.regsciurbeco.2018.11.009.

NACTO (n.d.), National Association of City Transportation Officials, website, https://nacto.org/publication/urban-street-design-guide/intersection-design-elements/traffic-signals/leading-pedestrian-interval/ (accessed 24 November 2021).

NYCDOT (2021), “14th Street Busway”, New York City Department of Transportation, https://www1.nyc.gov/html/brt/html/routes/14th-street.shtml (accessed 08 November 2021).

NYCDOT (2021b), “Turn Calming Program”, New York City Department of Transportation, https://www1.nyc.gov/html/dot/html/pedestrians/turn-calming.shtml (accessed 08 November 2021).

Pedestrian Safety Guide and Countermeasure Selection System (2013), “Sidewalks, Walkways and Paved Shoulders”, http://www.pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=1 (accessed 08 November 2021).

Pompeo, E. and Abdulsamad M. (n.d.), ‚Measure What Matters: Reclaiming Space for Pedestrians in Downtown Fortaleza”,https://globaldesigningcities.org/2019/12/10/metrics-matter (accessed 08 November 2021).

ROSEBUD (2006), Examples of assessed road safety measures, Road Safety and Environmental Benefit-Cost and Cost-Effectiveness Analysis for Use in Decision-Making, https://ec.europa.eu/transport/road_safety/sites/default/files/pdf/projects_sources/rosebud_examples.pdf (accessed 08 November 2021).

Santacreu, A. (2018), “Safer City Streets Global Benchmarking for Urban Road Safety” International Transport Forum Working Document, OECD Publishing, Paris, https://www.itf-oecd.org/sites/default/files/docs/safer-city-streets-global-benchmarking-urban-road-safety.pdf.

Schwartz, S. (2020), “14th Street Transit and Truck Priority Project”, https://static1.squarespace.com/static/5bc63eb90b77bd20c50c516c/t/5ec421b14abb5b1fa619df9e/1589912002654/14+Street+Report+2+Winter+2020.pdf (accessed 18 November 2021).

Soteropoulos, A., and Stadlbauer, S. (2017), “Convert 4-Leg Junction to Staggered Junction, European Road Safety Decision Support System”, developed by the H2020 project SafetyCube, https://www.roadsafety-dss.eu/assets/data/pdf/synopses/

Convert_4LegJunction_to_Staggered_Junction_03052017.pdf (accessed 08 November 2021).
Soteropoulos, A. and Stadlbauer, S. (2017b), “Convert junction to roundabout, European Road Safety Decision Support System”, developed by the H2020 project SafetyCube, https://www.roadsafety-dss.eu/assets/data/pdf/synopses/Convert_junction_to_roundabout_03052017.pdf (accessed 08 November 2021).

Soteropoulos, A., Stadlbauer, S. (2017c), “Sight Distance Treatments, European Road Safety Decision Support System”, developed by the H2020 project SafetyCube, https://www.roadsafety-dss.eu/assets/data/pdf/synopses/Sight_Distance_Treatments_02052017.pdf (accessed 08 November 2021).

Smart Dublin (2019), “Smart Bike Lights – Support Safer Cycling Infrastructure”, https://smartdocklands.ie/project/smart-bike-lights-synchronicity (accessed 08 November 2021).

Shackel, S.C. and Parkin J. (2014), “Influence of road markings, lane widths and driver behaviour on proximity and speed of vehicles overtaking cyclists”, Accident Analysis and Prevention, 73 (2014), pp. 100 108, https://doi.org/10.1016/j.aap.2014.08.015.

Stockholm Declaration and 3rd Global Ministerial Conference on Road Safety, https://www.roadsafetysweden.com (accessed 08 November 2021).

Seya, H., Kazuki Yoshida, K. and Inoue, S. (2021), “Verification of Zone-30-policy effect on accident reduction using propensity score matching method for multiple treatments”, Case Studies on Transport Policy, Volume 9, Issue 2, pp. 693-702, https://doi.org/10.1016/j.cstp.2021.03.007.

Transport for London (2017), “Collisions Before and After the Removal of Pedestrian Railings at 70 Junctions and Crossings on the Transport for London Road Network”, https://content.tfl.gov.uk/pedestrian-railings-removal-report.pdf (accessed 08 November 2021).

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 (accessed 08 November 2021).

Transport for London (2018), “Transport for London Budget 2018/2019”, http://content.tfl.gov.uk/transport-for-london-budget-2018-19.pdf (accessed 18 November 2021).

Urban Sustainability Exchange (n.d.), “TransMilenio Bus Rapid Transit System”, https://use.metropolis.org/case-studies/transmilenio-bus-rapid-transit-system#casestudydetail (accessed 08 November 2021).

U.S. Department of Transportation (2020), “Intersection Safety”, https://highways.dot.gov/research/research-programs/safety/intersection-safety (accessed 08 November 2021).

WRI (2018), Sustainable and Safe: A Vision and Guidance for Zero Road Deaths, Ross Center for Sustainable Cities with the Global Road Safety Facility, https://www.wri.org/research/sustainable-and-safe-vision-and-guidance-zero-road-deaths.

WRI (2013), Saving Lives With Sustainable Transport, EMBARQ, https://wrirosscities.org/sites/default/files/Saving-Lives-with-Sustainable-Transport-EMBARQ.pdf.

WSDOT (2021), “Traffic signals”, Washington State Department of Transportation, https://wsdot.wa.gov/Operations/Traffic/signals.htm#:~:text=It%20costs%20the%20taxpayer%20%24250%2C000,%2C%20time%20delay%2C%20and%20accidents (accessed 14 October 2021).

World Road Association (PIARC) (2019), “Infrastructure Safety Management: Policies, Standards, Guidelines and tools”, Road Safety Manual, Chapter 9, https://roadsafety.piarc.org/en/planning-design-operation/infrastructure-management (accessed 08 November 2021).

Ziakopoulos, A., Botteghi, G., Papadimitriou, E., (2017), “Traffic signal installation, European Road Safety Decision Support System”, developed by the H2020 project SafetyCube, https://www.roadsafety-dss.eu/assets/data/pdf/synopses/Traffic_signal_installation_20102017.pdf (accessed 08 November 2021).

Photo credits: cover Lélio Ivo/AMC; p. 8 SEMOVI/CDMX; p. 9 adapted from WRI (2018); p.10 Paulo Winz/NACTO-GDCI; p. 11 Camden Council, Urban Movement; p. 12 Patrick Shutterstock/ Shutterstock; p. 13 Authors (ITF); p. 14 Secretaría de Movilidad de Bogotá; p. 15 Pedro Alves Nave/CML, Pedro Alves Nave/CML; p. 17 Willy Barton/Shutterstock; p. 18 Jeremy Menzies/SFMTA Photo Archive; p. 19 Barcelona City Council; p. 21 Américo Simas/CML, p.21 Américo Simas/CML; p. 22 SEMOVI, CDMX; p. 23 NYCDOT; p. 24 WRI, based on data from TRANSMILENIO S.A.; p. 25 Secretaría de Movilidad de Bogotá; p. 26 Tupungato/Shutterstock; p. 27 Lélio Ivo/AMC; p.29 NYCDOT; p. 29 NYCDOT; p.30 Have a nice day Photo/Shutterstock p.31 Together For Safer Roads; p. 33 Estherpoon/Shutterstock, Enrico Pagliari/ACI; p. 34 Volodymyr_Shtun/Shutterstock; p. 35 See.Sense, See.Sense; p. 36 Vereshchagin Dmitry/Shutterstock; p. 37 Blue Planet Studio/Shutterstock; p. 39 NACTO, NACTO

International Transport Forum

Road Safety in Cities

Street Design and Traffic Management Solutions

This booklet presents measures that effectively reduce road traffic deaths and serious injuries in cities. It covers urban street design, traffic management and improving mobility options. Measures are illustrated with examples reported by cities collaborating in the ITF Safer City Streets network and include information on cost and effectiveness.

OECD

ROAD SAFETY GRANT PROGRAMME

FOUNDATION