TOD K P

GOOD PRACTICE NOTE

Integration of Road Safety Considerations in Transit-Oriented Development projects

WORLD BANK GROUP | TOD | Global Platform for Sustainable Cities | gef | UKaid from the British people | GRSF Global Road Safety Facility | IBI | WRI INDIA

TOD KP

This note was prepared with funding from UK AID, through the Global Road Safety Facility (GRSF), for the World Bank as part of the assignment: ***"Integration of Road Safety Considerations in Transit-Oriented Development Projects"***.

It has been prepared by World Resources Institute India (WRI India) team led by Prerna V. Mehta and included Abhishek Behera, Binoy Mascarehnas and Jaya Dhindaw, and supported by Madhav Pai, Chetan Sodaye, Dhawal Ashar, Himanshi Kapoor and Rajeev Malagi; under the leadership of Gerald Ollivier and Alina Burlacu, with peer review by Blanca Domine, Said Dahdah, Wanli Fang, and Juan Miguel Velasquez Torres. Dipan Bose offered helpful comments during the finalization of the document.

September 2020

ABBREVIATIONS

AE	Automated Enforcement
BRT	Bus Rapid Transit
FOB	Foot over bridge
GDP	Gross Domestic Product
IPT	Intermediate Public Transport
NMT	Non-motorized Transport
PIARC	World Road Association
RSIA	Road Safety Impact Assessment
ROW	Right of Way
RSA	Road Safety Audit
RSI	Road Safety Inspection
SAM	Safe Access Mass-transit
TOD	Transit Oriented-Development
VKT	Vehicle Kilometers Traveled
WRI	World Resources Institute

LIST OF TABLES

LIST OF FIGURES

CONTENTS

INTRODUCTION

1. Based on 2018 findings of the World Health Organization (WHO), the number of deaths due to road crashes is 1.35 million deaths per year. While this number is quite high and increasing every year, the rate of road crash deaths per 100,000 of population has remained constant, at around 18 deaths, over the years. This rate of deaths is however not distributed proportionately amongst the different regions and countries. The high-income countries have recorded lowest average rate at 8.3 per 100,000. In contrast to this number, low-income countries have the highest annual road traffic fatality rates averaging at 27.5 deaths per 100,000– more than three times the average for high-income countries.

ROAD CRASH AND IMPACT

2. Most of the deaths and injuries from road crashes are of the working age population, which negatively impacts both the economy and the demography of the region. Road traffic injuries are currently the 8th leading cause for death for all age groups, and further compounding the demographic impact is the fact that road crashes are the leading cause of death for children and young adults, between the ages of 5 and 29 years.

3. Road traffic crashes have a high economic impact, costing 3 percent of a country's GDP on average. They also cause a significant impact on the individuals as well as their families. Injuries arising due to road crashes can lead to trauma for the individual and loss in productivity. Along with costs of treatment, economic challenges may further be increased due to temporary or permanent loss of income as well. Along with the victim, road crashes take an emotional toll on the immediate family members and caregivers during treatment process or any deaths and add to the economic burden as they may need to take time off work or school to care for the injured.

4. The distribution of road users varies within different regions and income groups of countries. This impacts the variations in death rates amongst the users. The low- and middle-income countries have a significantly high proportion of pedestrians, cyclists and two- or three-wheeler motorized vehicles. Overall, the global road traffic deaths for pedestrians and cyclists is at 26% and another 28% for two- and three-wheeler motorcyclists, totaling nearly 54% of vulnerable road users. This proportion varies in comparison between the economic group of countries, with a high percentage of road crash victims being car occupants.

	Americas	Europe	Africa	Eastern Mediterranean	South-east Asia	Western Pacific	World
Drivers/ passengers of 4 wheeler vehicles	34%	48%	40%	39%	16%	22%	29%
Motorized 2-3 wheeled vehicles	23%	11%	9%	15%	43%	36%	28%
Cyclists	3%	5%	4%	2%	2%	6%	3%
Pedestrians	22%	27%	40%	34%	14%	22%	23%
Others/ unspecified	18%	9%	7%	10%	25%	14%	17%

Table 1. Distribution of deaths by road user type by WHO Region (Source: WHO 2018)

5. Globally, a significant percentage of road crash victims being car occupants is also an indicator of insufficient infrastructure for controlling traffic speeds and volumes. Furthermore, when people use private cars more for their daily activities, it results in a higher level of total vehicle-kilometers traveled (VKT). Choice of using personal vehicle over using non-motorized transport or public mass transport may be attributed to the car-centric planning and design of road infrastructure. Many countries lack adequate protected infrastructure for pedestrians and cyclists. This discourages users to walk or bicycle to their destinations.

6. Mode-choice plays a critical role in road safety. Public mass transit systems not only provide faster and safer transportation mode choices, they also help reduce dependency on privately owned vehicles on the road. Public mass transit services typically follow designated routes as well, thereby minimizing interferences between different types of road users. While many countries still have to develop mass transit infrastructure such as metro rails, public bus system is quite prevalent, with bus rapid transit (BRT) and bus only lane infrastructures being developed. Absence of proper first and last mile connectivity to the transit stations poses security threats for road users and discourages them from using public transport.

7. Additionally, a city's urban form conditions, such as built density, land-use mix and street layout, are also critical aspects for road safety, and can impact a variety of influencing factors, ranging from traffic speed to modal choice. Larger block sizes and suburban layouts mean longer walking and biking distances for users and hence a preference for private vehicles. Barcelona, Spain and Atlanta, USA both have comparative population sizes (2.8 million and 2.5 million respectively). However, they vastly differ in built-up area, with just 162 sq.km for Barcelona, compared to 4280 sq.km for Atlanta. This has a significant impact on mode choice, where only 20% of trips in Barcelona are car dependent, compared to 77% in Atlanta. The road safety impact is clearly evidenced by the traffic fatality rate of just 1.9 deaths per 100,000 population in Barcelona compared to 9.7 deaths in Atlanta.

SAFE SYSTEM APPROACH

8. The Safe System approach derives from the Swedish ***Vision Zero*** and Dutch ***Sustainable Safety*** strategies that have a long-term goal for a road traffic system to be eventually free from fatalities and serious injuries. It represents a shift away from traditional approach of preventing collisions to a more forgiving approach of preventing fatalities and mitigating serious injuries in road crashes. The traditional approach emphasizes the responsibility of road users to avoid crashes rather than the responsibility of system designers to provide a safe mobility system.

9. The Safe System approach takes into account that humans are vulnerable and fallible, and errors are to be expected. It aims at ensuring these mistakes do not lead to a crash, and if a crash does occur, it is sufficiently controlled to not cause a death or a life-changing injury. Thereby with a "zero-harm goal", it places a strong emphasis on road builder/operator and vehicle manufacturer accountability for road safety performance.

10. The Safe System approach emphasizes shared responsibility. Government agencies at different levels and a range of multi-sectoral agencies and stakeholders – including policy makers, road engineers, planners, vehicle manufacturers, enforcement officers, emergency medical agencies, road safety educators etc. – are accountable for the system's safety and all road users – drivers, cyclists, and pedestrians are responsible for complying with the system rules.

11. This approach further caters to the larger socio-economic and environmental challenges faced in urban areas. While making the road an equitable space for all users, ensuring accessibility and usability for all, it helps address issues associated with road traffic such as congestion, public health, and pollution.

12. The Safe System approach is anchored around the following four principles:

- **People make mistakes** that can lead to road crashes.
- **People are vulnerable** – The human body has a limited physical ability to tolerate crash forces before harm occurs i.e. being seriously injured or killed.
- **A shared responsibility** – Those who plan, design, build, and manage roads and vehicles and provide post-crash care share the responsibility to prevent crashes resulting in fatal and serious injuries. In a true Safe System, road users also have the responsibility such as vehicle safety feature maintenance, complying with the policies etc.
- **Strengthen all parts of the system** – There is a need to improve the safety of all parts of the system - roads and roadsides, speeds, vehicles, and road use - and if one part fails, road users are still protected.

13. Along with these principles, it must also be noted that road crash deaths and serious traffic crashes and injuries are preventable and should not be accepted as part of the mobility system. Lack of safety should not be a trade-off for faster mobility. Rather, the mobility system should be both safe and efficient.

14. Safe system comprises of four components below (Figure 1):

- **Safer Roads:** Safety features are to be included into the design of roads in order to reduce the risk of crashes and the severity of injuries if a crash occurs. Typical measures include segregation of different types of road users and traffic moving at different directions and speeds, traffic calming measures, targeted improvements of crash hot-spot etc.
- **Safer Speeds:** Speed limits help in avoiding crashes and the severity of the same. The human body being vulnerable has a limit for experiencing and enduring physical trauma. Based on road types and the contexts, appropriate speed limits need to be established and enforced.
- **Safer Vehicles:** Vehicles are to be designed and maintained to minimize the occurrence and consequences of crashes focusing on the survivability post a collision. While the vehicle design technology (braking systems, sensors, passive safety components etc) is critical, the onus is also on the users to buy safer vehicles and maintain them to the highest standards.
- **Safer Road Users:** As part of the shared responsibility, it is necessary for road users to comply with the road rules and for system designers to actively work towards reduction of traffic volumes, educating users of the risks, adhering to proper usage of roads, ensuring proper post crash health facility etc.

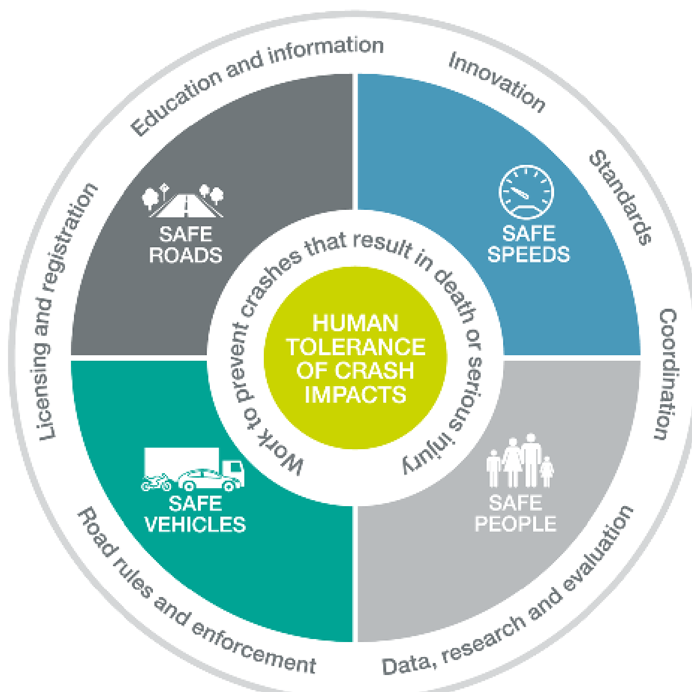


Figure 1. Safe system diagram

Adapted from Safer Roads, Safer Queensland: Queensland's Road Safety Strategy 2015–21 (www.roadsafety.gov.au/nrss/safe-system)

CASE FOR TRANSIT-ORIENTED DEVELOPMENT (TOD)

15. In order to achieve sustainable growth, globally cities are looking at integrating land use and transportation planning. An outcome of this endeavor is the application of transit-oriented development, better known by its acronym TOD. It is a “multidisciplinary planning and design strategy to ensure compact, mixed-use, mixed-income, pedestrian and two-wheeler friendly cities, and suitably dense urban development organized around transit stations”. By virtue of its character, a TOD scheme advocates for environmental sustainability by promoting public transit and non-motorized transport, and socially-inclusive economic development that is equitably distributed creating safe urban spaces for all users.

16. The World Bank’s TOD Community of Practice summarizes eight key principles for implementing TOD:

    - Align human densities, economic densities, mass transit capacity, and transit network characteristics for greater accessibility.
    - Create compact regions with short commutes.
    - Ensure the resilience of areas connected by mass transit.
    - Plan and zone for mixed-use and mixed-income neighborhoods at a corridor level.
    - Create vibrant, people-centric public spaces around mass transit stations.
    - Develop neighborhoods that promote walking and cycling.
    - Develop good-quality, accessible, and integrated public transit.
    - Manage demand for private vehicles.

17. TOD involves creating concentrated nodes of moderate-to-high density developments supporting a balanced mix of diverse land uses which are located within 5-10 minutes of walking distance, I,e, 800m-1km from mass rapid transit stations. This integration of transportation and land use planning, with other elements such as market demands, environmental systems, community input and technical efficiencies, allows for placement of employment, entertainment, leisure and residential uses near each other around the rapid transit stations. This allows for reduced trip lengths and number of trips and prioritizes public transit use and reduces dependency on private motor vehicles.

18. There is a strong interrelationship between TOD and road safety. A well-executed TOD scheme has the potential to make far-reaching impacts on the road safety scenario in the city. At the citywide level, TOD influences urban form and mode-choice; two very critical factors for road safety. The mixed-use land use developments with active frontage and accessible services centered within safe walking and cycling distances around transit stations, encourages users to choose for transit combined with non-motorized commute over use of cars. This pattern of considerable mode shift minimizes the number of cars on the street thereby reducing the chances of conflicts. At the neighborhood level, TOD promotes more pedestrian-friendly streets with lower traffic speeds, which significantly improves the safety of the most vulnerable road-user group.

19. This note forms a part of the engagement between the World Bank and World Resources Institute India (WRI India) to leverage existing work on “TOD Implementation and Resource Tools” being developed as part of the Global Platform for Sustainable Cities (GPSC), by identifying and addressing road safety gaps to develop improved guidelines to apply the safe system approach to existing TOD projects around the world.

SCOPING

20. As part of the engagement between the World Bank and WRI India, a review of existing literature and references on TOD projects developed by the World Bank and other leading organizations and practitioners across the world was undertaken to analyze best practices of urban road safety. A road safety diagnostic on the existing TOD Toolkit Knowledge Products was also carried to identify gaps and how to address the same.

21. It was observed that the existing literature and the toolkits discussed the importance of TOD and how to execute a TOD project from an institutional setup, planning along transit routes, and financing of the same. They however did not explicitly discuss the need for enabling or ensuring road safety within a TOD area.

22. These gaps have then been subsequently addressed by World Resources Institute to support systematic inclusion of roads safety and universal accessibility in TOD projects through five stages of TOD implementation - ***Assess, Enable, Plan & Design, Finance*** and ***Implement***.

23. This Good Practice Note summarizes the various road safety considerations and measures that may be undertaken.

ASSESS

24. 'Assess' is the first stage of the TOD Resources and Implementation toolkit. This initial stage helps in determining how "ready" a city is for TOD, based on "analysis of a complementary set of economic, geographic, demographic, economic, urban form, and institutional factors." TOD readiness assessment also involves road safety assessment. This further contributes to the case for implementing a TOD design.

25. The road safety assessment must be further aligned to a TOD network design, i.e. it should be able to highlight issues and direct towards appropriate design interventions catered for a TOD area. Through the knowledge products and the literature reviewed it is evident that road safety assessment for TOD readiness involves three distinct measures:

- Road safety capacity reviews: policy, regulatory and institutional framework assessment,
- Road inventory, road crash data collection and analysis,
- Road safety assessment and engineering tools.

ROAD SAFETY CAPACITY REVIEWS: POLICY, REGULATORY AND INSTITUTIONAL FRAMEWORK

26. The first measure looks at assessing 'efficiency and effectiveness' of the various existing policies and regulatory frameworks and institutional setups available at the local, regional, and national levels. These are analyzed based on their capacities to execute planning, design and implementation of a TOD project, including road safety.

27. The World Bank's Road Safety Capacity Review Guidelines present a two-stage, iterative process that culminates in the preparation and implementation of projects designed to launch the identified long-term country investment strategy. These two stages are based on the six recommendations provided for road traffic injury prevention:

    1. Identify a lead agency in government to guide the national road safety effort.
    2. Assess the problem, policies and institutional settings relating to road traffic injury and the capacity for road traffic injury prevention in each country.
    3. Prepare a national road safety strategy and plan of action.
    4. Allocate financial and human resources to address the problem.
    5. Implement specific actions to prevent road traffic crashes, minimize injuries and their consequences and evaluate the impact of these actions.
    6. Support the development of national capacity and international cooperation.

28. The first stage of the process concerns the conduct of a country capacity review (recommendation 2). The capacity review assesses the lead agency role (recommendation 1) and specifies a long-term investment strategy and identifies Safe System projects to be launched (recommendations 3 & 4). And the second stage of the process concerns the detailed preparation and implementation of the Safe System projects (recommendations 5 & 6).

29. While these Guidelines offer a comprehensive approach for any kind of road safety capacity review, as part of the "Assess" step of determining TOD readiness, we would focus on the first two recommendations.

30. Based on the reviews of existing literature, it was observed that more than often, road safety and TOD policies were independent of each other. However, road safety is an intrinsic component of TOD implementation, it therefore needs to be part of TOD readiness assessment. Any existing road safety mandate of the government such as Vision Zero – aiming at zero road crash – must be included as part of the TOD policy. Additionally, policies to prioritize implementation of public transport systems and encouraging citizens to use the same may be included in the TOD implementation policy as a champion cause.

31. Institutional capacities are also assessed to determine the right mix of professionals within the implementation agency. In order to make informed decisions to reduce road crashes and make safe spaces for all road users, it is essential to include road safety experts who are adept with safe system practices. Additionally, the team of experts should also ideally include urban designers and planners who have experience in complete street design.

32. This capacity assessment will help identify shortcomings in readiness for TOD implementation that may further be addressed through the remaining steps.

ROAD INVENTORY, ROAD CRASH DATA COLLECTION AND ANALYSIS

33. Evidence based advocacy helps in decision making and prioritizing funding and project implementation. Data collection and proper data analysis helps in sending the right message to communities and gaining their support and also support of various stakeholders, and provides the basis for making relevant improvements.

34. In order to undertake TOD readiness assessment of a city, it is essential to assess the existing physical infrastructure. Assessment of the existing physical urban fabric of the city and around the station areas – existing urban density and character, road network land use etc – help determine future planning and design, and strategies for implementation. These also have a direct correlation with ensuring road safety for all, especially the vulnerable users.

35. Socio-economic and demographic data, high-definition aerials and satellite imagery, site surveys, local employment data, travel pattern information, contextual information such as immediate land use, level of urbanization, future development and growth patterns, transport network information such as mode share, transit ridership, vehicle counts etc clearly play an essential role in TOD readiness. However, very often road crash data are not included during the data collection process for determining TOD readiness of a city. Analysis of crash data can help identify relevant patterns and assist in developing policies and institutional framework to reduce crash related deaths and injuries by using TOD development as a planning tool.

36. In order to make comprehensive road crash analysis, the crash data need to be supported by inventory of the roads and road network within the station area. Below there are typical components that should ideally be part of a road inventory. While this is not an exhaustive list of components in a road inventory, it may be modified based on the local context and data collection mechanisms available with the city

37. Typical inventory includes:

- Type of road – arterial or connector
- Width of Right of Way (ROW), length, number of lanes and width, directionality
- Presence of lanes for transit, shared vehicles, shared use etc
- Presence of median
- Presence of sidewalk and width
- Intersections – signalized or not
- Presence of cycle lane, type, width, buffer and type, shared
- Use of transit along the ROW and nature of transit.

- Transit amenities like bus stops, BRT stops, train stations
- On street parking and alignment
- Drainage
- Mid-block crossings and any other type of pedestrian crossing such as foot over bridge (FOB) and underpasses
- Safety measures such as hawk-eye, speed cameras, etc
- Street amenities such as street lights trees, furniture, utility etc
- On-street vending, and any other relevant information

38. At a city level, a high road fatality rate can be used to advocate for a TOD plan and the urgency for implementation. At the corridor level, the mapping of road safety data will identify the vulnerable road users and indicate the most critical zones that can be improved through the implementation of TOD. If road crash data are analyzed in conjunction with traffic data, such as VKT and mode-share, they can make a stronger case for assessing TOD readiness. At the station- area level, safe access to the transit station can be assessed through road crash data.

39. Below there is a list of variables that needs to be collected as part of road crash data. Depending on the contexts, resources, and budget, these may be adapted and modified at local, regional and national levels. Based on the information collected different types of analysis may be carried as discussed later.

40. These variables collected as part of crash data should be comprehensively analyzed in a holistic manner. If it is observed that certain data variables aren't robust, then necessary remedial measures must be undertaken by the concerned agencies.

DATE & TIME	Recording of date and time variable allows for seasonal and hourly comparisons of the incidents. Frequent occurrences of road crashes during a time of the day can be compared with the local traffic data to establish if any correlation exists between the occurrences and traffic volumes.
CHARACTERISTICS OF PERSONS INVOLVED	Crash data must include the number of persons involved in the incident and other basic information. Variables that need to be recorded about the persons involved in the crash include road user type (pedestrian, cyclist, vehicle driver, passenger etc), age and gender, persons with special needs including disabled and pregnant women, physical condition of the users including level of alcohol in the body, details about use of any safety equipment such as protective gears, seat belts etc and type of injury sustained.
CHARACTERISTICS OF VEHICLE	Data about the vehicles involved in the crash including type, age, country, safety equipment if any, date of last periodical technical check according to applicable legislation.
CRASH SEVERITY	Crashes are also defined by their severity – which is based on the impact on the persons involved - fatal injury, serious injury, minor injury, property damage/non-injury.
CRASH TYPE	Information on the type of crash including modes involved, for example vehicle-vehicle or vehicle-pedestrian or vehicle-bicycle, etc. during the crash needs to be recorded. Other information that is required includes maneuvering of vehicles during the crash: type of impact or collision, speed of vehicles etc. Understanding the events of the crash can help in determining the interventions necessary.
CRASH LOCATION (GEO-CODED)	Maintaining records of crash location over a period will help identify blackspot and critical areas within the city. A higher number of occurrences in an area would mean a higher priority and a greater scope of implementing improvements.

41. Based on the information available, following types of analysis techniques may be adopted:

- **Basic Trend Analysis:** This requires data to be recorded at the crash-level (date & time of crash, vehicles & modes involved, location of crash and number of serious injuries and fatalities) and each record in the dataset must correspond to one unique crash.
- **Crash Factor Analysis:** It is observed that the cause of road crash is often identified as an error on the part of the driver. Non-behavioral factors, such as road design or vehicle failure, are almost never considered. For a crash factor analysis, it is important to analyze the detailed crash report recorded by the police, and not just rely on the aggregated dataset.
- **Blackspot Identification:** Blackspots are locations with high crash risk, as determined by high crash occurrences. The analysis requires the geographic location of each crash, recorded as accurately as possible. Location information is particularly important in identifying priority areas for intervention and course correction.

42. Road crash data can be sourced from multiple agencies. However, each have their own challenges and limitations. A single crash-injury database does not always provide adequate information to give a holistic picture of road traffic injuries. Many countries have therefore started using both crash data collected by the police along with the health sector data.

- **Police records** are the primary source for crash data. Most road crash reports will typically contain date & time of crash, location, vehicles involved and number of injuries & fatalities. In addition, the crash description may contain information about how the crash occurred, Precinct-level data are then rolled-up and aggregated by the central police department, which is usually what is made available publicly. This information isn't always the most accurate information – primarily due to human errors in the process of collecting and recording the data. Additionally, only major crashes that cause serious injuries or fatalities or involve more vehicles often get reported to the police. Minor crashes or near misses are often under-reported and thus do not always get included in this primary crash data source. It is therefore recommended to complement police data with other secondary data sources.
- **Hospital Records** are maintained by the government bodies like a City Municipal Health Department. These data are useful in cases where there isn't adequate follow-up by the Police for example when a road crash victim is initially reported as injured but may have subsequently died after the police report was filed. Also, in some cases, a police report does not get filed due to various reasons.
- **Vehicle Insurance Records** supplement police records, especially in cases where a police report was not filed. Insurance records tend to provide a more comprehensive description of vehicle damage information, which is useful in understanding the causes of the crash.

ROAD SAFETY ASSESSMENT AND ENGINEERING TOOLS

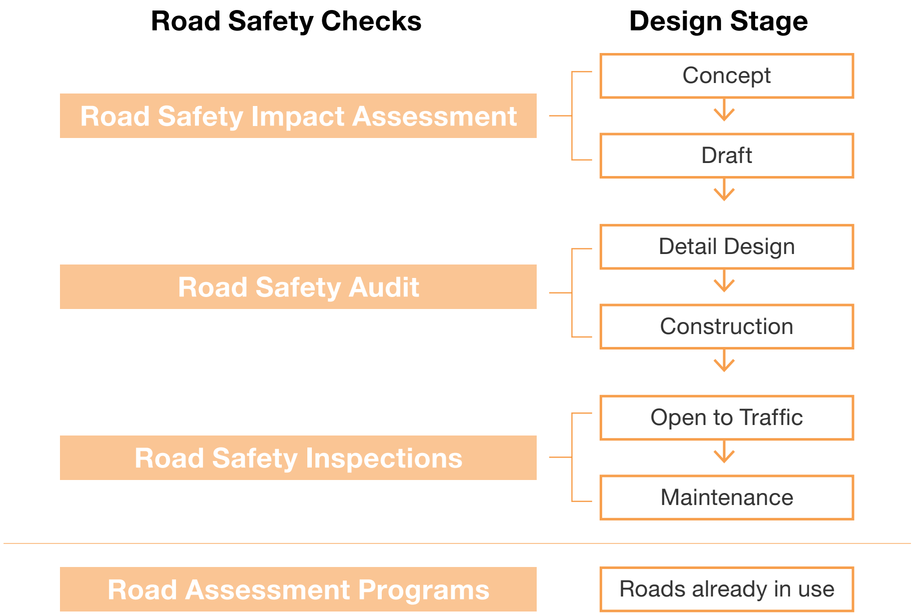
43. Use of crash data for risk assessment mentioned above has traditionally been considered a reactive approach. In recent years, more proactive tools for risk identification have been developed. These aren't merely a check on design compliance, but a holistic assessment of the road by considering the various elements present.

44. These risk identification tools are adopted at different stages of implementation of a road design and may be undertaken for both new roads or road feature or modification to an existing road. These tools also help in the identification of solutions to the risks identified and prioritizing suggested interventions.

45. The road safety check types are:

- **Road Safety Impact Assessments or RSIA** is a strategic comparative analysis of impact between different possible schemes of a new road design or any modifications to an existing network, to ensure that the scheme selected is the one that has the best outcome for road safety. This is carried out before detailed planning begins and helps in the decision-making process.

- **Road Safety Audit or RSA** is a formal detailed systematic and technical safety check performed to check that the selected scheme is designed and constructed in such a way as to yield the greatest road safety benefits, and to detect any potential hazards throughout all stages from planning to early operation. The auditors carrying out the checks should be trained and must be independent from the designer and from the contractor. Usually a list of potential safety deficiencies and recommendations for improvement are included in the audit report.
- **Road Safety Inspection or RSI** is a periodical on-site verification of road characteristics and defects, undertaken as part of a dedicated inspection of an existing road or through maintenance procedures to enable the detection of potential crash risks. These are largely a preventive safety procedure carried out by independently trained experts.
- **Road assessment programs** – typically undertaken on existing roads, these quantify the expected safety outcomes for a network, route or location.



46. While these tools are applicable for all types of contexts and road types, for the purpose of TOD readiness, these need to be applied within a framework created specifically for a TOD station area environment, reflecting their key characteristics:

- **Functionality of roads in TOD station area:** what is the function of the road around the station, as part of the overall road network: arterial road? Connector that caters to local traffic? Road including a mix of transit with the typical vehicular and pedestrian movements? Within a TOD area, roads are designed to include the mass transit within the ROW or are catered towards the mass transit station to accommodate the inflow and outflow of the users – feeder routes.
- **Homogeneity of road design in TOD station area:** what is the character of the road within a TOD context: orientation of streets towards the transit station; unidirectional or bi-directional; different types of speed limits that are enforced; level of segregation across the different road users using protective measures or adequate buffers with different speeds or having a common shared speed based on the most vulnerable user.
- **Predictability of road network in TOD station area:** what is the predictable use of the road space: are the road users familiar with the behavior demanded by different road types, and what they may expect from them and others? Do the roads have legible markings and signage for efficient use; what kind of priority is given to which road user and where, are these measures being enforced etc.

47. While these tools will help in determining the quality of the existing physical road infrastructure by identifying potential threats that may cause severe or fatal crashes in the future, they however need to be analyzed specific to the principles of TOD and the local socio-cultural contexts. Based on these assessments, any future planning and design interventions may be determined along with implementation strategies that may be temporary or tactical in nature leading to more permanent solutions.

ENABLE

48. The second step in the TOD Implementation and resources tool is ‘Enable’. It lays down “proactive tasks that cities and states will need to take towards creating successful TOD planning processes”. This stage focuses on strategies to institutionalize the process and objectives of TOD; build local capacity, both institutional and in civil society; and pursue policy and financial reforms conducive for successful TOD implementation.

49. As highlighted in the toolkit, successful TOD implementation requires advocacy to align stakeholder interests, and garnering political support for identification and elimination of policy barriers. This would eventually help in creating a mandate for TOD and establish the goals and objectives that align with the local needs and caters to its immediate context.

50. Road safety can be used as one of the metrics for making a successful case for TOD to the leadership, highlighting its social and economic benefits. As highlighted earlier, road crashes have a negative social and economic impact – leaving aside the individual emotional impacts it may have for the victims and their families. Formulating mitigation strategies around road safety primarily includes modal shift to Non-Motorized Transport (NMT) modes and public transport which further has far reaching economic and environmental benefits. TOD influences road safety in several ways:

    - It moves more people onto public transit, thereby reducing the frequency of private motorized trips, which reduces the frequency of crashes.
    - It promotes an urban form that is high density with mixed land-use; which facilitates more trips to be within walking or biking distance; thereby further reducing dependence on automobiles which further reduces crash frequency.
    - It is designed to be pedestrian and bike friendly, providing safer infrastructure for the most vulnerable road user groups.

51. These safety benefits of TOD and their inter-relationships are not always easily apparent to stakeholders. It is crucial to demonstrate this linkage to stakeholders, both within government and in the community. The communication strategies and outreach mechanisms within the institutions, political leaderships, stakeholders and public needs to be strengthened to highlight that road safety is a shared responsibility and requires a buy-in from all those involved in decision making.

52. Safe system approach requires a shift in responsibility from road users to system designers, builders and managers. Therefore the existing regulations and institutional setups require changes that include mandates and provisions to enable road safety. In order to achieve this, education and capacity building needs to be extended to these system designers - planners, engineers, architects, health professionals, law enforcement officers and others.

53. This can be achieved through joint collaborative sessions or multi-agency workshop sessions with implementation agencies local civic bodies, professionals and different stakeholders with a wide representation that is inclusive of all age, gender, user groups and physically challenged and disabled persons. Results from crash data and physical infrastructure assessments discussed earlier may also be used to educate the participants about the road safety challenges and help in enabling them to advocate for better systems and strategies to mitigate these issues. This will help institutionalize road safety within the respective areas or jurisdictions. Such collaborations will help align interests of the different parties and identify a common road safety goals and objectives, addressing individual interests, motives and possible trade-offs.

54. These communication strategies will help champion the cause for road safety within the institutions and decision making agencies and will help include road safety as an integral component while drafting area TOD specific policies and regulations at local or regional scales. It will also advocate for a shift to more efficient and sustainable transport mode choices and create supporting infrastructure

Safe Access to Mass transit: Role-playing activity

The Safe Access to Mass-transit (SAM) workshop toolkit is developed in the form of an interactive activity to address the need for safe access around mass transit stations. It includes the SAM capacity building workshop, which is based on the WRI India publication ***Safe Access to Mass Transit Manual:*** *Safe Access to Mass Transit Stations in Indian Cities.*

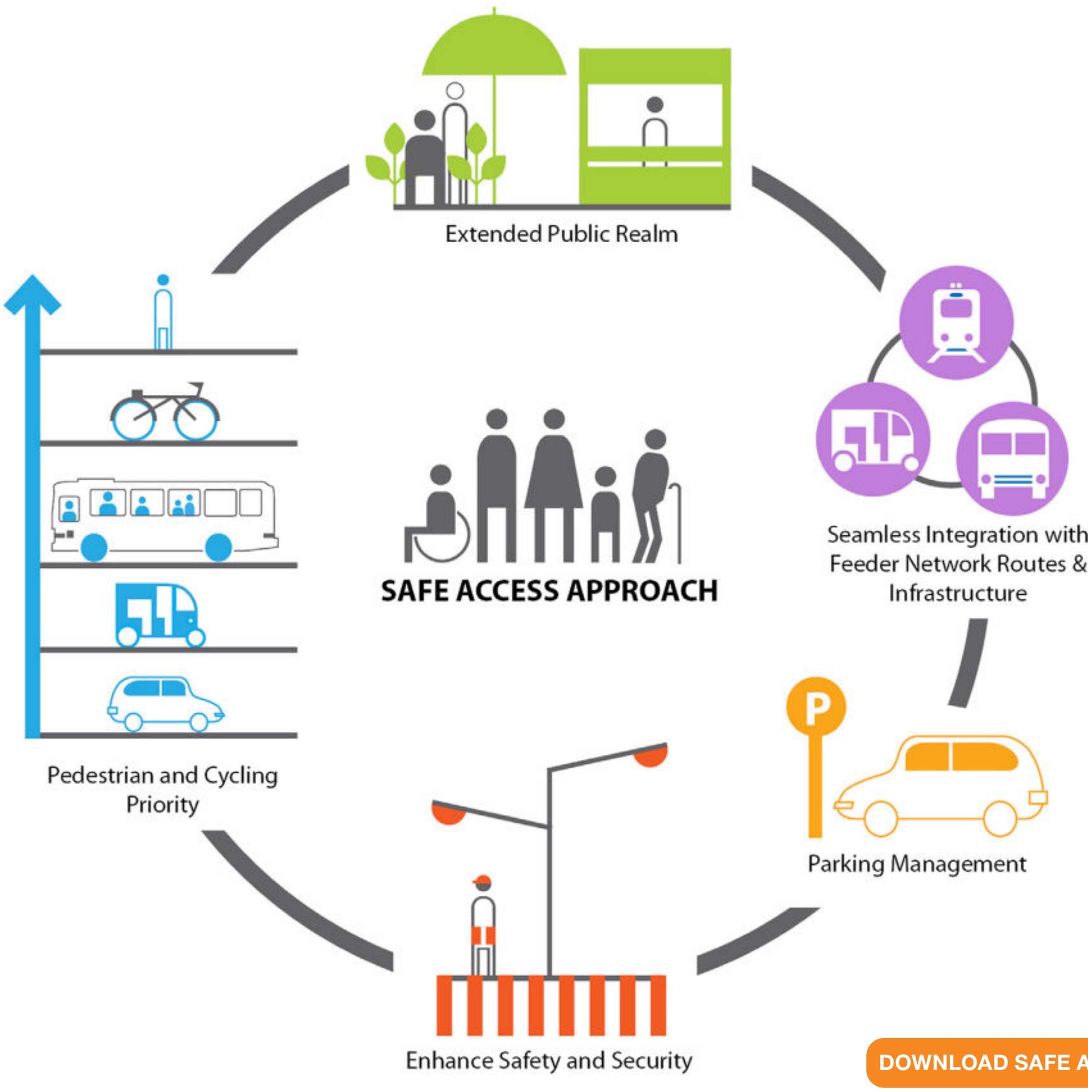


Figure 2. Five principles of Safe Access

DOWNLOAD SAFE ACCESS MANUAL HERE

Or Visit the link below to download the manual.
www.wrirosscities.org/research/publication/safe-access-mass-transit-manual

Using a workshop format, participants divided into groups will explore the processes involved with developing last-mile connectivity, and co-create proposals with community and city representatives for such strategies. It aims at inculcating awareness about the importance of safe and equitable access (through its principles) for all street/ public space users and help derive solutions through a collaborative decision-making process.

The outcome of the exercise is to derive implementable solutions that are based on safe access principles, while negotiating the complexities involved in their adoption. These solutions are then prioritized based on an interactive bottom up role-play interactive activity. This activity solely focuses on last mile connectivity solutions to provide safe and livable station areas, applying the 5 principles of last mile connectivity, i.e. walking, cycling, public spaces, etc.

PLAN+DESIGN

55. The Plan & Design stage of TOD Implementation and Resources tools has a significant role to play in ensuring road safety in comparison to the other four stages. It "focuses on providing guidance on the planning and design process that remain flexible and relevant to adapt over time specific challenges, and contexts change. It also presents action strategies and tools to create a more compact land development pattern hinged upon pedestrians and cyclists."

56. TOD planning and design typically takes place at three levels - the city, the corridor and the station area. However, it is at the station area level that issues around the provision of safe access infrastructure are the most relevant. The station is the anchor point for the station area; and all development should be oriented towards it with a high level of safety for first and last mile connectivity. An efficient TOD neighborhood is one that facilitates the safe and convenient access to transit for all modes.

57. TOD projects highlight the co-relation between land use planning, transport planning and design. These developments advocate for a modal shift from private motorized vehicles to more safer and sustainable modes of transport. This leads to increased number of users within a station area and with availability of different mode choices, increase in number of conflicts between different modes and their respective speeds. These changes make road safety a crucial component in the context of a TOD

58. An essential aspect of a TOD project is the identification of the conflict points and provision of safe and efficient connectivity between the transit station and the neighborhood around the station. It must be therefore be noted that this stage includes many specific features of street design for TOD, such as the creation of pedestrian networks with trunk routes oriented towards the transit station; the delineation of speed zones; and transfer and feeder service integration. Therefore in order to enhance the road safety considerations one has to consider two interconnected themes:

- Planning of networks in the TOD zone
- Design of the infrastructure within these networks.

PLANNING OF TOD NETWORKS

59. Typically, TOD is understood as densification around a transit station by increasing the built-up density and diversifying the permissible land uses with the station area. With such dense urban environments, the number of users in the public realm also increases significantly, posing safety concerns for all users. This requires provision of efficient networks connecting these developments to the transit station. If these networks are not adequately provided, then it discourages the use of transit and NMT infrastructure to access these developments, resulting in a much lower transit use than planned for.

60. To achieve safe networks within a TOD area, the "Sustainable Safety" principles of functionality, homogeneity and predictability will need to be looked more comprehensively for planning and designing of roads, so that they align with the TOD principles and can be integrated with the local context. These principles tailored for TOD requirements have been briefly explained below:

- **Functionality of roads in TOD area:** While assessing road safety it is critical to understand the mixed function of the road network – whether it is an arterial road that includes a mix of transit or a connector that caters to traffic accessing the developments in the TOD or feeders that focus on accessing the transit stations as well as distributing traffic within the station area. The planning and design considerations are therefore made keeping in mind the mixed function in the street. The functions of the road in a TOD are also related to the mix of land use along it and may vary through the time of the day impacting the volume of users on it.

- **Homogeneity of road design in TOD area:** Homogeneity of road design refers to the prevention of large differences in speed, mass and direction. The road network in a TOD area caters to all kinds of speeds and volume of vehicles within its ROW – slow moving pedestrians and persons with needs, cyclists, faster moving cars and other motor vehicles, feeder services such as intermediate public transport (IPT) and public buses, and high speed mass transit vehicles such as BRT or metro rails. It is crucial to ascertain the capacity of these network based on the function they serve and segregate the users and different modes by using protective measures or adequate buffers between the modes to ensure maximum safety. It is supported by orienting streets towards the station, determining directionality of these streets to enable ease of traffic flow within the station areas, and maintaining speeds based on the immediate context – nature of land use and function of the streets. These principles are detailed out on PD-H07 subsection Capacity, Orientation and Safety; as well as in safety design guidelines provided in PD-R02.

- **Predictability of road network in TOD area:** This refers to the usability of the road space – "are the road users familiar with the behavior demanded by different road types, and what they may expect from them and others". The design of road infrastructure and amenities are such that the users can recognize the type of road and are aware of its function. Within a TOD, higher mix of users, reinforces the need for predictability to achieve safety. Prioritization of road users, distribution of lanes within a ROW, stops and utilities, markings on the roads, signage, visibility, movement lines at intersections (especially for pedestrians, cyclists and other vulnerable users) gets highlighted.

61. The most critical aspect for the creation of a strong inter-linkage between the transit station and the developments within station area is network planning. There are five key principles of network planning for TOD zones. This note briefly discusses each of the principles, which have been detailed out in the updated toolkit.

- **COVERAGE:** The network should have an extensive reach so as to connect every property within TOD zone.
- **CONTINUITY:** There should not be missing links (gaps) in the network.
- **ORIENTATION:** The network should be oriented towards the transit station, providing as direct connectivity as possible.
- **CAPACITY:** The capacity of the network should be adequate to meet the high volumes of transit commuters, particularly along the trunk routes leading to the station.
- **SAFETY:** Achieve a high standard of safety should be the guiding principal behind each and every decision on network planning; especially for the safety of vulnerable road users.

62. "Coverage" helps define the extent of street network and accessibility for different road users and hence provide for suitable solutions to ensure safe access. "Continuity" refers to the connectivity within the network and its density, ensures equitable access to the transit without congesting any area, and channelize traffic flow within the TOD zone. "Orientation" is facilitating the directed movement to and from transit stations and hence help in placing required infrastructure for safe movement. "Capacity" refers to the spatial quality of the network for all road users to ensure adequate space within the ROW based on the volumes of each type of user the network is catering to. Lastly "Safety" refers to creation of safer and segregated infrastructure within the network to avoid any type of crash. These as principles of network planning, help in creating framework for implementing physical safety measures.

63. For example, sidewalks are designed to function separate from vehicular travel lanes and cycle infrastructure. They are designed as per best practices and recommended design guidelines to accommodate the anticipated number of pedestrians using the segment of the network depending on how it connects to the transit station and any other node within the station area. However, these attributes will become redundant if the sidewalks are not part of a network that is not continuous and connect different nodes within the TOD area including the transit station.

Appendix A summarizes these five principles and includes guidelines and strategies on how to implement them.

DESIGN OF ELEMENTS WITHIN TOD NETWORK

64. The design of TOD network infrastructure looks at specific components of access infrastructure from a micro, site level scale. The objective is to ensure that the infrastructure meets the highest standards for safety for all road users, especially for commuters accessing the transit station.

65. Out of the various street design elements, the following are essential from a road safety perspective in TOD areas as they cater to the movement patterns of the users within the station area:

- **Walking infrastructure:** Walking is the direct mode to access transit stations and also are the most likely means for first and last mile connectivity to other modes
- **Cycling infrastructure:** Cycling has a higher reach than walking, and as a healthy and sustainable mode of transport, greatly increases the commutable distance to the transit station.
- **Feeder transit and para-transit infrastructure:** feeder and para-transit services considerably enhance the service area for a station and function to support the main transit service.
- **Design of shared streets:** Shared streets are designed to cater to the needs of the most vulnerable user and deploy various measures to reduce traffic volumes and decrease speeds.
- **Design of the station area:** the area around the transit station is meeting points for trunk routes and transfer of commuters from feeder services to main transit route takes place.

Appendix B provides design guidelines and consideration regarding these five elements with respect to a TOD area.

66. The guidelines in Appendix B are not intended to encompass design standard and guidelines for streets in the general context. For such guidance, one may refer the national codes of the relevant country, or one of the many published street design guidelines that are intended for this purpose. The intention of the Appendix is to cover only design guidelines that are specific to the provision of safe access to the transit station, within the context of the TOD zone. These guidelines must be seen as additional (and not a replacement) to general street design codes or guidelines, as the case may be.

FINANCE

67. The Finance stage of TOD Implementation and Resources Tool creates a framework for estimating capital costs for transit infrastructure and urban development, determining possible funding sources for execution of plans, establishing mechanisms for investments in real estate and user safety, enabling methods for forging public private partnerships, and identifying revenue generators. These financial tools are supported by various local and regional laws and other enabling regulatory tools, guidelines and different development incentives for developing successful TOD projects.

68. TOD implementation in high income countries is sometimes characterized by the intent to increase population densities and transit ridership supported by economic development. On the other hand, middle- and low-income countries are either characterized by high urban densities or else very low in areas that are at early stages of development.

69. TOD projects are developed with an intent to increase urban density (or support the existing high urban density in many medium- to low-income countries) and are supported by increased transit ridership and economic development that is derived from well-defined regulatory and policy frameworks and strong institutional capacities. This may increase traffic exposures resulting in increased road crash risks. Therefore, high quality transit investments supported with comparable investments in safe public infrastructure, timely revisions in development regulations, and active participation of the private sector are a must.

70. The resources available mostly cover financing mechanisms to support investments in developing transit and supporting infrastructure and real estate development, but they do not discuss tools for supporting road safety issues such as infrastructure provision or transport management. It should also be noted that financing of TOD projects doesn't end with execution of the project on ground. Funding mechanisms and a sustainable business model needs to be developed that would also take care of financial aspects of maintenance of this newly developed infrastructure.

71. As discussed earlier, road crash related deaths and injuries have a significant economic impact. Additionally, different transit alternatives will also have a different impact on road safety. Therefore, it is prudent to include cost comparisons of alternatives and road safety net benefits when conducting cost-estimation studies for TOD.

72. Developing infrastructure for safety is an expensive task, and on many occasions, the local city governments may not have enough capacity and resources or finances to implement such interventions. As an alternative, development incentives are provided to the developers to implement pedestrian and cyclist safe infrastructure through their property in lieu of additional FAR or any other incentive. Large property owners would either subdivide their plots to create a NMT network through their property or else will grant easement access. These owners benefit by increasing footfall within their commercial establishments.

73. These property owners may also 'adopt' sidewalks adjacent to their property and help maintain them. This may require the city government to also layout guidelines for designing and maintaining sidewalks by property owners. Many city bye-laws have a provision for setbacks. Adjacent large developments may amalgamate their side setbacks along the common edge to create pedestrian and cyclist friendly space. Front setbacks may also be combined with the sidewalk to increase its width.

74. Furthermore, there may be local or national laws that may be specifically targeted towards generating funds for implementing NMT needs within their jurisdiction. These may be directed towards improving safety within the TOD projects.

75. Cordon area congestion road pricing is a system of charging users for entering and using roads in a demarcated or restricted area that is subject to congestion due to excess demand. This kind of a pricing strategy helps regulate demand and helps in managing congestion without increasing the supply. In some other countries, like Argentina, a percentage of money collected as insurance fees is directed to Agencia Nacional de Seguridad Vial (ANSV) – the nodal agency in charge of road safety.

IMPLEMENT

76. The “Implementation” stage is the final stage of the TOD Implementation and Resources Toolkit. It concerns with “mobilizing a multitude of resources, partnerships and innovative implementation mechanisms that help leverage public sector investment in transit and infrastructure with private sector development”. The execution of a TOD project doesn’t follow a linear process and requires addressing institutional and regulatory shortcomings, guidelines for planning and execution – including prioritizing of projects, distribution of finances, as well as monitoring and evaluation followed by regular updates based on the feedbacks.

77. Like in any urban development project, TOD implementation takes shape after analysis of existing plans, institutional setup and infrastructure, completion of detailed planning and designing process, establishing a finance model with adequate investments etc. The issue of road safety doesn’t have much overlaps with this stage, however, based on the outcomes of these earlier stages, this stage may be strengthened with safety considerations at different steps of implementation:

INSTITUTIONAL SET-UP AND CAPACITY BUILDING

78. As part of the Assess stage, TOD readiness assessment captures the existing institutional capacity of the implementation agencies. Based on their existing team structure, necessary modifications may be made. In order to mitigate any road safety related shortcomings in the assessment, it is essential to include it as part of capacity building – given its importance as a co-benefit of TOD implementation.

79. As is the case of any large-scale public project, a multi-disciplinary team is required that is spread over different sectors. This would include local government officials, professionals with technical knowledge, and a range of specialists and advisors. New experts may need to be hired as staff or included as consultants. As mentioned earlier in the Assess section, qualified road safety experts with knowledge of safe systems are essential to be part of the project team to help it taking informed decisions to help reduce road crashes and improve safety. It would be more effective if the other members of the team, i.e. planners and urban designers, have prior experience and knowledge of transportation planning and complete street design. While this forms the core team, additional advisors and experts may also be engaged to make holistic decisions regarding the implementation and impact of TOD projects. Representatives from various government departments and private sector that are related to different aspects of TOD such as housing and real estate, environment, public works, economic development, and marketing and communication are desirable.

80. Representatives from the civil society such as neighborhood associations, business improvement districts, resident welfare associations, advocacy groups etc as part of the project team is also ideal as they have first-hand knowledge regarding challenges they face in their vicinity especially regarding road safety and security. This can be used to garner the required political support as well.

EXECUTION OF DESIGN

81. After developing the necessary plans and design of safety elements within a TOD project, and securing financing for the projects, the actual execution of the project may be carried out in phases after setting up the priorities. This priority-based phasing of projects may be prepared as part of an Implementation Plan by the nodal agency and infrastructure providers after discussions with stakeholders and public.

82. Stakeholder engagement is a continuous process since the project inception. This participatory design process not just helps in identifying the challenges and opportunity areas of a project and integrate with any other plan or development happening in the project area, but also contributes to placemaking and helps in contextualizing the project. It allows the implementation agency with prioritizing of the projects and mitigate road safety issues in the afore said implementation plan.

83. As these projects are expensive to implement, and full-fledged and permanent implementation of design should be executed after a temporary or interim re-design process that may be done as a pilot project in a small selected area within the TOD station area to monitor the impact and then implement at a larger scale across other station areas. Additionally, it may also be carried out using temporary tactical installations or cheap constructions to test the impact on the site. If needed, minor design changes or additions can be made for the entire design before making it permanent.

Intersection redesign at HP Intersection in Mumbai (WRI India)

MONITORING AND EVALUATION

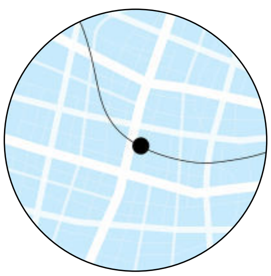
84. Implementation of a TOD project doesn't complete with its execution. As mentioned earlier in Finance, maintenance and management of the built infrastructure is equally important in a TOD project cycle. A Maintenance Plan may be developed that would focus on maintenance of the road safety infrastructure to increase its usable lifespan and safety measures of the development. This avoids frequent repair work and the attached additional costs.

85. As also mentioned above, impact of any intervention has to be measured to understand its effectiveness. While earlier it was looking at feasibility and testing of an intervention, here one is measuring the long term impact of a more permanent implementation. For this comparison a before and after implementation stage data needs may be collected.

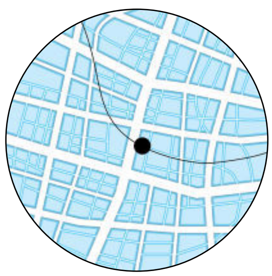
86. This measured project impact and user feedback further needs to be communicated to decision makers and community members. This will help formulate new regulatory policies and guidelines and inform design approach for future projects and assist in advocating for the same to community members, political leaderships and other stakeholders.

APPENDIX A

1. Typically, TOD is understood as densification around a transit station by increasing the built-up density and diversifying the permissible land uses with the station area. Along with this, another equally important aspect of TOD planning includes the provision of efficient networks connecting these developments to the transit station. If these networks are not adequately provided, then it discourages the use of transit and NMT infrastructure to access these developments, resulting in a much lower transit use than planned for. The most critical aspect for the creation of a strong inter-linkage between the transit station and the developments within station area is network planning. There are five key principles of network planning for TOD zones:

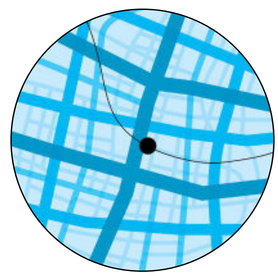


COVERAGE
The network should have an extensive reach, such that every property within the TOD zone is connected to the network.

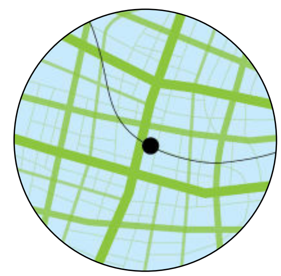


CONTINUITY
There should not be missing links (gaps) in the network.

ORIENTATION
The network should be oriented towards the transit station, providing as direct connectivity as possible.



CAPACITY
The capacity of the network should be adequate to meet the high volumes of transit commuters, particularly along the trunk routes leading to the station.



SAFETY
Achieving a high standard of safety should be the guiding principle behind each and every decision on network planning; especially for the safety of vulnerable road users.

TOD Knowledge Product PD-H07 provides more details and covers these five principles in more detail.

Principle 1: Coverage

2. The principle of Coverage means that every property within the defined influence area, must connect to a network leading to the station. It is neither practical nor desirable, for the coverage of every network to be as extensive as another. The importance of direct access of a network will depend upon the property's location with relation to the station.

3. As shown in Figure 3 below, a station area in the denser parts of the city, where transit network coverage is high, will normally only have two realms for the planning of access, the walking realm and the area outside the walking realm. This walking realm is normally considered as what an average commuter can walk in 5-10 minutes, which is about 400 to 800m. This distance increases in a low-density suburban area to a walking reach of 10 - 15 minutes (800m - 1.2km).

4. The realm for cycling is much higher, typically 3 - 5 times the size of the walking realm; based on an average cycling speed of 18 to 25km/h, and an average willingness to cycle time of 10 - 15 minutes. Likewise, the feeder service or para-transit realms are likely to reach up to 3 - 5km from the transit station, which typically extend up to and beyond the TOD zone boundary.

5. A key component for the planning of these realms is the delineation of trunk routes leading to the station. It is not possible for every property to have direct connectivity to the station across all realms. The more practical solution is to connect properties to a few trunk routes leading to the station. This creates a strong an extensive network that offers multiple choices to the users. Additionally, it is not practical to provide distinct networks for each feeder mode, and therefore prioritizing of network planning is required based on mobility needs of each mode as shown in Figure 4.

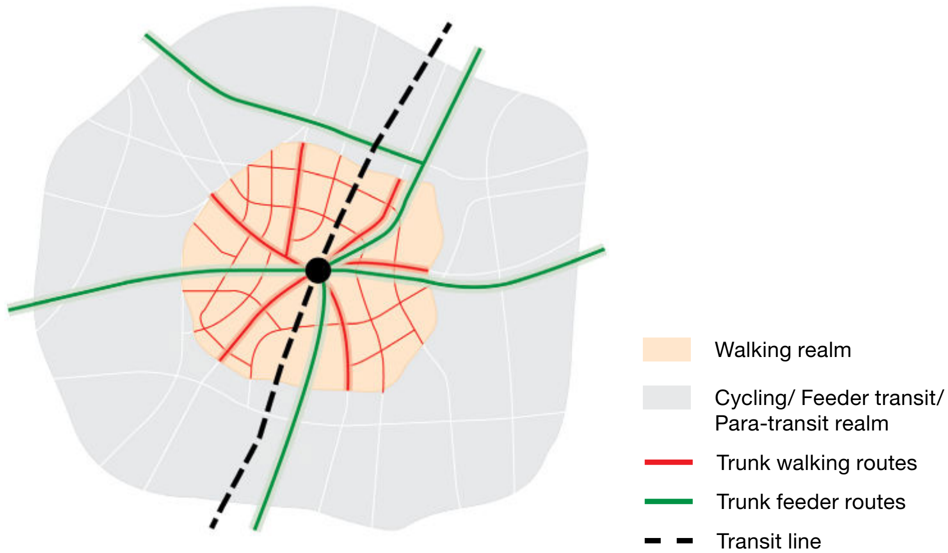
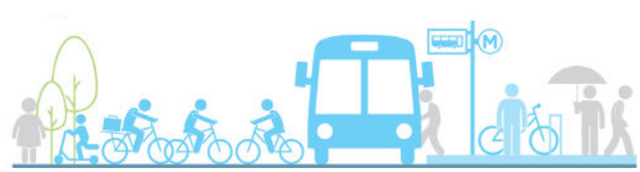


Figure 3. The different realms for planning of station area

PRIORITY 1: Walking



PRIORITY 2: Cycling and Feeder transit services

PRIORITY 3: Para-transit and Shared vehicles

PRIORITY 4: Personal motor vehicles

Figure 4. Hierarchy of priority for mobility planning

Adaptation of hierarchy of priority for mobility planning, prominent in many global cities at the forefront of sustainability. This hierarchy of priorities is all the more relevant for station areas, given the focus of moving people away from personal vehicles and onto transit.

Principle 2: Continuity

6. Maintaining the network continuity within the context of the station area, means that every property should be seamlessly connected to every other property, and to the transit station without any gaps or missing links in the network. If access networks to the station are not continuous, then it forces the commuter to use other elements of the road infrastructure that do not meet its safety requirements.

7. The critical importance of network continuity is often neglected in cities in developing countries, where infrastructure provision is scattered and disjointed, making it near impossible to complete a trip entirely along the network.

8. In built-up, dense urban areas, it is generally difficult to build new infrastructure to complete the network. Therefore, one must rely on other more practical strategies to achieve a satisfactory result. Measures to bridge network gaps include:

    - Developing off-road connectors
    - Using development incentives to augment the network
    - Developing grade-separated infrastructure
    - Designing for shared infrastructure

Principle 3: Orientation

9. In the third principle of Orientation the station is placed as the anchor point of the network and connects properties to the transit station as directly as possible. The key component to ensure a network is well-oriented towards the station is to identify and develop trunk routes. As these trunk routes are expected to carry the majority of commuter volume to the station, these routes are therefore to be planned to be as straight as possible in the direction of the station.

10. In a greenfield TOD zone, orienting the network is a lot easier, as there aren't too many hindrances that would interfere in this process. In this scenario, the network is likely to reflect with the station at the center and trunk routes emanating outward in every direction. Branch connectors can then be provided connecting to the main trunk routes, thus ensuring that every property is well connected to the station.

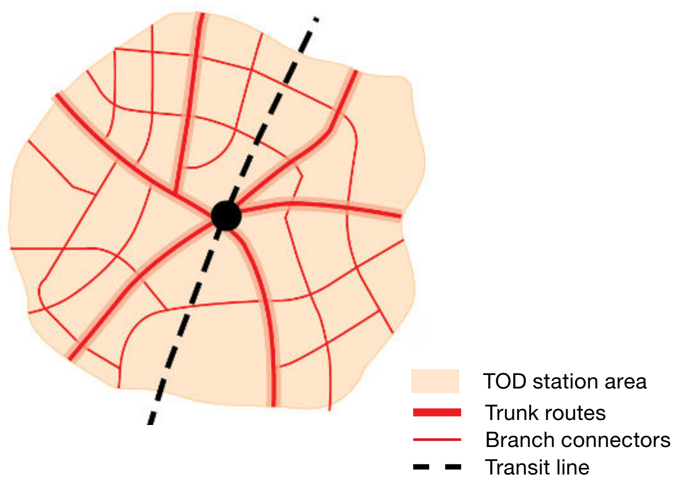


Figure 5. Oriented the feeder network in a greenfield station area

11. However it is a challenge in an already built-up urban environment. Here, one has to work within the limitations of the existing built-environment as well as the available right-of-way.

12. There are, broadly, three aspects to determining the alignment of the trunk routes that offer the best possible orientation towards the station. It is to be noted that these aspects aren't necessarily to be assessed chronologically, because it is likely that one will have to iteratively assess different options, before arriving at the best possible solution. The three aspects are:

    - Determining the main nodes or activity generators
    - Assessing strategies to minimize deviations
    - Assessing favorable local conditions

Principle 4: Capacity

13. Capacity deliberations are most pertinent in the planning of the trunk routes along the network. The following sub-sections discuss various measures to augment capacity along the network. The following measures to augment network capacity have been briefly discussed:

- **Reallocate road space**
  The most important tool to ensure adequate capacity is to reorganize the use of road space in the TOD zone. Road space is a critical and finite commodity, especially in built-up urban areas. The judicious allocation of this space plays an important role in determining the quality and safety of mobility in the TOD zone. In order to determine what's appropriate, it is important to carry out pedestrian and cyclist volume by capacity studies similar to determining vehicular traffic. This helps in understanding the requirements for reallocating road space to accommodate wider sidewalks that can meet the desired Level of Service for pedestrians.

- **Incorporate building setbacks**
  A TOD policy can be introduced to allow for the transformation of the street level floor of a residential property for commercial uses along major trunk routes. The city can link the permissions to develop ground-floor retail activities where the setback is maintained as an extension of the public sidewalk. The ownership of this space can remain with the property owner, but its built conditions and usage will be guided by the city TOD policy.

- **Eliminate on-street parking & streamline other road uses**
  An effective way to free-up road space is to reduce the provision of on-street parking, especially along the trunk feeder routes leading to the station. This additional space can then be allocated to sidewalks, cycle lanes or feeder-bus lanes.

- **Create one-way street networks**
  If there is a good network of parallel streets, and relatively small block sizes, one can consider creating a network of one-way streets, alternatively running in opposite directions. One-way street networks have the advantage of being easier to manage at intersections, as they require fewer signal phases than a regular two-way intersection. A one-way C-shaped loop is also a great way to connect to the transit station. By making loop one-way for vehicular traffic, more road space can be allocated to other feeder network infrastructure, such as sidewalks, cycle lanes and station transfer points.

- **Reduce interruptions in flow**
  The capacity of a trunk route on a feeder network is not only determined by the road space allocated to it, but also by the frequency of interruptions to its flow. The more frequent the interruptions to free-flow conditions, the greater will be the reduction in capacity. A crucial aspect of trunk route planning along the network is the adoption of various strategies to minimize interruptions, mainly through the diversion of conflicting traffic movements. Some measures for reducing interruptions in flow:
  - Eliminate traffic intersections along major trunk routes leading to the station. This can be achieved by converting intersecting streets into cul-de-sacs or by modifying the intersection to only allow vehicles to enter and exit the minor street, but not cut across the trunk route.
  - Limit the number of driveways on the main trunk routes. This reduces the number of breaks along the sidewalk, again improving free-flow conditions.
  - Another important measure especially pertinent to feeder transit service, is signal priority. Signal phasing can be designed to give more green time for traffic and pedestrians along the main trunk routes.

- **Provide more entry & exits at the station**
  The capacity of any network is determined by its most constrained point. In the context of feeder networks, this point is often the immediate station area, which has the highest volume of commuters utilizing the smallest amount of space. Station infrastructure can be designed with multiple entries and exits, directly taking people further along on the feeder network.

  One can even consider different points of access for commuters on different modes, to reduce the load at one location.

Principle 5: Safety

14. Planning for the safe provision of access networks in a TOD zone, requires one to make certain hard decisions that may somewhat lessen the mobility of other traffic, in favor of the safety and mobility of the feeder network traffic. Traffic in a TOD zone (both vehicular and pedestrian) can broadly be divided into two buckets: traffic destined to or originating from the station; and traffic not concerned with the station in any way. In most instances, the priorities of these two groups will clash with each other. However, the principle of safety must have the highest priority.

15. The process of balancing these conflicting priorities can be made easier by defining the boundaries within a TOD zone, where the priorities of transit commuters are to be placed higher than those of other traffic. Typically, in the area closest to the station, traffic bound to the station must be given the highest priority. Similarly, traffic directed to and from the station should be of high priority along all the major trunk feeder routes leading to the station. Once the feeder priority areas of the TOD zone are defined, the next step is to determine measures to ensure a high level of safety for the feeder modes in question.

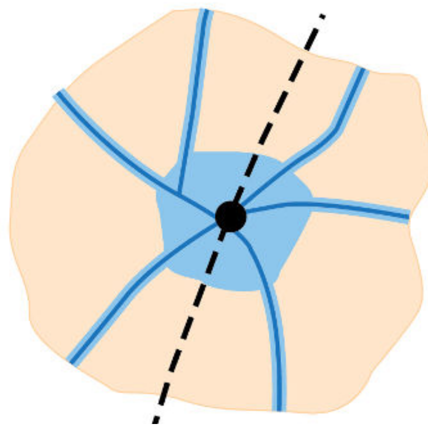


Figure 6. Determining the feeder priority area in the station area.

16. Measures to improve safety

- **Provide dedicated infrastructure**
  Dedicated infrastructure is a good measure on wide trunk routes, especially where there is a high volume of vehicular traffic, moving at a very high speed. It is considered as the safest measure, though not always the most practical. Excluding infrastructure for walking, it is not necessary, or even desirable, for the entire feeder network to be made up of dedicated infrastructure. This can take two forms; namely physically segregated infrastructure, and lane-marked infrastructure.

- **Implement speed zoning & traffic-calming measures**
  The severity of road crashes and injuries sustained, including fatality, is also related to the vehicle speeds. Vehicle speeds more than 50km/h have high fatality risks and have risk more than five times than that for vehicles driving below 30km/h. Furthermore, higher speeds reduce the driver's capacity to stop the vehicle on time or having greater stopping distances and reduce the maneuvering ability to avoid a crash.

  Speed zoning is the single most effective measure for the provision of safe mobility in the TOD zone. It is recommended to adopt a uniform speed limit for the walking realm across all TOD zones in the city. Within the walking realm, a speed limit of 15-30km/h is strongly recommended. In certain short sections, where the high pedestrian volumes, coupled with local traffic accessibility demands, a significantly lower speed limit (of 5km/h) may be desirable.

  Recommended speeds for TOD zone planning

  – 5km/h: Narrow streets where traffic & pedestrians share the road
  – 15 - 30km/h: All streets within the station walking realm & neighborhood streets outside the walking realm
  – 30km/h: Trunk feeder bus / cyclist routes to the station
  – 50km/h: Maximum prescribed design speed for all other roads in the TOD zone

It is also important to note that the desired speeds and speed zoning measures do not only entail enforcing speed limits through regulation, but also requires the implementation of appropriate traffic-calming infrastructure (discussed later) to ensure that the design speed is in sync with the speed regulation. Enforcing speed limits may also be supported by the use of Automated Enforcement (AE) technologies that detect and record violation of road rules without direct human involvement. Speed cameras enforcing speed limits are a common application of AE.

- **Reduce vehicular traffic volume**
  There are different measures that can be considered to reduce traffic volume in the TOD zone, particularly in the walking realm. The measures are discussed here.
  - **Restrictive measures:** Traffic volume in the walking realm can be significantly reduced, by adopting strategies to discourage personal motor-vehicle usage. For instance, reducing parking availability, or increasing the cost of parking, in the walking ream encourages more commuters to avoid personal motor-vehicle usage.
  - **Regulatory measures:** Another strategy is to adopt regulatory measures, such as restricting certain vehicle classes during peak commuter time periods. For instance, freight vehicles may not be allowed in the walking realm from 8:00 AM to 9:00 PM.
  - **Alternate bypass routes:** Traffic volume in the walking realm can also be reduced through the creation of alternate routes that bypass this area. For instance, a new road may be developed to carry through traffic that does not originate, or is not destined to, a location within the walking realm.
  - **Eliminating through traffic:** Another measure to limit traffic volume within the walking realm is to convert certain streets into dead-ends (cul-de-sacs) or loops back to the same road outside the walking realm. This discourages the use of these streets by any traffic that is not locally bound. Loops are preferable to cul-de-sacs because often the streets in the near vicinity of the station are not wide enough to accommodate a functional cul-de-sac.
  - **Full Pedestrianization of Streets:** Pedestrian-only paved streets could be created for routes in the TOD station area that connect to the transit station with developments having high footfall, or generate heavy pedestrian traffic due to commercial and recreational activities along those routes. Barring access for emergency vehicles and delivery vehicles during early morning or late night hours, no motor-vehicle is allowed in these streets. Cyclists may also be required to dismount and walk their cycle (see Figure 7 below). Along with promoting economic activities and keeping the streets active, these pedestrian-only streets provide uninterrupted movement to and from the stations for pedestrians without any kinds of obstructions and safety concerns from other vehicles.

Figure 7. Pedestrian only street in Sao Paulo, Brazil *(Source: © WRI)*

All diagrams present are to intended to be illustrative of the concepts and should be adjusted to the urban and traffic flow context.

APPENDIX B

1. The design of TOD network infrastructure looks at specific components of access infrastructure from a micro, site level scale. The objective is to ensure that the infrastructure meets the highest standards for safety for all road users, especially for commuters accessing the transit station. This covers five subsections :

    - Walking infrastructure
    - Cycling infrastructure
    - Feeder transit and para-transit infrastructure
    - Design of shared streets
    - Design of the station area

Walking infrastructure

2. Walking is the most important mode choice within any station area, not just for direct access to the transit station, but also, as the most likely means of first and last mile connectivity to other commute modes.

Sidewalk Design

3. The most crucial component of the walking network is the sidewalk which is assigned for the specific use of the pedestrians. A cohesive and dense network of sidewalks, (of adequate capacity), ensures a high level of safety for walking in the station areas. A well-functioning sidewalk will have spaces assigned for other important elements and uses. A sidewalk comprises of three components, namely the frontage zone, walking zone and the multi-utility zone as shown in Figure 8. The following Table 2 includes important considerations and challenges for designing sidewalks. Additional design guidelines for these and other concerns have been provided in the PD-R02 Knowledge Product.

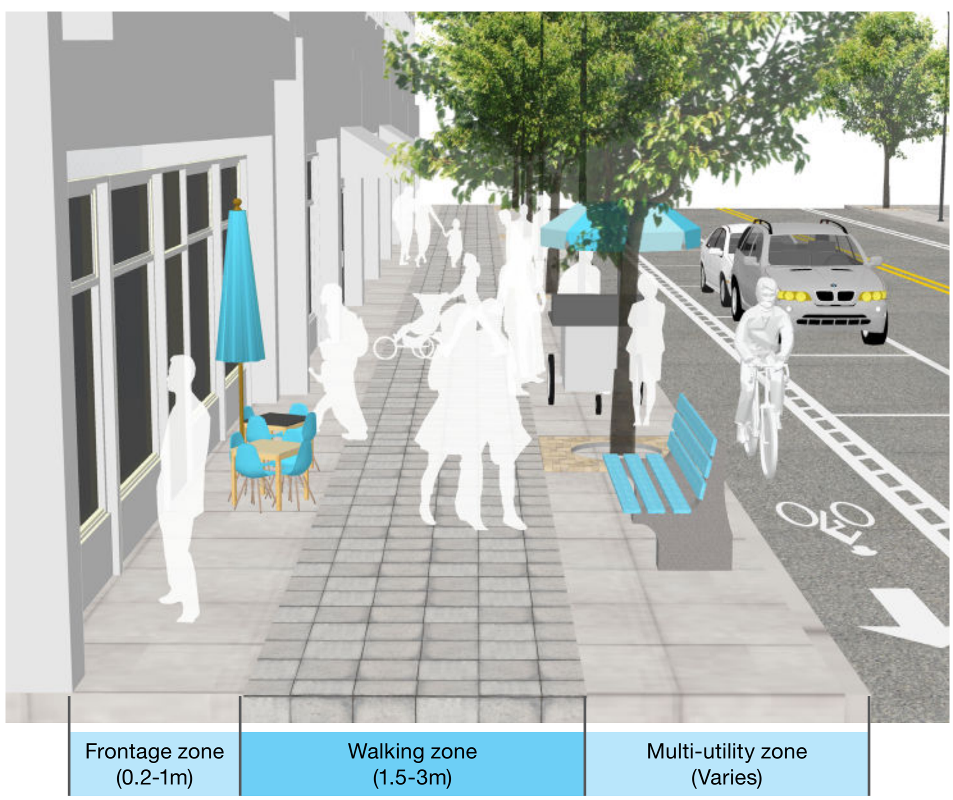


Figure 8. Three components of a sidewalk

	Frontage Zone	Walking Zone	Multi-utility Zone
Purpose	This is the area touching the boundary of the right-of-away, that is, abutting the property edge line or compound wall. It is meant to accommodate spill-over uses from the adjacent property. Active frontage and multi-utility zones provide 'eyes-on-the streets' and creates a sense of security for pedestrians.	It is the area immediately adjacent to the frontage zone which is actually used by pedestrians to walk. This space should be kept free of encumbrances that impede walking.	It is the area, normally located between the walking zone and the traffic or parking lane. Its use will vary depending on the context, to accommodate street vending, street furniture, trees, utility boxes, light poles, signal posts, signage posts, crossing waiting areas, etc.
Typical Widths	The width of the frontage zone can be between 0.2 to 1m. In the case of large developments, it is a good practice to ensure that building setbacks are designed to serve as additional frontage zones	For feeder lines to the main walking routes, a walking path width of 1.5m minimum may be acceptable. Typically, 3m should be the minimum width for the walking zone on a trunk route.	There is no standard width for this zone, as it will depend on context and the available right-of-way.

Table 2. Three components of a sidewalk

Distinguishing the walking path

4. It is important to note that the boundary lines of the three stated components of the sidewalk are notional. Their actual space requirements are likely to vary along the corridor, depending upon the context at that particular point along the right-of-way, as well as the adjacent land-use. However, it is a good idea to offer some visual cues to distinguish the walking zone, especially along the trunk walking routes to the transit station. This can be achieved by the use of softer design elements, such as a different pavement style or surface treatment (paved versus landscaped) or creating a marginal height difference. These cues aid in guiding road user behavior, informing people about the appropriate use of the space.

Deviations in the walking path

5. In some situations, deviations in the walking path are unavoidable - on account of the presence of a tree or a difficult-to-relocate utility box. In such cases, the walking path should be designed to curve around the encumbrance, preferably with a gradual transition.

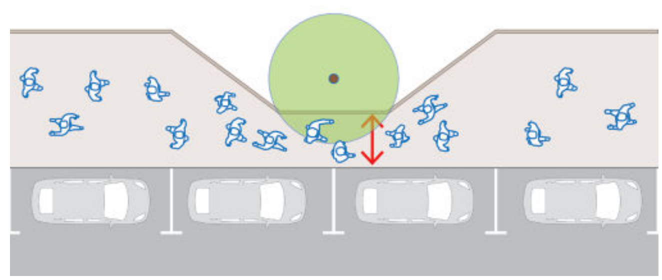


Figure 9. Immovable obstructions on the sidewalk restricting pedestrian movement

Walking path continuity

6. Another important design consideration for the walking zone is to ensure a uniform height along the entire length of the sidewalk. This is especially important on the trunk walking routes, because it allows for a faster and more convenient movement of commuters. This is achieved by maintaining the same height for the walking path across property entrances and exits. There are two aspects as to how this can be achieved; the planning aspect – restricting vehicular access on main pedestrian routes; and the design aspect - bringing vehicles up to the sidewalk height through the use of ramps. The space for ramps can be accommodated in the multi-utility zone space on the traffic lane side, and in the frontage zone or within the property on the property edge side.

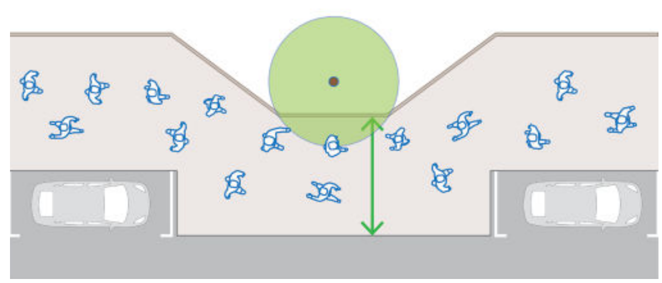


Figure 10. Deviations made around obstructions for continuous walking path.

Streetlights & 'Active' Sidewalks

7. Streetlights contribute towards improved visibility, thereby help in preventing road crashes and injuries. Additionally, they also improve the pedestrian realm by providing a sense of security along with visibility of the walking space. An 'active sidewalk' can be achieved through active frontage from commercial and recreational activities at the street level of the developments as well as encouraging vending and other activities in the multi-utility zone. This ensures there are 'eyes-on-street' and provides a sense of security to pedestrians.

8. Lack of activities on the sidewalk (especially in the frontage and multi-utility zones) and inadequate street lighting can create unsafe experience for pedestrians and force them to use the vehicle travel lanes which are typically more well lit. This raises conflicts between the different road users leading to potential crashes. It must be noted that the lighting needs for pedestrians and vehicular traffic are different and therefore must be designed and integrated within the overall lighting strategy of the street.

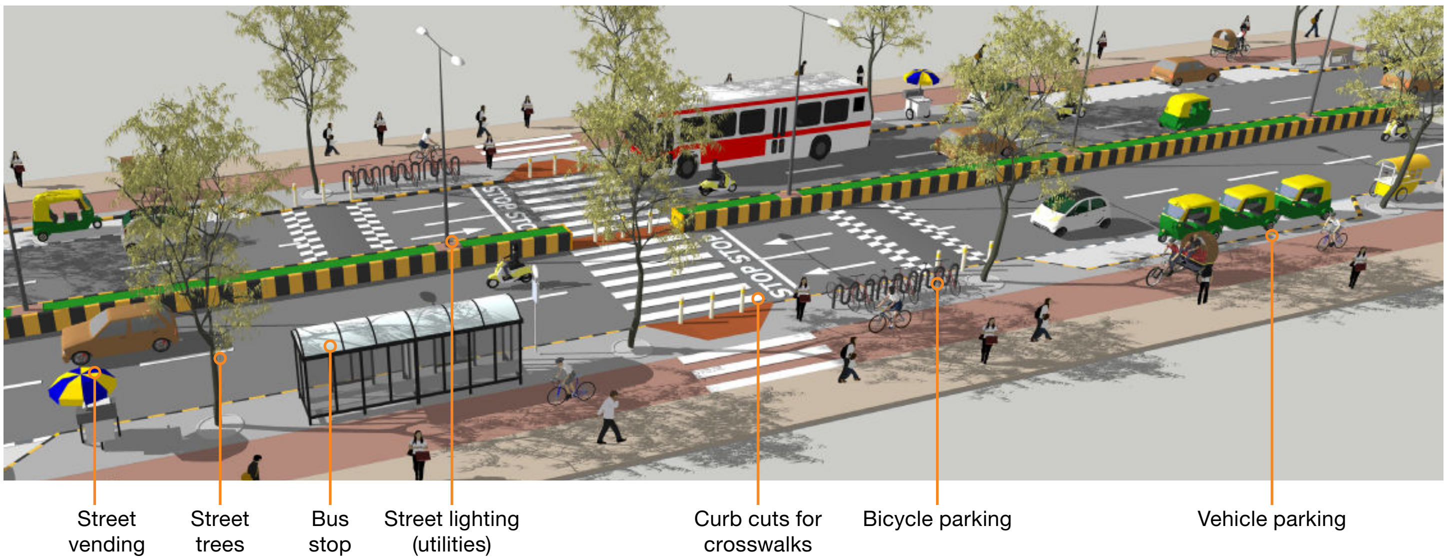


Figure 11. Typical multi-utility zone with different types of uses

Crossing Design

9. Almost every walking trip will require the pedestrian to cross a road at some point along the trip. From the perspective of safety, they are as critical because it is at the crossing that the pedestrian is at the highest risk of collision with other traffic. Hence, the design of safe crossings is a crucial component of the walking network for a TOD zone. There are many important considerations for pedestrian crossings, which are discussed over the following sub-sections. Refer PD-R02

Crossing frequency and location

10. The most important aspects of pedestrian crossing provision are their frequency and location. From the perspective of access to the transit station, crossings must be provided such that the continuity of the walking network is maintained. The crossings are the bridges of the network, and hence, their location and design features should be congruent to its role in the network. If a particular stretch of the walking network cuts through the middle of a block, then a mid-block crossing must be provided to continue the network.

11. A TOD zone with a higher density of crossing opportunities is, typically, safer and better for walking. Crossing infrastructure must be provided at all intersections. Block sizes should be limited such that intersections crossings are not more than 150-200m apart in the high-density areas close to the station. In already developed areas, it may not be possible to modify block sizes. In this scenario, one should consider the provision of mid-block crossings, where necessary.

Crossing width

12. A pedestrian crossing must be at least as wide as the sidewalks that it connects. An even wider crossing width may be desirable, along the trunk walking routes to the transit station, as it allows for more people to cross at the same time, which reduces delay and allows for shorter pedestrian signal cycles. Moreover, a wider crossing is more likely to be distinctly visible to vehicular traffic. We recommend a minimum width of 3m, though a width closer to 5m may be desirable on high volume routes that connect to mass transit stations or BRT stops catering to the pedestrians going towards and coming out from the stations or BRT stops at the same time. Wider crossing would facilitate this opposite directional movement and avoid collisions between pedestrians in the station area with pedestrian traffic specifically due to transit station.

Crossing alignment

13. Deciding on the alignment of a pedestrian crossing raises two questions. Should the crossings be so aligned that it continues the natural walking path between the two adjoining sidewalks? Or should it be aligned perpendicular to the traffic lanes, such that crossing distance is minimized? Based on the type of intersection - right-angled or skewed - the crossing alignment would follow the natural walking path or else the shortest path to avoid increased exposure of crossing pedestrians to the incoming traffic. These alignments are same in right-angled intersections, whereas if the angle of the intersection is skewed, then there will be a deviation in the two paths. These have been compared in Table 3

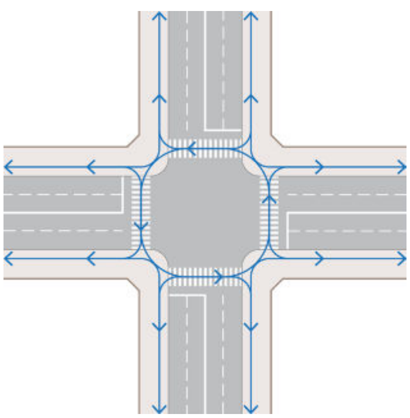
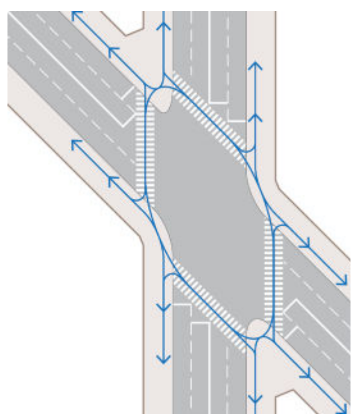
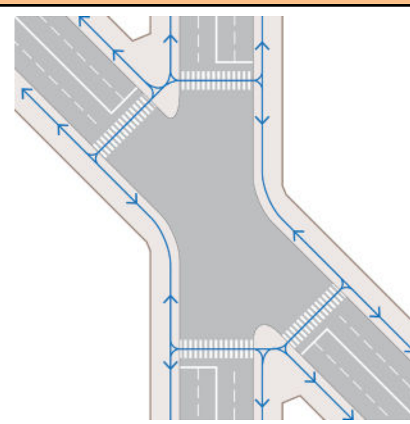
Right-angled intersections	Skewed intersections	
 Figure 12. Natural walking path and desire lines for a right-angled intersection..	 Figure 13. Crosswalks aligned along desired movement patterns in a skewed intersection.	 Figure 14. Crosswalks aligned along shortest crossing distance in a skewed intersection.
The natural walking path and the shortest crossing distance will align at a 4-arm, right angled intersection.	For **signalized intersections**, pedestrians will like to avoid deviations to their natural walking path. It is recommended aligning the crossing to the straight line connecting the two sidewalks. The pedestrian phase in the signal cycle should allow for the safe completion of this crossing distance.	For **non-signalized intersections**, crosswalks are aligned to minimize the crossing distance. This reduces the amount of time that the pedestrian is put into potential conflict with vehicular traffic. Moreover, it positions the pedestrian and traffic perpendicular to each other, which improves their visibility of each other.

Table 3. Comparison between location of crosswalks in different types of intersections.

Intersection corner curvature

14. The curvature of intersection corners has a significant impact on pedestrian safety. A generous curvature allows vehicles to make left turns (in the case where traffic drives on the left), or right turns (in the case where traffic drives on the right), at high speeds, which puts pedestrian at risks, particularly at un-signalized intersections. Moreover, a wide curvature increases the size of the intersection, which increased the area of undefined road space where conflicts may arise. Furthermore, pedestrian crossings get pushed further back and away from the natural crossings path. A wide intersection curvature eats into the sidewalk space, reducing the availability of space to accommodate pedestrians waiting to cross the road.

15. It is recommended to have intersection corner curvature radius approximately 4-6m, which allows for most vehicles to make a safe turn at a slow speed, from the corner-most lane to the corner-most lane. Larger vehicles may require entering into the adjacent lane either before or after the intersection. This is an acceptable design compromise, if this is not a major transit bus-turning route, and there aren't too many large vehicles expected to use this intersection. These differences have been highlighted in Figure 15

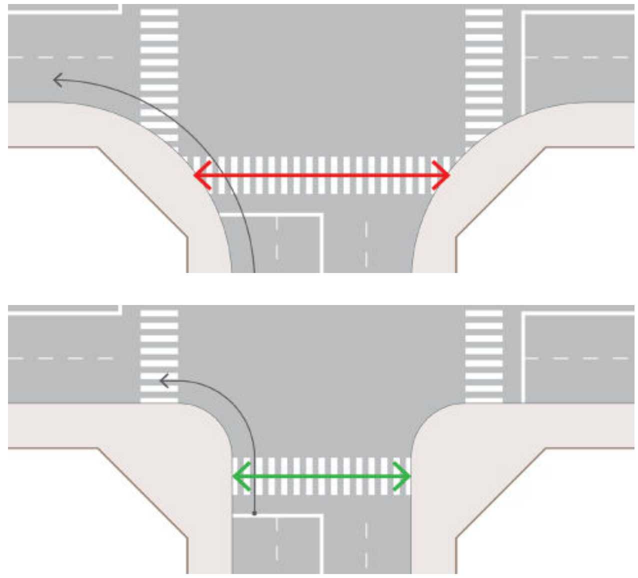


Figure 15. Reduced intersection corner curvature for pedestrian safety

Reducing intersection corner curvature increases pedestrian safety as it enables drivers to turn at significantly slower speeds and also reduce pedestrian crossing time.

Pedestrian waiting area

16. The pedestrian waiting area is an important component of a crossing that often gets ignored in the design of intersections. This space is especially important for signalized intersections to accumulate the build-up of pedestrians waiting for their light to turn green. The space requirement of the pedestrian waiting area is likely to be very high on the trunk walking lines in a TOD zone. Table 4 below indicates different ways of accomplishing this.

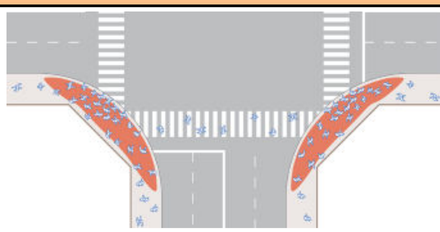
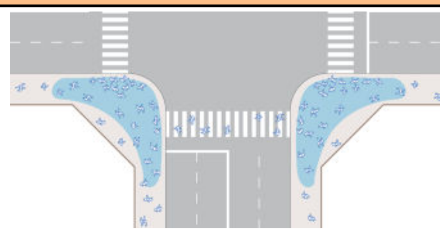
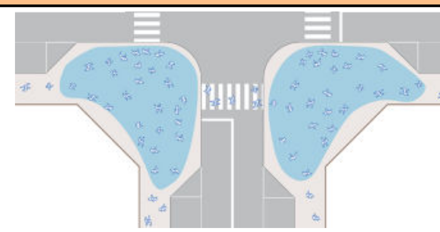
Existing concerns	Tighter curvatures	Curb extensions
 Figure 16. Existing conditions with wider corner radius	 Figure 17. Tighter corner radius provides more waiting area for pedestrians.	 Figure 18. Curb extensions created by removing travel lanes further reduce crossing times for pedestrians.
If adequate space is not provided, pedestrians may spill onto the traffic lane. The pedestrian waiting area must be kept distinct from the walking area, especially along the trunk walking routes; otherwise waiting pedestrians will hold up walkers who just want to pass through.	The pedestrian waiting area must be kept distinct from the walking area, especially along the trunk walking routes; otherwise waiting pedestrians will hold up walkers who just want to pass through. The best way to ensure a large waiting space, is to keep the intersection corner curvature as tight as possible.	Another measure is to eliminate the parking lane, if present, at the intersection, and create a curb extension to accommodate the waiting area.

Table 4. Comparisons highlighting issues of inadequate pedestrian waiting areas and mitigation measures

Traffic Signals

17. All major intersections in the TOD zone must be equipped with traffic signals, which incorporate pedestrian signal cycles. In general, any crossing that has more than two lanes, without the presence of a median, must have a pedestrian signal. The pedestrian green phase must be long enough to allow for most pedestrians to cross the road in one phase.

18. The pedestrian green times may have to be even longer on the main walking routes within the immediate station areas which may be synchronized with the timings of transit services to accommodate the higher volume of pedestrians going towards or coming out from the mass transit stations or BRT stops. These time synchronization are critical where interchanges between one mode to another takes place, and the connections aren't direct and require crossing a road to access the stations.

19. On the major walking routes leading to the mass transit station, one can consider the implementation of signal priority and signal synchronization for pedestrians. This allows for pedestrians to face a "green wave" (uninterrupted green phases as soon as they reach the intersection); which aids in the safe and convenient access to the station.

20. Additional Intelligent Transportation System (ITS) technologies can be incorporated which include use of AE cameras to detect over speeding of vehicles and turning the signal red to ensure speeds under safety limits are maintained within the station area. Saw-cut loop detectors can also be buried at intersections to detect traffic presence and accordingly phase the signal cycles so as to avoid traffic jams that may impede movement of shared modes and feeder services.

21. Normally, right-turning traffic (in right-side driving countries) and left-turning traffic (in left-side driving countries) are allowed to share the phase with pedestrians. However, on the main walking routes in TOD zones, the high volume of pedestrians may warrant that turning traffic be restricted, at least for some length of the pedestrian signal cycle.

Off-road pedestrian paths

22. Off-road pedestrian paths aid in augmenting the walking network in a TOD zone, and also in mitigating network gaps. Normally, at-grade paths will cut through properties, public plazas, gardens, etc. These paths are for the exclusive use of pedestrians and/or cyclists. Motor-vehicle traffic is not permitted entry. Thus, the safety considerations for such paths are limited.

23. Off-road pedestrian paths may also be augmented with the utilization of grade-separated infrastructure. There are broadly two categories for such infrastructure. The first category is infrastructure only meant to cross a single road, such as a FoBs or an underpass. The second category is grade-separated infrastructure of a much longer length that provides direct connectivity to multiple locations including the transit station, and may comprise of a network of interconnected sections. Such infrastructure is normally elevated, and commonly referred to as sky-walks, though there are cases of sub-terrain pedestrian networks as well.

24. As a general principle, FoBs and underpasses are not recommended as crossing substitutes. This infrastructure is very expensive, and impractical to implement at each location where a crossing is needed. Pedestrians also do not prefer them, because of the physical exertion and time delay involved, in comparison to crossing at street level. This infrastructure is unfriendly to the needs of differently-abled users, such as wheelchair-bound pedestrians, senior citizens and people using wheeled units like trolleys and strollers. Moreover, the access points of such infrastructure tends to impede the free movement of the sidewalk, because of the presence of stairwells and elevator shafts.

25. On the other hand, grade-separated pedestrian networks may be useful to augment at-grade pedestrian infrastructure. They are particularly useful in connecting to the transit station, when the station is at the same grade as the network. This eliminates the need to change grades for pedestrian commuters, at one of their trip. Such infrastructure can also provide direct connectivity of major establishments to the transit station, which can be have a positive impact both for walking and for transit patronage.

26. While there are contexts where the provision of such infrastructure has benefits, their provision must only be considered as additional to at-grade infrastructure, intended to provide commuters with more options. It should not be used indiscriminately, or at the cost of providing functional sidewalks. Care should be taken to ensure that this infrastructure is accessible for all users, and its civil structures do not impede the free flow of pedestrians on the sidewalks.

Cycling Infrastructure

27. Cycling is a healthy and sustainable mode of commute that can play an important role in enhancing connectivity to transit. It has a higher reach than walking, which greatly increases the commutable distance to the transit station.

28. The most crucial aspect for cycling safety is the design of street infrastructure. It is recommended to use dedicated cycling infrastructure, because average motor-vehicle speeds tend to be unsafe for cyclists. This is a good guiding principle for greenfield development. However, it is rarely practical to uniformly implement dedicated cycle lanes in most existing developments, due to either the paucity of road widths, or other land-use constraints. In these contexts, the cycling network for the TOD zones will comprise of the judicious use of dedicated cycle lanes where viable, in combination with traffic-calmed, shared streets. As a general principle, cycle lanes are recommended for the trunk routes leading to the station; while feeder lines to the trunk route may comprise of traffic-calmed streets.

Cycle Lanes

29. It is recommended to use dedicated cycle lanes on trunk routes of the cycling network, leading to the station. Normally, the trunk cycling corridors will also contain the trunk transit and motor-vehicular routes, and hence will have a high volume of large vehicles and fast-moving traffic. Thus, the provision of dedicated cycle lanes can have a significant positive outcome on cyclist safety. Table 5 below compares the types of dedicated cycled infrastructure that can be incorporated.

Physically segregated cycle lanes	Marked cycle lanes
Segregated from vehicular traffic, either, by curbs, medians, railings or landscaping.	Normally delineated through the use of road-marking and roadside signage on the main carriageway.
Segregated infrastructure reduce the possibility of a motor-vehicle entering the cycle lane and colliding with a cyclist. It is recommended to avoid use of railings as segregation, because it effectively reduces the usable width of the cycle lane, as cyclists don't tend to ride closer to the railings. Median curbs or landscape strips should be used instead.	A uni-directional cycle lane, marked on the main carriageway, must be at-least 1.5m wide, and it will depend on whether there is parking space or a bus lane on the adjacent space. This allows for some buffer from traffic moving in the adjacent lane; but it does not provide enough width for a faster cyclist to overtake a slower one. For long block lengths, it is recommend the provision of pull-out zones to allow for cyclists to safely overtake.
Can be designed to be either uni-directional or bi-directional. When designed to be bi-directional, the cycle lane acts much like a sidewalk, and cycle crossings can be designed in sync with pedestrian crossings.	Typically, are uni-directional, and cyclists are expected to ride in the same direction as traffic on their side of the road. It is recommended to avoid use of contraflow cycle lanes.

Table 5. Comparing different types of dedicated cycle lanes.

30. There are two kinds of cycle lanes:

- A uni-directional cycle lane, marked on the main carriageway, must be at-least 1.5m wide. This allows for some buffer from traffic moving in the adjacent lane; but it does not provide enough width for a faster cyclist to overtake a slower one. For long block lengths, it is recommend the provision of pull-out zones to allow for cyclists to safely overtake (Figure 19).
- A bi-directional cycle lane must be at least 2.5m to allow for cycling units to pass each other. Keep in mind that the cycle lane is not only for bicyclists, but for all wheeled, active modes of transport, which includes wider vehicles, such as tricycles or cycle-rickshaws (Figure 20).

Figure 19. Uni-directional marked cycle lane.

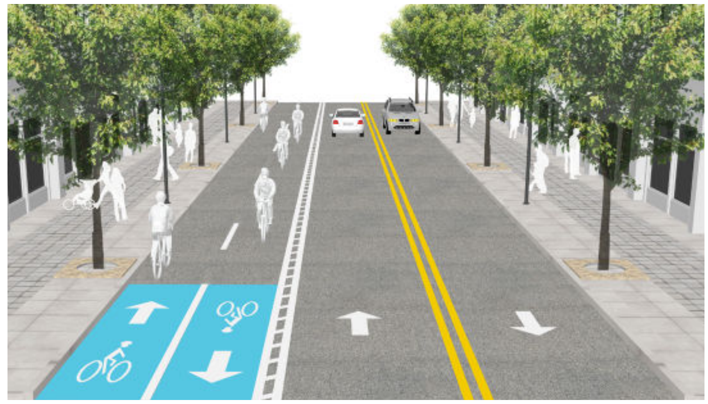


Figure 20. Bi-directional marked cycle lane.

Cycle lanes positioning across bus stops

31. The overlap of cycling routes and feeder bus routes can create potential safety conflicts. Buses need to stop next to the sidewalk to pick-up and drop-off commuters. This may mean that the bus has to cut across the cycle lane to access the bus stop. This is a potential safety risk, given the mass and speed of the bus in relation to the cyclist. This risk is further heightened by the fact that the bus driver has to change lanes behind the line of sight of the cyclist.

32. It is recommended that, where possible, trunk cycling routes and bus-feeder routes be kept separate. If there are parallel roads leading to the station, then this becomes easier to implement. Where sharing the route is unavoidable, we recommend that the cycle lane be continued behind the bus stop, such that the bus does not have to enter the cycle lane to reach the bus stop. Here, the bus stop area is separated from the sidewalk, and commuters will have to cross the cycle lane to access the bus stop.

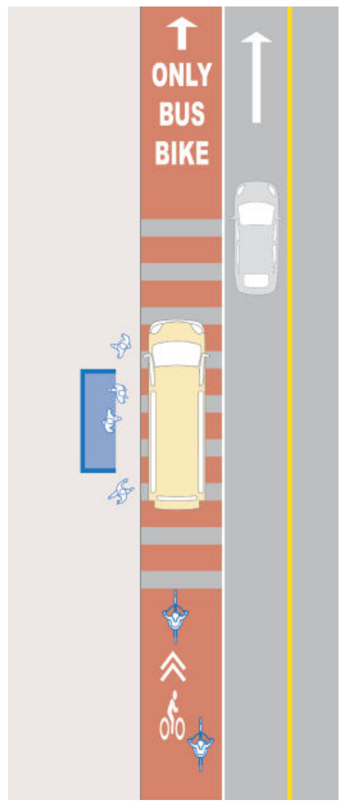


Figure 21. A shared bus and bike lane

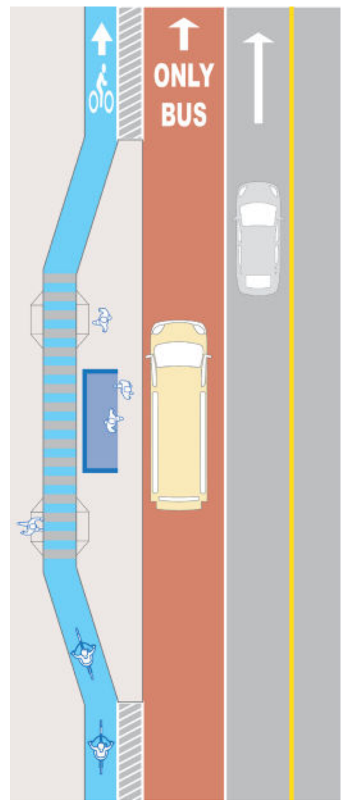


Figure 22. Separate bus and cycle lanes, with cycle lane going behind the bus stop

Figure 23. A bus station bypass in Rio de Janeiro, Brazil that raises the bicycle lane to the sidewalk level while bypassing the bus waiting area. Source: WRI

Cycle lanes and on-street parking

33. It is not recommended to provide on-street parking on trunk access routes leading to the transit station, unless there is enough road width remaining after providing for all feeder network infrastructure. This is generally a very impractical condition for already built-up TOD zones in the developed areas of the city. Often, the creation of a cycle lane is possible only by taking away space from on-street parking.

34. On-street parking creates other potential safety conflicts for cyclists. Vehicles benefit from being parked as close to the sidewalk as possible. This requires them to cut across the cycle lane (Figure 24), creating similar safety concerns as described in the previous sub-section on bus stops. Moreover, when the door of a parked car is suddenly opened on the side of the cycle lane, it creates a safety hazard for the cyclist (Figure 25).

35. It is recommended that paid on-street parking be provided on streets with cycle lanes, only where there is a possibility to separate the parked vehicles from the cycle lane by a buffer (Figure 26). This buffer should be at least half a meter wide, to contain the width of an opened car door, and also allow people to enter and exit their car safely, without standing on the cycle lane. It could also be designed as a raised median. (Figure 27).

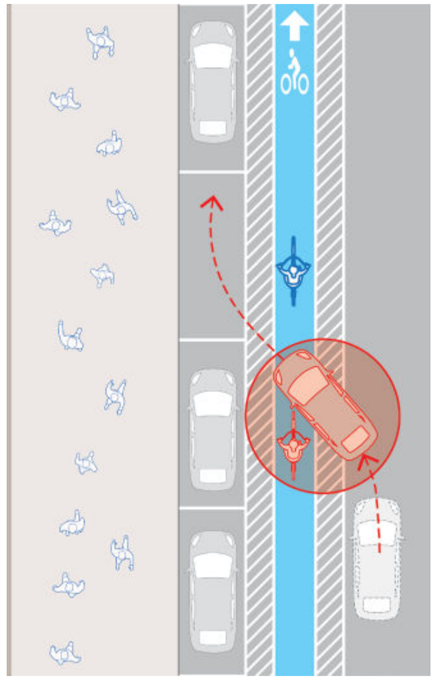


Figure 24. Cycle lane between travel lane and parking lane

Vehicles cutting across cycle lanes to access on street parking adjacent to sidewalk create safety hazards for cyclists

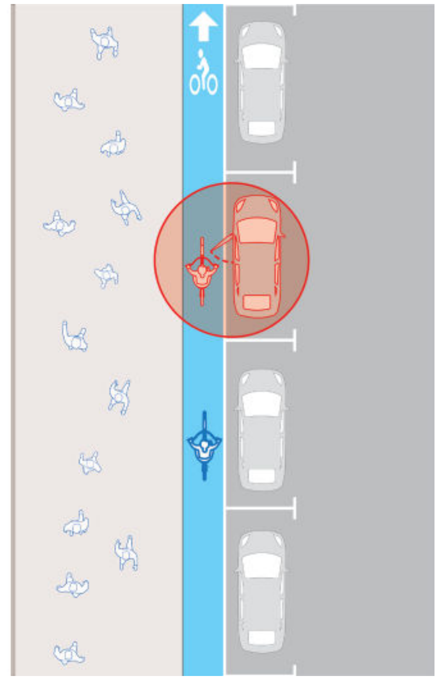


Figure 25. Cycle lane between sidewalk and parking lane without any buffer

Doors of cars opening on the side of cycle lane without adequate buffer may conflict with cyclists

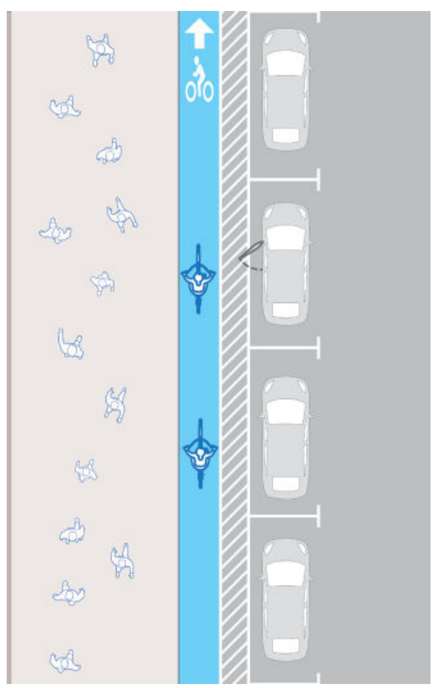


Figure 26. Buffer between cycle lane and parking lane using on-street markings using paint.

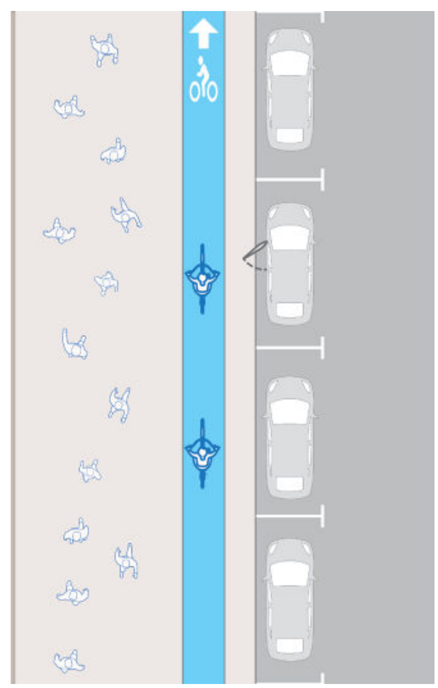


Figure 27. Protected bike lanes with physical separations using raised median as buffers

Intersections and cyclist movement

36. The design of intersections is a crucial aspect for the overall safety of the cycling network. There have been a number of design alternatives that have been developed, which have different benefits and disadvantages with respect to the mobility and safety of cyclists. The traffic lights in such intersections should include a traffic signal for cyclists, which is synchronized with pedestrian lights. In larger intersections with multiple lanes, an advance phase cycle signal may also be provided. These alternatives have been summarized in Table 6 with details explained in TOD Knowledge Product PD-R02, followed by a graphical representation of an intersection with bus priority lanes and a two-stage cycle turn lane (Figure 34).

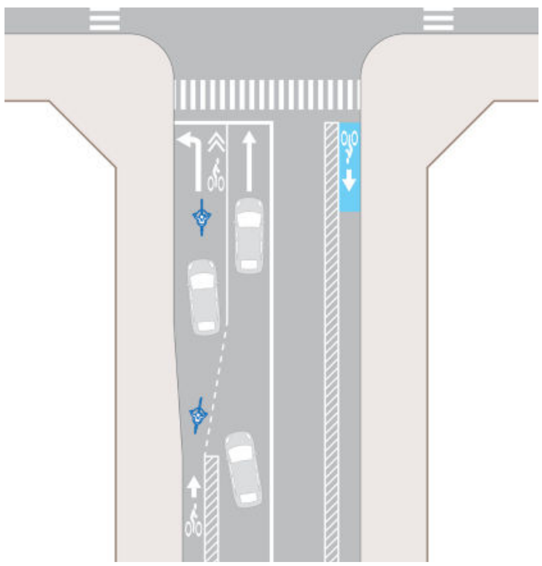
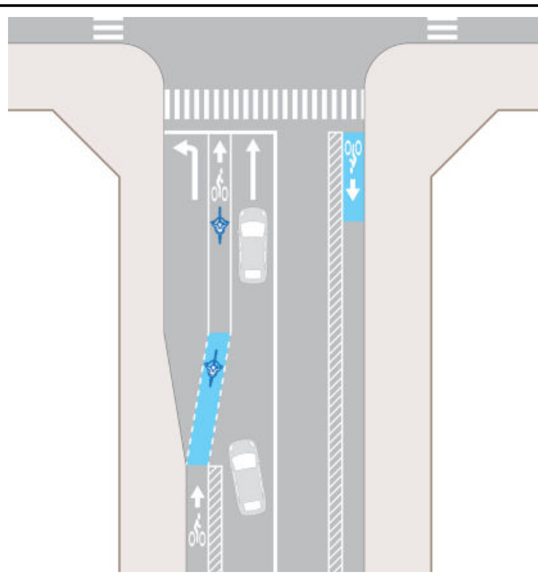
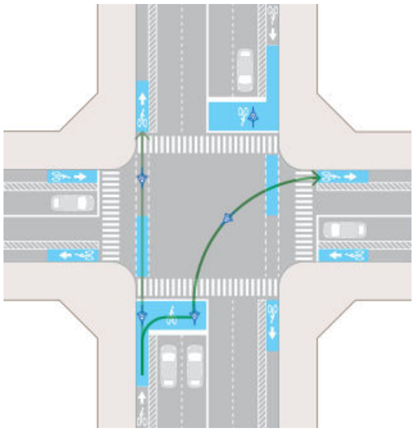
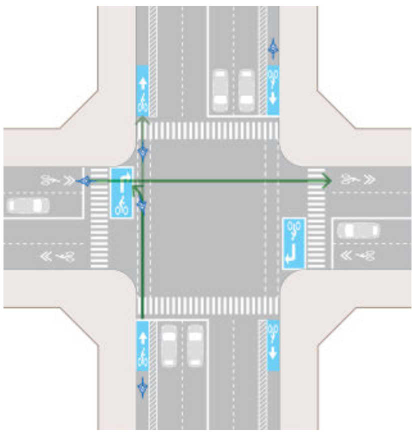
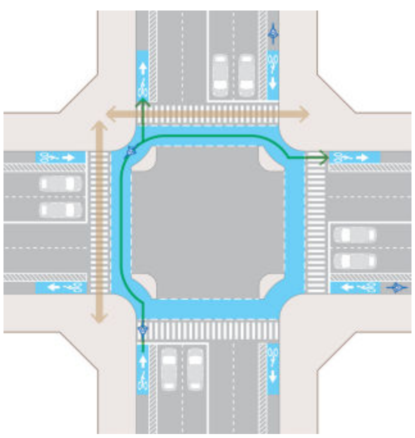
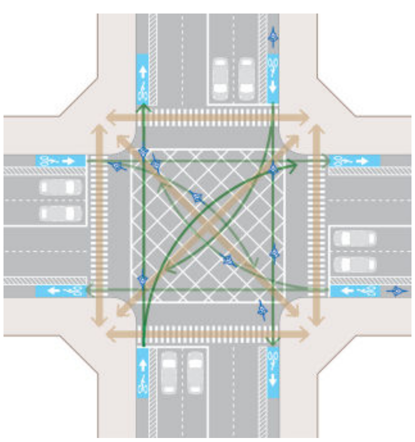
Type	Diagram	Description
Regular, traffic calmed intersection	*Refer diagrams for modified intersections in a shared street: Figure 59 on Page 55, and Figures 60, 61 on Page 56.*	No definitive cycling infrastructure is provided; but intersection is designed with speed control standards of a shared street
Advanced termination of the cycle lane	 Figure 28. Advanced termination of bike lane as it nears an intersection.	The cycle lane is terminated a few meters before the mouth of the intersection.
Provision of a turning lane between the cycle lane & sidewalk	 Figure 29. Turning lane inserted between cycle lane and sidewalk.	A left turning lane* for general traffic is provided between the sidewalk and the cycle lane.

Table 6. Summary table for different types of intersections

Advantage	Disadvantage	Suitability
Easy to implement. Doesn't require much street area.	It is not appropriate for high speed intersections, with high traffic volumes and/or high number of large vehicles.	Suitable for neighborhood, traffic calmed streets, that are normally non-signalized.
It allows motor-vehicles and cyclists to align themselves in the correct position at the intersection, depending upon the direction they intend to go.	No dedicated infrastructure for cyclists, where it's need the most. There is a risk of collision be-tween vehicles & cyclists, while they're changing lanes.	Should be used very sparingly, only after all other options are considered.
It allows cyclists to continue straight through the intersection, without conflict with left-turning motor-vehicles.	There is a risk of collision at the place where the cycle lane and the motor-vehicular lane cross each other.	Should be used very sparingly, only after all other options are considered.

* Description is written on the context of countries where traffic drives on the left side of the road.

Type	Diagram	Description
Cycle boxes with 1-phase right turn	 Figure 30. Advanced stop lines with cycle boxes for cyclists to align in direction of turn	Cyclists align themselves in a cycle box, (provided between the pedestrian crossing & the stop line)
Cycle boxes with 2-phase right turns	 Figure 31. Two-phase cycle turn boxes	During the green signal phase, cyclists intending to turn right enter the intersection and align themselves in the cycle box of the perpendicular street.
Hooked cycle lanes	 Figure 32. Cycle lanes hooked with pedestrian crossing	The cycle lane is slightly deviated at the intersection to align it with adjacent street pedestrian crossing.
Scramble signal phase	 Figure 33. Single phase for cycle movement in all directions. *Can be combined with pedestrian movement in all directions*	A separate signal phase is provided for cyclists to move to and from all arms of the intersection; all motor-vehicular traffic has a red light.

Advantage	Disadvantage	Suitability
It provides dedicated infrastructure right up to the intersection mouth. It allows cyclists to complete a turn in one signal phase.	It creates some ambiguity on where the cyclist should wait if it reaches the intersection during the green signal phase for vehicular traffic on the same arm of the intersection	Suitable for trunk cycling routes with a high volume of cyclists. It is especially useful when the majority of cyclist movement makes a right* at the intersection
It provides dedicated infrastructure right up to the intersection mouth. The design is more intuitive to both cyclists and motorists.	It needs 2 signal phases for cyclists to complete a right turn.	Suitable for trunk cycling routes with a high volume of cyclists. An appropriate universal design principle, as it is likely to fit most contexts.
It slows down cyclists as they enter the intersection area. It provides better visibility for cyclists and motorists of each other.	It creates some deviation from the shortest path across the intersection for cyclists. It requires a larger intersection area to be implemented.	Appropriate and safe option wherever there is adequate inter-section area. It can be used for both signalized and un-signalized intersections.
An intuitive design that allows for the free movement of cyclists in any direction.	The addition of a signal phase may affect intersection through-put which may result in longer delays for both motorists and cyclists.	Appropriate when there is a high volume of cyclist, with no single dominant direction of movement. Suitable for intersections with more than 4 arms

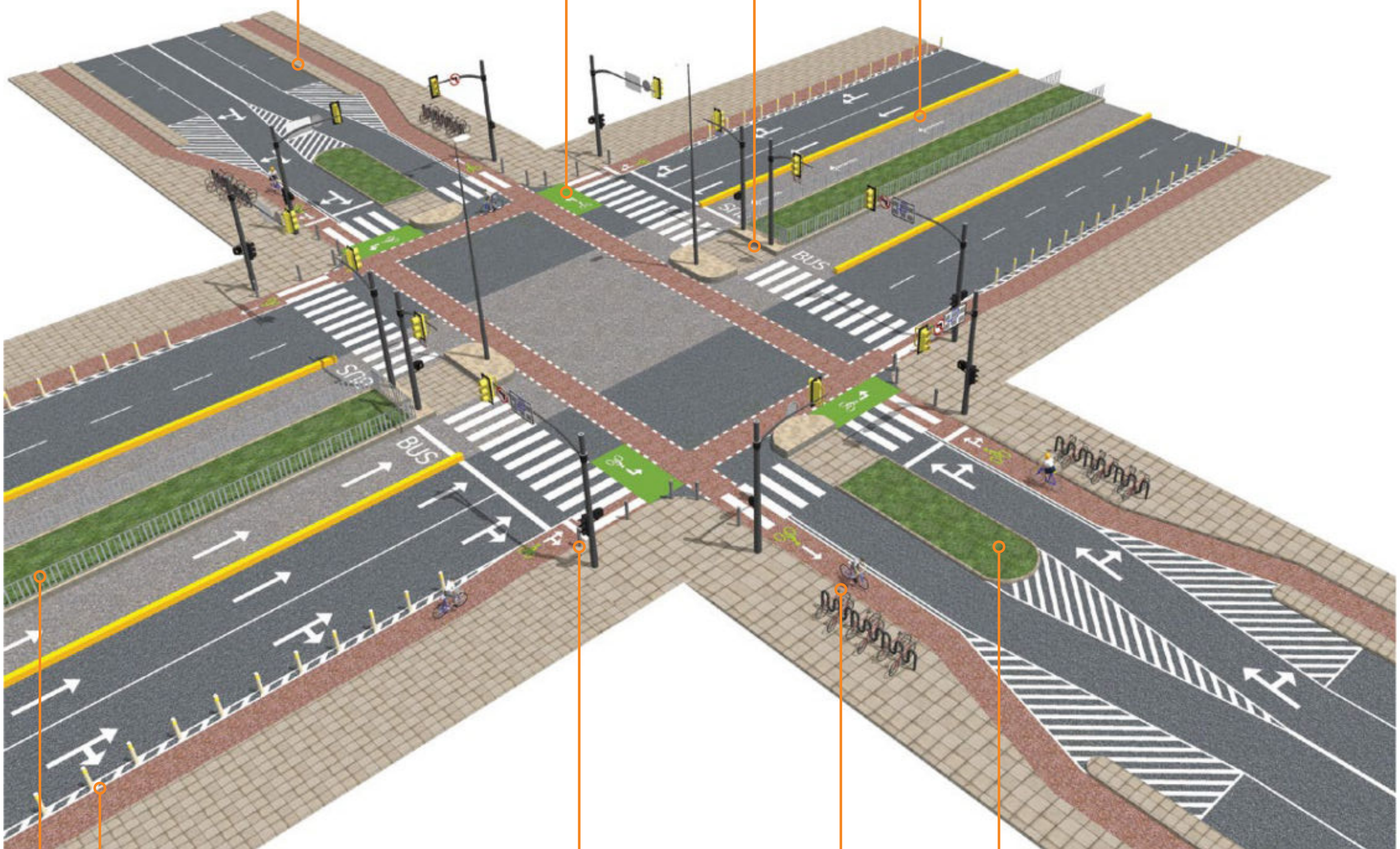


Figure 34. Two-phase cycle turn at intersection with Bus priority lanes (Source: WRI)

Feeder Transit and Para-transit Infrastructure

37. Feeder transit (generally in the form of buses) and para-transit (in the form of vans, taxicabs or auto-rickshaws) provide a valuable service in enhancing the commutable distance for transit users. This is particularly important for TOD zones in lower density area, where distances from the station may be too long for walking and cycling to be the only feeder alternatives.

38. In most cases, feeder transit and para-transit services will share the same road infrastructure as general motor-vehicular infrastructure. As such, the general design principles for safe streets will apply here. However, there are a few additional guidelines that have to be kept in mind, particularly with respect to the design of locations where these vehicles stop to pick-up and drop off passengers. These guidelines are discussed in the following sub-sections.

Bus stops near intersections

Service area for bus stops near intersections

39. The intersection is an optimal location for a bus stop for two important reasons:

- A bus stop located at an intersection is likely to have a larger area within walking distance as compared to a mid-block stop, because of the intersection of streets moving in different directions (Figure 34 and Figure 36 below).
- It reduces the walking distance to transfer between two intersecting bus routes, if their respective bus stops are located at, (or near) the same intersection (Figure 37 and Figure 38)

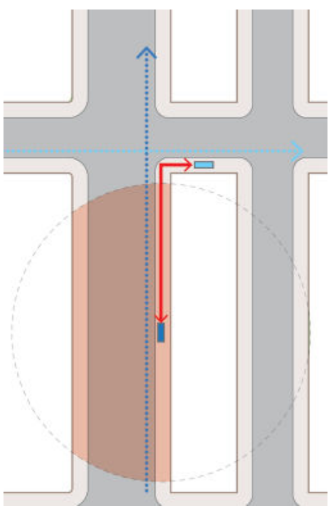


Figure 35. Bus stop location at mid-block has a limited reach and longer interchange distance

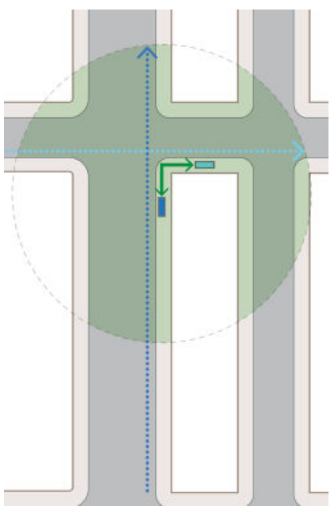


Figure 36. Bus stop located near an intersection increases connectivity and reduces the interchange distance.

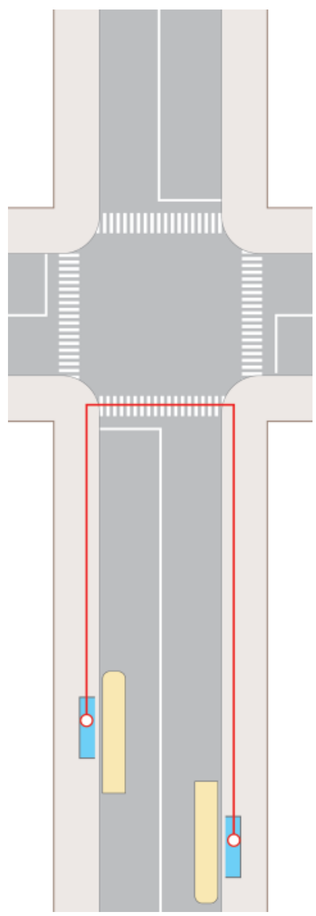


Figure 37. Transfer distances of two stops positioned at mid-blocks

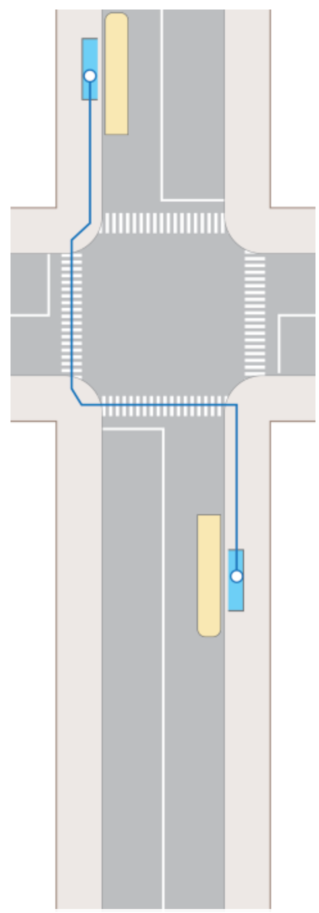


Figure 38. Transfer distances of stops near the intersection

Position of Bus stop with respect to intersection

40. The presence of a bus stop in close proximity to an intersection can create certain challenges for traffic mobility and for safety. A bus waiting at its stop may hold up traffic trying to clear the intersection, which affects intersection throughput capacity. Furthermore, the waiting bus may act as a visual impediment for motorists and crossing pedestrians, which can have a negative impact on safety. These issues raise some crucial concerns with respect to the design and positioning of bus stops at intersections.

41. Normally, a bus stop is best positioned a few meters after the intersection. In this way, the bus would have to cross the intersection before reaching the stop. The advantage of this positioning is that it does not hold up traffic that wants to go through or make a turn at the intersection. This is especially important for signalized intersections. If the bus stop were to be located just before the intersection, then, if a bus happened to reach the stop during the green signal phase, it would unnecessarily hold-up traffic behind it even though the light is green. Motorists cannot overtake the bus from the other side if they plan to turn left at the intersection (in contexts where traffic drives on the left), so they would end up queuing behind the waiting bus (Figure 39).

42. Locating the bus stop after the intersections allows all traffic, (including the bus) to queue up in the correct lane, depending on which direction they intend to move. It mitigates the risk of motorists trying to overtake or cut across the bus in order to make a turn (Figure 40).

43. Another safety advantage of locating the bus stop after the intersection is that the pedestrian crossing for this intersection (which will also service the bus stop) will be located behind the bus. A bus is a large vehicle and can block the view of motorists and crossing pedestrians of each other. By positioning the bus stop after the intersection, it ensures that most bus commuters will walk back to the intersection in order to cross the road, putting them out of the blind-spot created by the bus.

Distance of bus stops from intersections

44. The bus stop should be located some distance away from the intersection to allow for vehicles entering this arm of the road to move out of the lane occupied by the bus in order to overtake the waiting bus (Figure 41 and Figure 42).

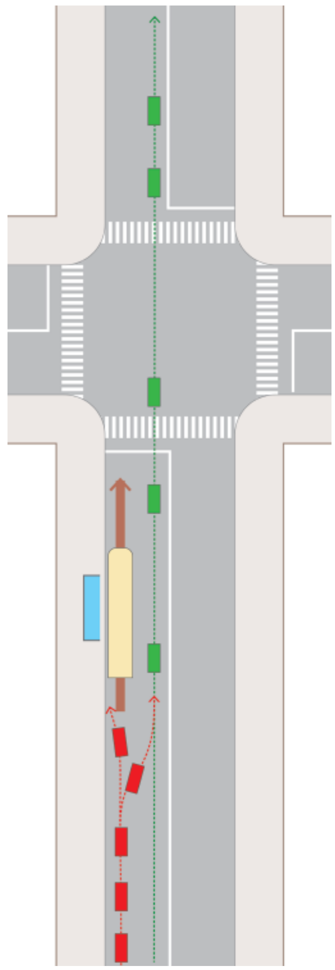


Figure 39. Impact on traffic due to stop positioned before intersection

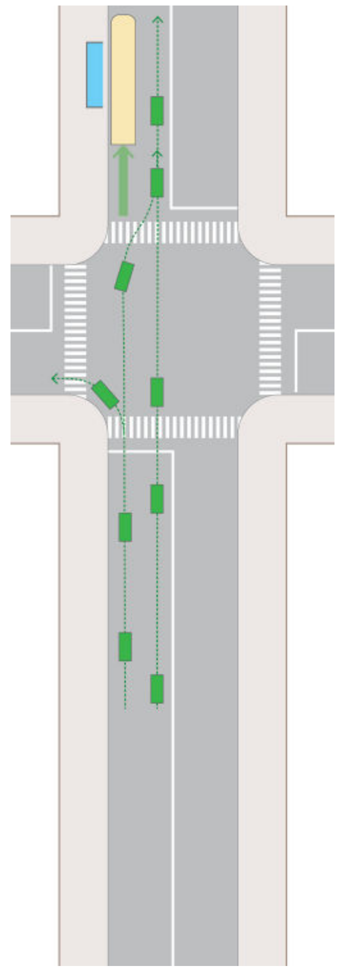


Figure 40. Impact on traffic due to stop positioned after intersection

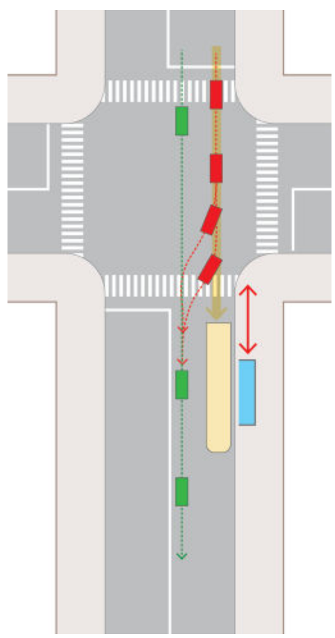


Figure 41. Impact on traffic due to stop positioned close to intersection

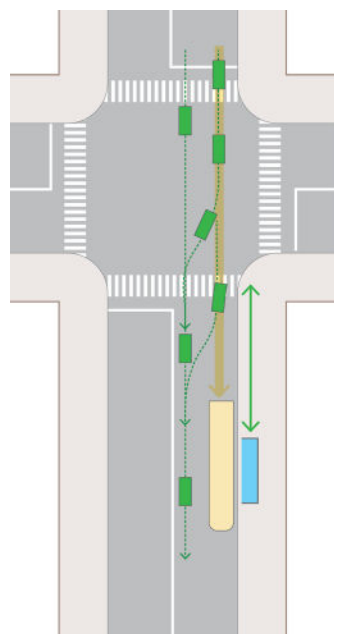


Figure 42. Impact on traffic due to stop positioned short distance from the intersection

Mid-block bus stops

45. In some context, locating a bus stop along the mid-block of a road may have some advantages. The intersections in the near vicinity may have certain complications that make it difficult to locate the stop there. In some cases, the distance between successive intersections may be very far, warranting the need for a mid-block stop. In other cases, adjacent land-use conditions may dictate the location of the stop. For instance if a prominent node, such as an educational institution or a hospital, is located at the mid-block, then it may warrant the positioning of the stop as close to this node as possible.

46. There are certain aspects to be kept in mind regarding the provision of mid-block stops. Avoid locating the bus stops along curves or slopes in the roadway, as this effects visibility of crossing pedestrians (Figure 43). As a general principle, try to locate the bus stops on opposite sides of the road, such that they share a common pedestrian crossing that is located behind both stops (Figure 44). The safety implications of locating a crossing in front of a stop were already discussed in the previous section, that is, the waiting bus blocks the visibility of motorists and crossing pedestrians of each other.

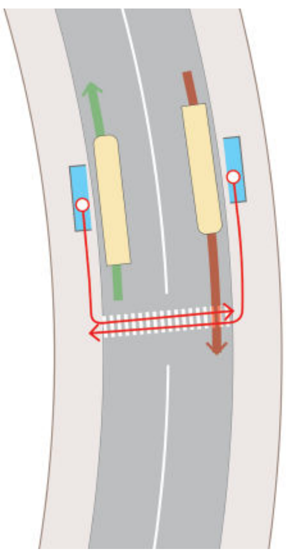


Figure 43. Incorrect location of mid-block bus stops along curved roads

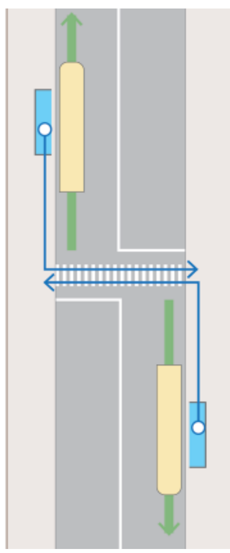


Figure 44. Ideal mid-block location of bus stops with common crosswalk

Para-transit nodes

47. Para-transit normally operates along the general traffic roadway in mixed traffic conditions. Typically, pick-up and drop-off happens all along the roadway, except where there are legal restrictions against stopping. As such, para-transit commuters do not normally require specific street infrastructure elements.

48. However, certain locations may warrant the provision of specific para-transit, where there is a high demand for para-transit services. These include nodes of high commuter footfall, such as shopping malls, educational institutes, office complexes, etc. Where demand is high, there tends to be a concentration of para-transit vehicles waiting to pick-up passengers. If adequate infrastructure is not provided, this can result in the haphazard stalling of vehicles along the roadway, which affects both traffic throughput and safety.

49. It is recommended that the provision of dedicated pick-up and drop-off infrastructure at all such nodes, to facilitate the orderly alignment of para-transit vehicles, which allow for passengers to embark and disembark these vehicles safely. The pick-up and drop-off zones function best when they are physically separated from each other, in a manner that allows for a para-transit vehicle to quickly move from the drop-off zone to the pick-up zone, (in order to pick-up new passengers). The length of each zone should be adequate to meet demand and operational conditions.

Traffic-Calming Measures for Shared Streets

50. A shared street is one where the infrastructure is designed to meet the mobility and safety standards of all road users. These standards are very different for motor-vehicle traffic than for non-motorized traffic. Thus, if a street is to be designed for all road users, it is essential that is meets the safety standards of the most vulnerable road users - pedestrians and cyclists.

51. The implementation of traffic-calming measures is an essential component of creating safe, shared streets. In most built-up urban areas, it is impractical to provide dedicated lanes to every feeder mode due to pre-existing constraints, like availability of right-of-way, traffic dynamics or adjacent land-use conditions. Where possible and practical, one may consider off-road connectors, (through parks and public places); or off-grade infrastructure. However, the opportunities for such interventions are limited, or their installation is immensely expensive. They cannot be considered as a blanket resolution for all areas where street right-of-way is limited. The most practical solution then becomes the implementation of shared streets.

52. The most important aspect of developing safe, shared streets is to slow down traffic speed. A slower street reduced the probability of conflicts between road users, while also reducing the severity of a crash when it happens. A second aspect of developing shared streets is the reduction of traffic volume, achieved mainly through the diversion of non-local traffic.

53. In some contexts, certain motor-vehicle user groups may prefer a slower street. For instance, local traffic accessing adjacent properties, will have a slower speed expectation than thoroughfare traffic. Similarly, feeder buses may also prefer slower streets, due to their need to frequently stop to pick-up and drop-off passengers. This is also true of para-transit services that may prefer slower movement, while scoping for passengers.

General design measures

Lane diet

54. The total width of the section of the road reserved for vehicular movement is often referred to as the carriageway. The width of this carriageway is a crucial factor in influencing traffic speed. There are two aspects to be considered here:

- **The traffic lane width- Wider traffic lanes allow motorists to drive faster, because of perceived lower conflict risk with traffic in other lanes.**
- **Number of traffic lanes- Greater number of traffic lanes result in increased carrying capacity, which improves traffic free-flow conditions, which further allows for faster travel.**

55. Streets in urban areas are still being designed as per inter-city highway standards, where lane width of 3.5m and more, are considered the norm. This standard allows for a design speed in excess of 50km/h, which is an extremely unsafe speed for urban conditions. Figure 45 illustrates a typical four-lane street.

56. If a street has to be shared with vulnerable road users, then the design speed should be closer to 30km/h. For local, neighborhood streets, and even lower design speed is desirable.

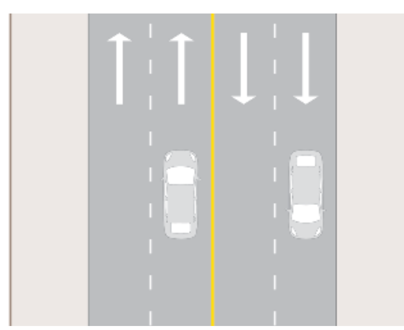


Figure 45. Existing typical distribution of ROW with wide travel lanes

57. A shared street must not have more than 2 traffic lanes in either direction. Anything more than 2 lanes makes it difficult to implement a design speed close to 30km/h. In most cases, 1 lane in each direction is adequate for local, neighborhood streets. If an existing road of more than 2+2 lanes is to be redesigned along shared street principles, then consider converting the additional lanes into a parking lane; or utilizing the additional road width to increase space for other street elements, such as sidewalks. Table 7 below includes some alternatives for re-distributing the street ROW.

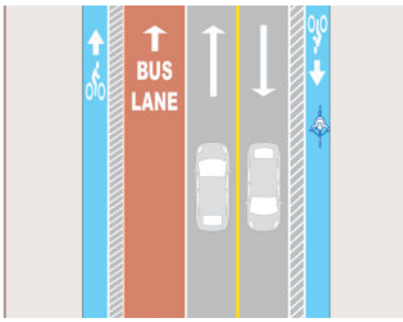
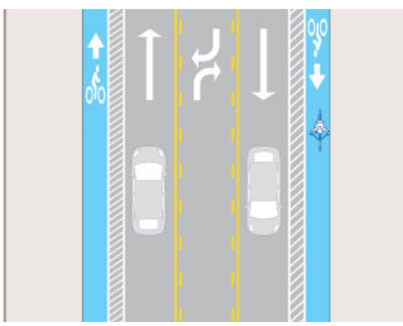
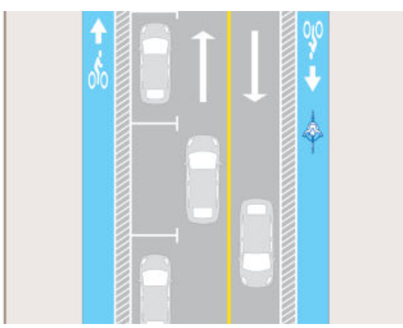
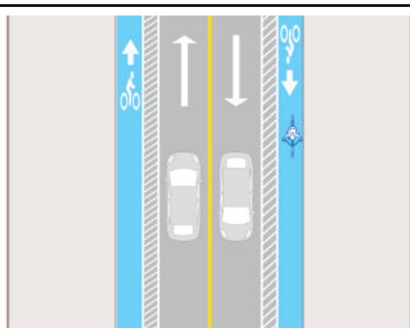
Diagram	Description
 Figure 46. Redistributed ROW with narrower travel lanes, cycle lanes, and bus lane	A traffic lane width of 3m (upper limit) is recommended for all shared streets. An exception may be made for roads that are part of the transit bus network, where the lane utilized by the bus, (in most cases adjacent to the sidewalk), may be as wide as 3.5m. For neighborhood streets, and even narrower lane width than 3m is desired, especially if this street is meant to cater primarily to local traffic movement.
 Figure 47. Redistributed ROW with narrower travel lanes, cycle lanes, and center turn lane	Travel lanes rearranged to have a center turn lane and unidirectional cycle lanes.
 Figure 48. Redistributed ROW with narrower travel lanes, cycle lanes, and on street parking	Additional on-street parking lane
 Figure 49. Redistributed ROW with narrower travel lanes, cycle lanes, and wider sidewalks	Extended sidewalk widths to provide space for pedestrians.

Table 7. Alternatives for ROW redistribution

Urban design measures: Streetscapes and gateways

58. Traffic-calming measures include several engineering interventions to slow down of traffic. In addition, there are many urban design measures that act as visual cues, encouraging motorists to select the appropriate speed for this zone.

59. The presence of setbacks along the road front have a psychological impact on speed selection. A street where buildings are set nearer the road edge are perceived to be narrower than streets of similar widths, but where the buildings are further apart. This induces motorists to drive slower on the former kind of street, due to the narrower visibility range. Trees planted close to the carriageway edge have a similar impact on speed selection. From a TOD zone planning perspective, regulations can be implemented to relax frontage setback norms, (where appropriate), to encourage more compact development

60. Another measure to encourage motorists to slow down when entering a traffic-calmed street is to include more diverse road users, such as on-street parking and street-vending. These uses increase the perceived disruptions to the motorist, which encourages them to slow down. In addition, softer streetscape elements may also be considered to signal to the motorists that they have entered a traffic-calmed street. This include measures such as change of carriageway surface material and color, as well as the increased use of landscaping and other street furniture.

61. If there are definitive entry points into a neighborhood from a main street, it is a good practice to install a gateway feature across the entry point, which informs motorists that they're about to enter a different kind of right-of-way. This encourages them to slow down and choose the appropriate speed for this zone.

Mid-block design measures

Vertical speed controls: Speed humps, speed tables and speed bumps

62. There are three kinds of vertical deflectors, that are effective in controlling vehicular speed as shown below in Table 8. They have slightly different design features which also impacts their functionality and applicability.

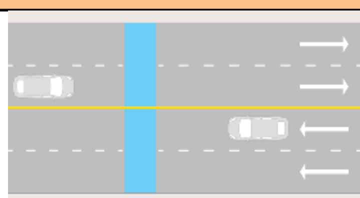
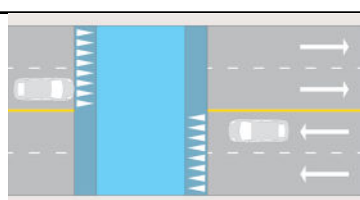
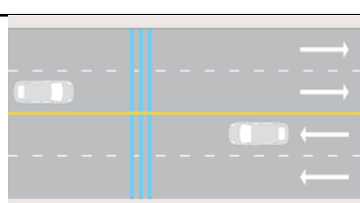
Type	Diagram	Description
Speed Hump	 Figure 50. Speed hump	Curved, raised area, along the width of the carriageway, which causes a vertical deflection for vehicles as they traverse it, which induces motorists to slow down in order to cross the hump comfortably.
Speed Table	 Figure 51. Speed table	Refers to an elongated speed hump, with a flattish section between the up and down slopes of the hump. A pedestrian crossing may be included along the flat section of a speed table.
Speed Bump	 Figure 52. Speed bump	Significantly narrower in cross-sectional width than a speed hump, which causes a more striking vertical deflection for a vehicle. A vehicle, normally, has to come to a near stop, in order to cross the bump comfortably.

Table 8. Vertical speed control alternatives

63. Speed humps or tables are recommended for local, neighborhood streets as a traffic-calming device. Speed bumps are normally not recommended for public streets, because of their abrupt impact on vehicles. They are more suitable for driveway or parkway entries. The frequency of speed humps along a stretch of road should be such that it discourages speeding in-between two humps.

64. Speed humps may be provided before pedestrian crossings, especially in cities where motorists are unlikely to slow down for a crossing pedestrian (Figure 53).

65. If there is no median barrier on the roadway, it is better to locate the pedestrian crossing on top of the speed table (Figure 54).

66. If such vertical speed controls are needed near to an intersection, it is recommended to use a speed hump instead of a speed table so that pedestrians don´t confuse it with a pedestrian crossing.

67. Speed humps must be avoided along curved sections of the road, or in sections where forward visibility of the roadway is low. Speed humps should also be avoided on sloping sections of the road. Normally, a speed hump should not be installed just before a traffic signal, as it affects the green phase traffic throughput for this signal.

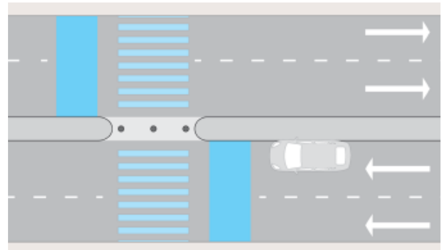


Figure 53. Speed humps before pedestrian crossing.

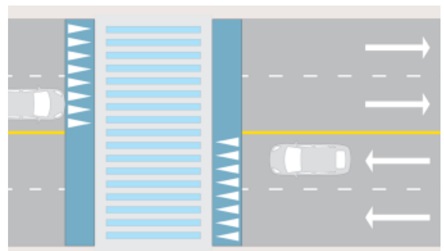


Figure 54. Pedestrian crossing on top of speed table

Figure 55. Speed table doubling up as a mid-block crossing with safety bollards in New Delhi, India. (Source: The World Bank)

Horizontal speed controls: Chicanes, curb-extensions, bulb-outs and staggered on-street parking

68. Table 9 below discusses the various types of horizontal speed control measures.

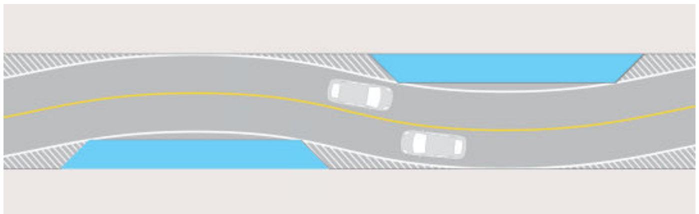
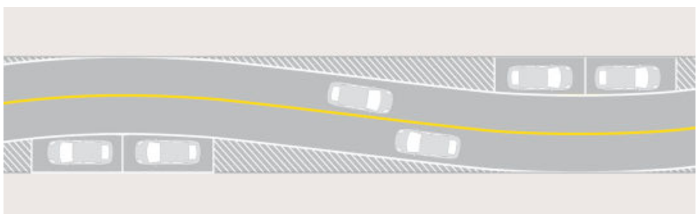
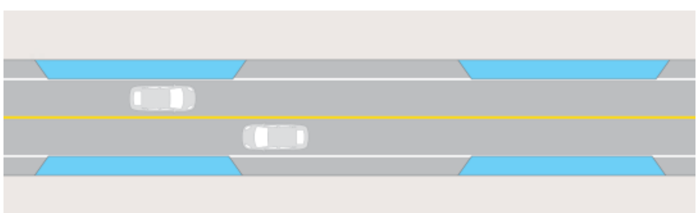
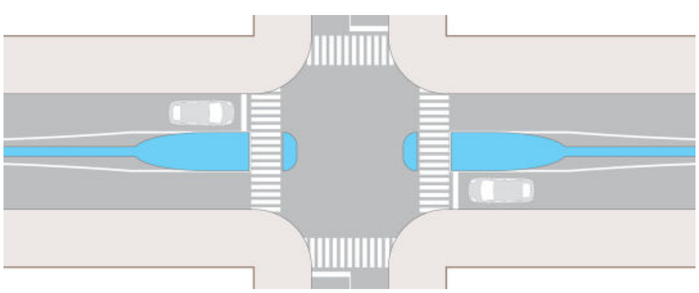
Type	Diagram	Description
Chicanes	 Figure 56. Chicanes	These refer to the series of physical deflectors that are installed along alternating sides of the road, which result in the creation of a serpentine-like roadway. This forces motorists to slow down as they steer left and right through the successive chicanes. Chicanes are a useful retrofit for long, neighborhood streets, though consideration should be given to their impact on cyclists and emergency vehicle movement.
Staggered on street parking	 Figure 57. Staggered on-street parking	A similar traffic-calming impact that chicanes provide can be achieved by staggering the provision of on-street parking. The presence of on-street parking has the added advantage of increasing perceived traffic disruptions, which induces motorists to drive slower.
Curb Ex-tensions	 Figure 58. Chokers	This refers to the physical extension of the curb, (normally the sidewalk curb) into the carriageway, partly or fully cutting out a traffic lane. Curb extensions are also referred to as chokers, because, they, in effect create a physical bottleneck, with the intention of choking traffic. This induces motorists to slow down while driving through the curb-extension area.
Median bulb-out	 Figure 59. Median bulb-out	Curb-extensions may also be provided along a curbed median, which then creates, what is called a bulb-out in the center of the road. The advantage of such a bulb-out is that is allows for the inclusion of a pedestrian refuge area between the crossing, where pedestrians can stop and wait while crossing the road.

Table 9. Horizontal speed control alternatives

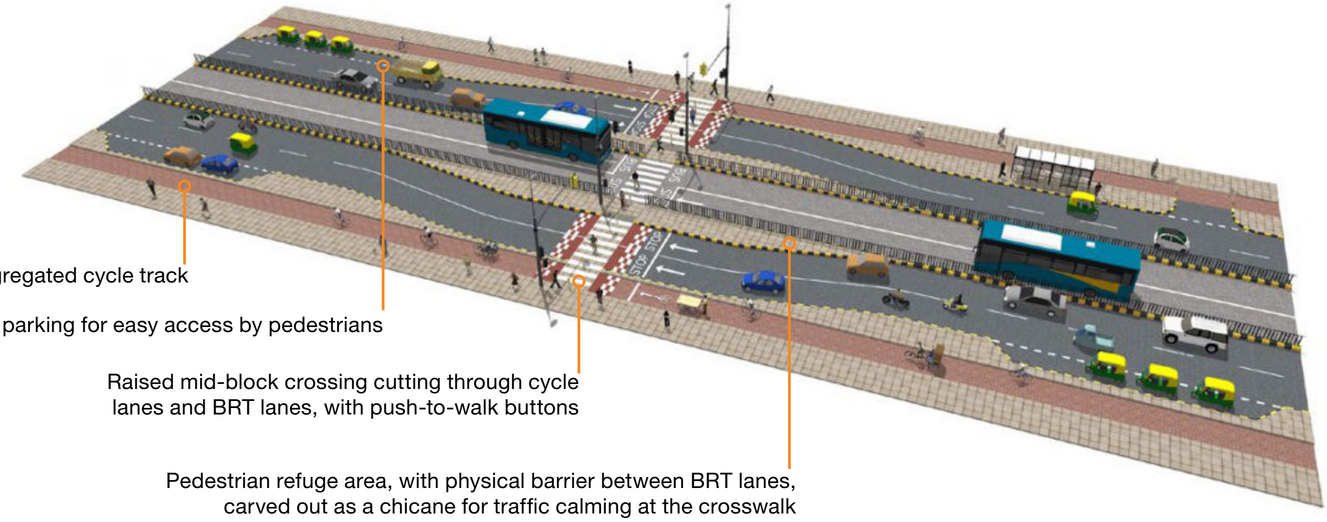


Figure 60. Mid-block crossings in BRT lane as a combination of horizontal and vertical traffic calming measures

(Source: © WRI India)

Intersection design measures

Tightening and/or extending curb corners

69. The most important measure to reduce traffic speed at intersection is to minimize the radius of curb corners at intersections. A tighter corner induces motorists to slow down to make a turn, which adds to safety. It also increases the available sidewalk area at the intersection and decreases the crossing length, which allows for safer crossings.

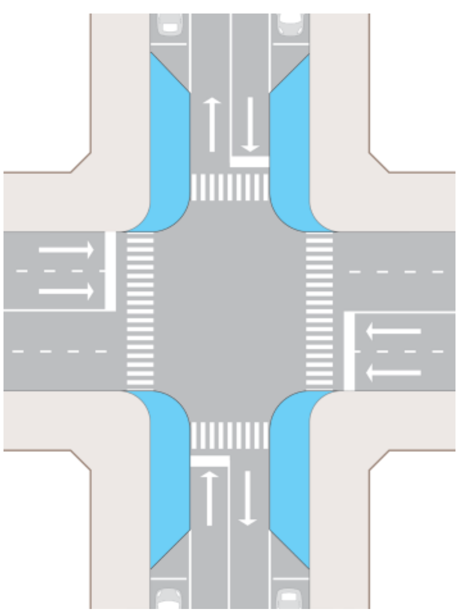


Figure 61. Extending curb corners at intersections to create gateways

Modified intersection

70. Table 10 below highlights features of different types of modified intersections.

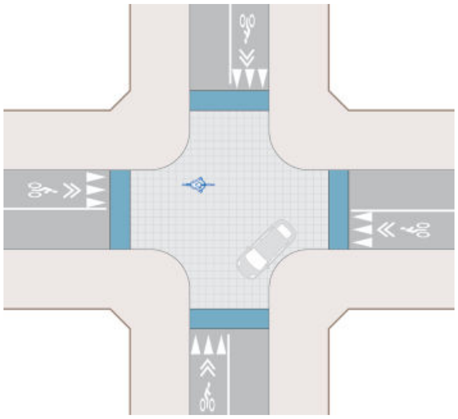
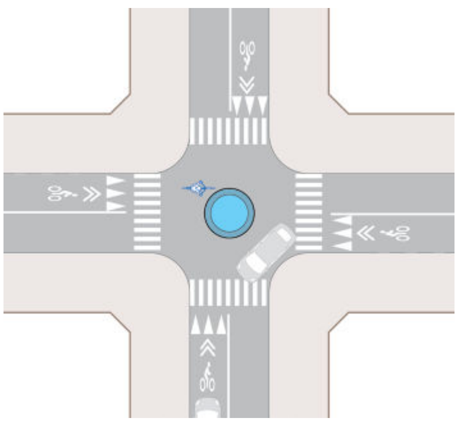
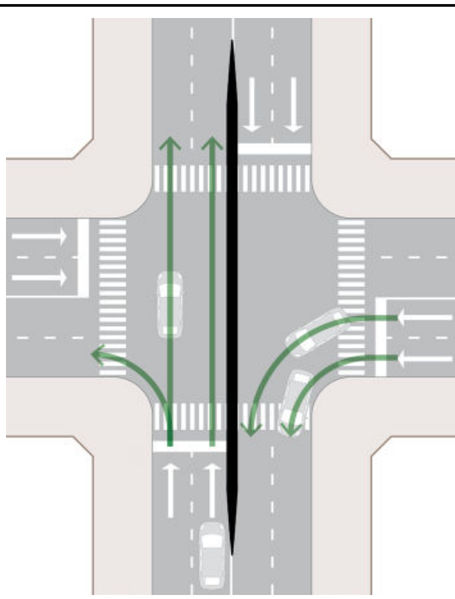
Type	Diagram	Description
Raised intersection	 Figure 62. Raised intersection, at the level of sidewalk	A raised intersection is an effective traffic-calming measure, applicable for un-signalized intersections between neighborhood streets. They are similar in profile to a speed table, wherein the entire intersection area is slightly raised to create a vertical displacement for vehicles.
Mini roundabout	 Figure 63. Mini roundabout	Mini-roundabouts consists of a small circle located within the intersection area, which creates a lateral displacement for vehicles, forcing them to slow down. They differ in form and function from conventional roundabouts, which are much larger, and their primary function is to channelize traffic circulation, rather than slowing down traffic.
Physical barriers	 Figure 64. Restricting movement at intersections using barriers	Restricting movement at intersections through the installation of physical barriers (median barrier across an intersection), impacts the volume of traffic using this intersection, (and the adjoining streets), by curtailing thoroughfare traffic. Another measure is to install a diagonal barrier across the intersection, preventing through movement in either direction.

Table 10. Alternatives for a modified intersection

Primary Station Area Design

71. The primary station area in the context of TOD, refers to the area immediately surrounding the transit station i.e. within 0 – 400m or 5 minutes walking, where the transfer of commuters between feeder modes and the main transit line takes place. This is the meeting point for the trunk routes of all feeder modes. Hence, safety and mobility challenges are the most crucial at the station area, given the high concentration of commuters and traffic into a relatively small space. Infrastructure for the transfer of pedestrian commuters should be provided nearest to the station gates, followed by infrastructure for cyclists and feeder buses, then para-transit, and finally, for personal motor-vehicles.

Figure 65. Cycle parking facility and pedestrian only area at the entrance of Transmilenio in Bogota, Colombia (Source: The World Bank)

Figure 66. Transit station access using segregated sidewalks, Mexico (Source: The World Bank)

PRIMARY AREA

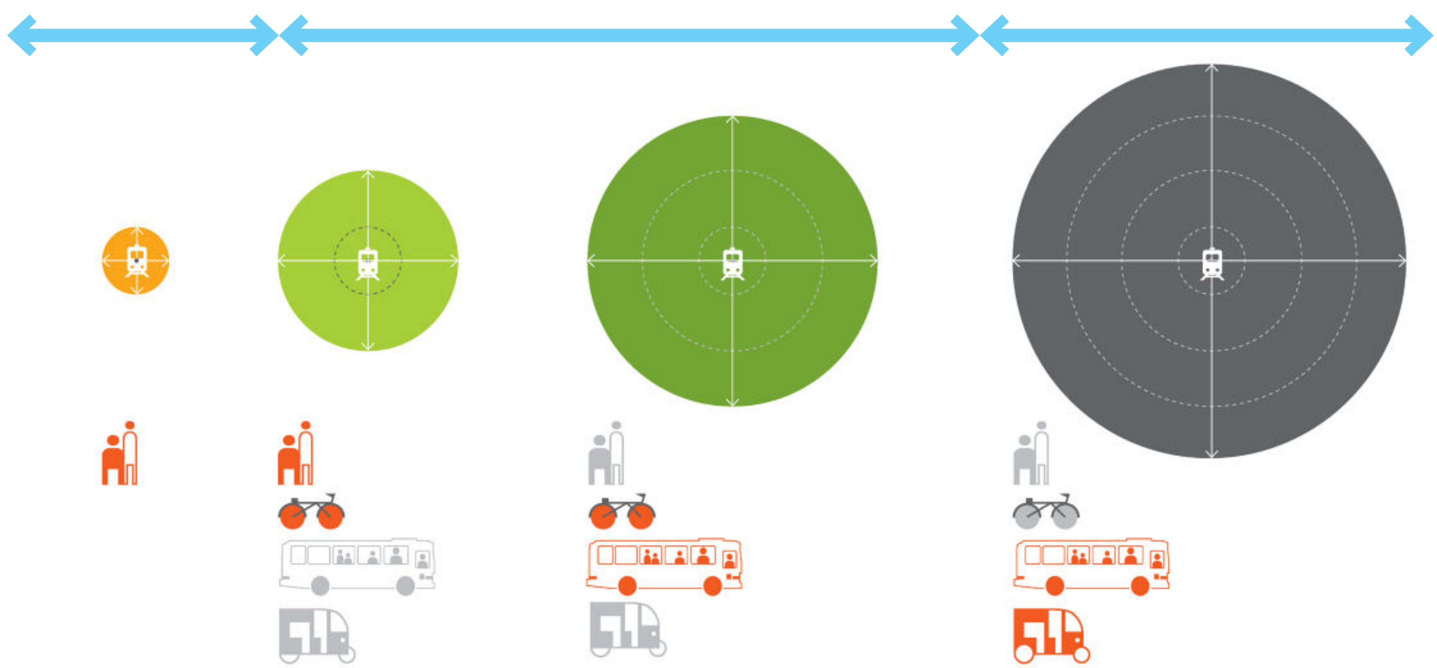
Includes the transit station and the immediate access routes within 5minutes of walking distance prioritizing pedestrian needs.

SECONDARY AREA

Includes the area and major destinations around the station, which are direct and safe, and can be accessed by walking and cycling.

CATCHMENT AREA

Catchment areas include the broader area of influence from the mass transit station, where feeder and paratransit services are critical.



72. It is important to ensure that transit infrastructure, including station structures, do not impede the movement of any mode. It is commonly observed that the pillars of elevated transit stations completely block the sidewalks below them. In other cases, elevator shafts and stairways to the stations are placed across the sidewalk, forcing pedestrians to walk on the roadway.

Station access points

73. A transit station with one access point can become a potential bottleneck for commuter movement, especially during the peak commuting hours of the day. For a high-volume station, it is recommended to provide multiple entries and exits to the station, ideally connecting to different roads and different directions of the station areas as can be seen in Figure 67

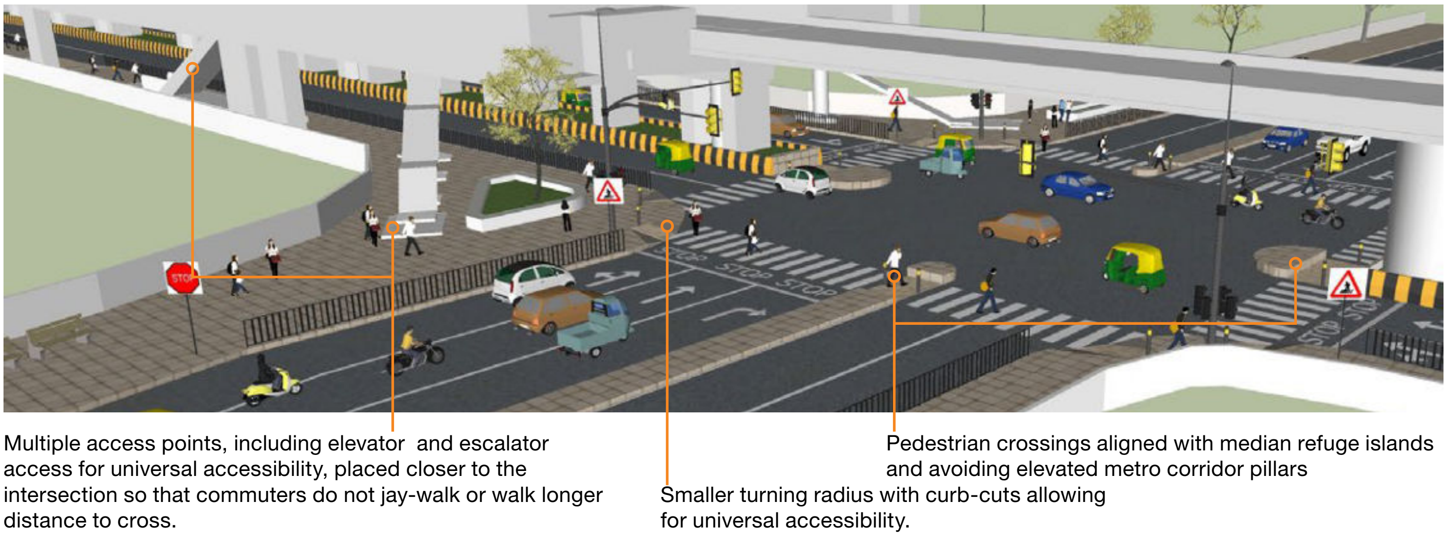


Figure 67. Designed access to DN Nagar Metro Station Mumbai near an intersection (Source: WRI India)

74. Often local access needs are combined with station access points. Access to underground mass transit stations also double up as underpasses to cross major roads. Similarly, BRT stops located in the middle of a highway do not typically have at-grade access. FOBs with ramps or elevators to access the stops are provided. However, if these stations are not functioning during some hours or closed, then the local access can get impeded due to closing of the access facility as well. It is advisable to have these FOBs or underpasses to remain functional all day long and have a connection made from these off-road connectors to the transit facility.

75. BRT services requiring dedicated lanes must be protected to avoid jay walking, with access to stops provided at intersections with wider crosswalks or at mid-block crossings. Additional button-activated mid-block crossings must be provided in the station area where the blocks are large or a high volume of pedestrian movement is expected.

76. Station access points can also be separated according to the transfer mode (Figure 68, Figure 69). A direct access link may be provided, connecting the station to the feeder bus routes separating the movement of bus commuters from other commuters.

77. Grade separated infrastructure can be utilized in conjunction with sidewalks, to increase access points to the stations. This is particularly useful when the grade separated infrastructure connects directly to important nearby land-uses that are likely to generate a high footfall of commuters, such as a shopping center or an office complex. However, such infrastructure must only be provided in addition to at-grade infrastructure, and must never come at the expense of at-grade sidewalks.

Pedestrians crossing along the median, especially with longer BRT Green phase.

(Many Latin American BRT Systems have such design including Macrobus in Guadalajara)

Wide at-grade refuge island in the median to accommodate passengers entering and exiting the BRT station using a protected ramp.

Figure 68. Pedestrian access to a raised BRT station in the center of the ROW (Source: WRI)

Cycle rack on sidewalk along the road perpendicular to the BRT lane, allowing riders to lock the cycles and transfer to BRT system.

Figure 69. Facilities for cyclists to access the BRT station along with pedestrians (Source: WRI)

Transfer facility design

78. As far as possible, transfer zones in the vicinity of the transit station, should be provided such that it eliminates, or reduces the crossing requirement.

   - Traffic management at the Thane suburban railway station in the Mumbai Metropolitan Region, India involves grade separated infrastructure for public bus services and IPT infrastructure. The bus services are on an elevated deck and connect to the railways station through skywalks, and the IPT services are available at grade with pick-up, drop-off and queuing areas (Figure 70).

Figure 70. Thane Suburban station in India with lower level for auto-rickshaws and upper levels for bus bays. It connects to the road level via elevated walkways (Source: WRI India)

79. Wherever possible, the transfer stop should be provided on the same side as the transit station access point. For instance, a feeder bus-loop / terminal may be located near the transit station. In such a case, it is a good idea to ensure that there is no road in between the feeder bus-facility and the station access point. Similarly, a para-transit facility is best located on the same side of the transit station.

   - A typical transfer station along Bogota, Colombia's TransMilenio BRT corridor includes an integrated transfer facility between the trunk BRT route and the feeder service (Figure 71). These terminals are designed to have a common central platform where both the services can dock on either side of the platform allowing the passengers to transfer by crossing across it.

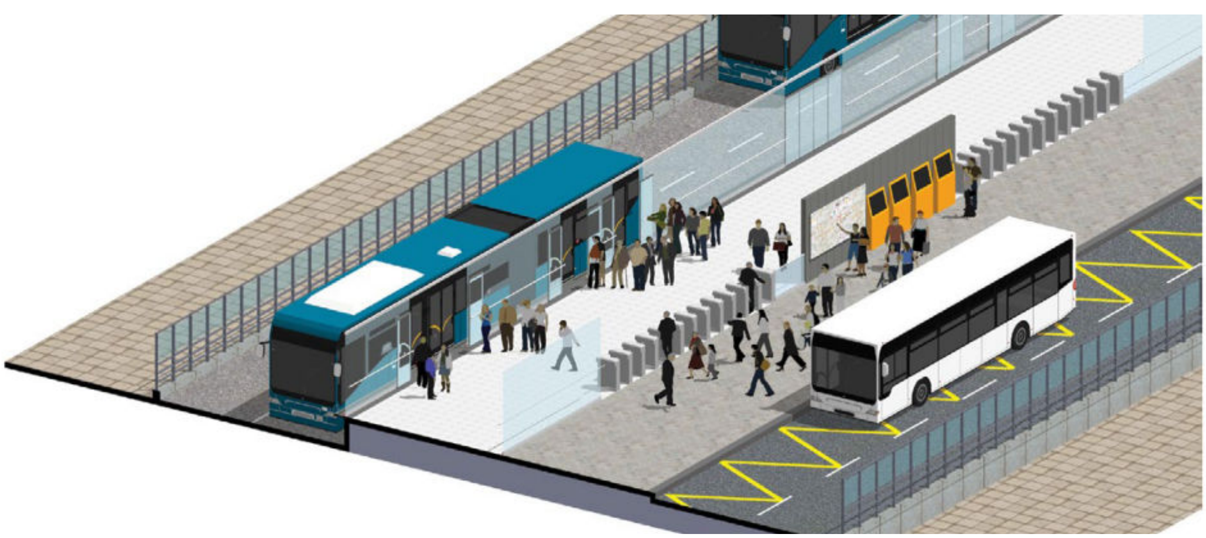


Figure 71. Typical transfer platform at station along Bogota, Colombia's TransMilenio BRT corridor with height differences on either side to accommodate the different floor heights of BRT bus (on left side) and feeder services (right side) (Source: WRI)

80. It may not always be possible to locate all transfer facilities on the same side of the transfer station. This may be the case, for feeder buses plying in opposite directions, in which case, only the stop for one direction can be located on the station side. In such contexts, it is essential that safe crossing infrastructure is provided to access the station. Given the high expected transfer volumes, a signalized crossing may be warranted.

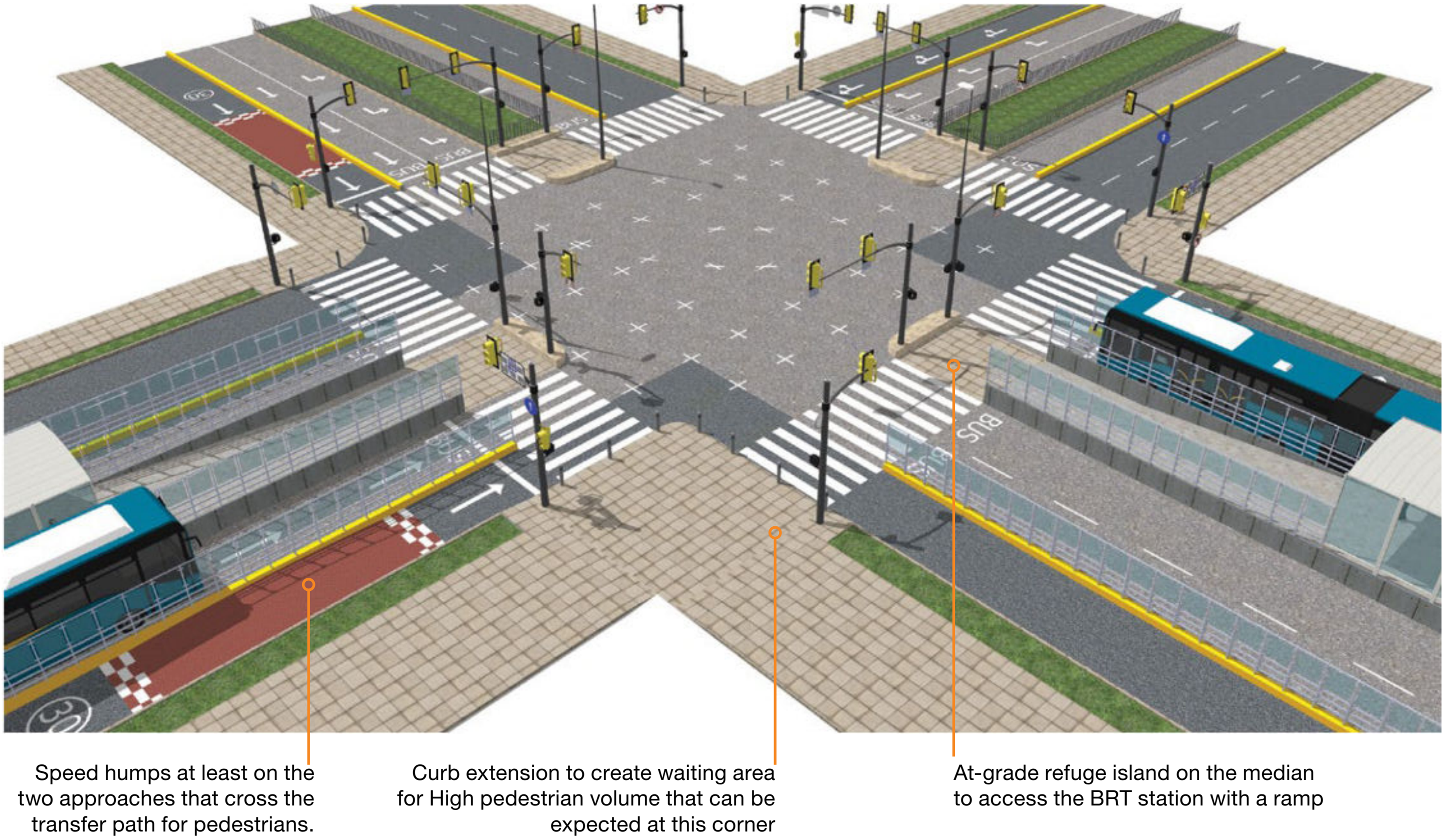


Figure 72. Transfer facility between two intersecting BRT Lines (Source: WRI)

81. If the transit station is located at a different level than the road, it may be a good idea to extend the grade-separated connector across the width of this road. In normal circumstances, grade-separated structures are not recommended for crossing the road. However, if they provide direct connectivity to a the grade-separated station, then this becomes acceptable.

82. When designing para-transit zones in station areas, it is important to separate the drop-off zones from the pick-up zone, to allow for the smooth functioning of such facilities. Normally, the drop-off zone should be located before the pick-up zone, which allows for the para-transit driver to enter the pick-up zone after dropping off passengers. There should also be a provision for the vehicle to leave the drop-off zone, in case the driver does not want to pick up new passengers.

83. Care should be taken to ensure that the movement of para-transit vehicles does not impede the movement of feeder bus services. This can be achieved through the physical segregation of both zones, which add to safety, while also creating more access points for the transit station.

Figure 73. Para-transit access and transfers to transit station, with connections for vehicular traffic, and with connections through motor-vehicle free shared streets (Source: WRI India)

REFERENCES

Bertaud, Alain , and Harry W. Richardson. 2004. *Transit and Density: Atlanta, the United States and Western Europe*.

CEREMA. 2014. *Signs and signals for cyclists and pedestrians: Comparison of rules and practices in 13 countries.*

Global Road Safety Partnership. 2008. *Speed management: a road safety manual for decision-makers and practitioners.*

IRTAD. 2018. *Road Safety: Annual Report*. OECD.

ITDP. 2018. *Pedestrians First: Tools for a Walkable City*. ITDP.

ITDP. 2018. *Streets for Walking & Cycling: Designing for safety, accessibility, and comfort in African cities.*

ITDP. 2017. "*TOD Standard 3rd Edition.*"

ITDP. 2018. *Walking and it's links to transportation: Practical Guidance and Good Practice examples*. World Bank Group.

Kidokoro, Tetsuo. 2019. *Transit-oriented development policies and station area development in Asian cities*. ADBI.

Litman, Todd. 2014. *A new transit safety narrative.* Journal of Public Transportation 17.

Ministry of Urban Development Government of India. 2016. *TOD City Specific Plan - Mumbai*.

NACTO. 2016. *Global Street Design Guide*. New York City, NY: NACTO.

NACTO. 2011. *Urban Bikeway Design Guide*. New York City, NY: NACTO.

NACTO. 2013. *Urban Street Design Guide*. New York City, NY: NACTO.

NACTO. 2016. *Urban Transit Design Guide*. New York City, NY: NACTO.

Ollivier, Gerald, and Gunes Basat. n.d. *Transit-Oriented Development for Sustainable Cities*. World Bank Group.

Ollivier, Gerald, and Serge Salat. 2017. *Transforming the Urban Space through Transit-Oriented Development: The 3V Approach*. World Bank.

Santos, Valerie. 2016. *An overview of common Land Value Capture tools*. World Bank Group.

Shah, Sonal, Shahana Goswami, Lubaina Rangwala, Robin King, Himadri Das, and Akhila Suri. 2014. *Safe Access Manual: Safe Access to Mass Transit Stations in Indian Cities*. Bangalore: EMBARQ India.

Suzuki, HIroaki, Robert Cervero, and Kanako Iuchi. 2013. *Transforming Cities with Transit: Transit and Land-Use Integration for Sustainable Urban Development*. World Bank.

Suzuki, Hirosaki, Jin Murakami, Yu-Hung Hong, and Beth Tamayose. 2015. *Financing Transit-Oriented Development with Land Values: adapting Land Value Capture in Developing Countries*. World Bank.

The Department of Infrastructure, Transport, Cities and Regional Development, Government of Australia. n.d. *National Road Safet Strategy*. www.roadsafety.gov.au/nrss/safe-system.

The World Bank. 2013. *Road Safety Management Capacity Reviews and Safe System Projects Guidelines*.

The World Bank. 2018. *TOD Implementation Resources and Tools*. Washington D.C. The World Bank Group.

UNEP. n.d. *Share the Road: Design Guidelines for Non-Motorised Transport in Africa.*

United Nations Economic Commission for Europe. 2018. *Road Safety Audit and Road Safety Inspection on the TEM network.* Geneva.

Wegman, Fred, Atze Dijkstra, Govert Schermers, and Pieter van Vliet. 2005. *Sustainable Safety in the Netherlands: the vision, the implementation and the safety effects.* Leidschendam: SWOV.

World Bank Group. 2018. *Disability Inclusion and Accountability Framework.* The World Bank.

World Bank, and World Resources Institute. 2015. *TOD Corridor Course.*

World Health Organization. 2018. *Global status report on road safety*. Geneva.

World Road Association (PIARC). n.d. *Road Safety Manual.* https://roadsafety.piarc.org/en/planning-design-operation.

WRI EMBARQ. 2015. *Cities Safer by Design: Guidance and Examples to Promote Traffic Safety through Urban and Street Design*. WRI.

WRI EMBARQ. 2018. *Sustainable & Safe : A Vision and Guidance for Zero Road Deaths.*

WRI EMBARQ. 2014. *Traffic Safety on Bus Priority Systems*. WRI.

TOD K P