IRC:103 - Guidelines for Pedestrian Facilities (Draft)

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1. Introduction

Walking is the primary mode of travel in Indian cities. It forms about 25-35 percent of the total trips as per the mode share data in Indian cities. Census 2011 data showed that nine out of every ten trips by women were on foot and public transport.

Short trips in urban areas can be easily covered on foot or cycle. Even a public transport and a private motorized transport user is often dependent on walking for the last mile journey. A good walking and cycling infrastructure increase dependence on public transportation. Walking and cycling provide affordable travel to all sections of the society to reach work, education, recreation and other day-to-day activities. It provides resilience during difficult times such as oil crisis, pandemic outbreak and natural calamities.

Pedestrians and cyclists are the most vulnerable towards injuries and fatalities due to crash. As per the Ministry of Roads Transport and Highways (MoRTH) data on road accidents in India for 2019, about 70 pedestrians and 12 cyclists died daily. Absence of safe and comfortable pedestrian infrastructure is discouraging walking, and resulting in increased dependence on personal motorized vehicles especially for short trips. Increased use of personal motorized vehicle is resulting in congestion and air pollution in cities. This is having a negative impact on health, environment and economy.

Pedestrian facilities that are safe, comfortable, continuous and enjoyable attract more walking. Pedestrian facilities should provide seamless movement to all road users including vulnerable road users such as persons with disabilities, caregivers with prams, children and the elderly.

2. Policies and acts

There are existing policies and acts that are adopted nationally and at city-level to ensure the rights of pedestrians and promote non-motorized transport-

- National Urban Transport Policy, 2006 stresses the need to promote walking and cycling. It stresses that the urban streets should move people instead of vehicles. Cities like Chennai (2014) and Coimbatore (2017) have adopted Non-Motorized Transport policy to ensure city provides high quality walking and cycling infrastructure. Similarly, Pune has adopted pedestrian policy (2016).
- The Ministry of Housing and Urban Affairs (MoHUA) under the Smart Cities Mission has adopted the Complete Streets Framework Toolkit in 2019. It is a comprehensive toolkit that guides the Indian cities on the process of planning, designing and implementing Healthy Streets to achieve safe and enjoyable walking and cycling infrastructure.
- The Government of India enacted the Rights of Persons with Disabilities Act, 2016 and signed and ratified the UN Convention on the Rights of Persons with Disabilities Act in 2008. To realize all the rights under the Rights of Persons with Disabilities Act and the UNCRPD, stakeholders need to understand and implement universal accessibility in its holistic sense.
- Goal 11.2 of Sustainable Development Goals also known as Global Goals that were adopted by all United Nations Member States in 2015 mandates *to provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons by 2030.*

3. Scope

IRC:103 provides various planning-level guidelines and design standards for safe and enjoyable pedestrian infrastructure in urban areas. The guidelines and standards take into consideration the way urban streets are used in Indian cities. The guidelines are well explained with illustrations and images. IRC:103 will be useful to city engineers, transport planners, urban planners, urban designers, decision makers, civil society organizations and students involved in the design and implementation of pedestrian facilities.

4. Pedestrian facilities principles

Safety, security, continuity, comfort and liveability are the key five principles to consider in the planning and design of pedestrian infrastructure for a safe and enjoyable walking experience. These principles make walking more attractive over personal motor vehicle use especially for short trips.

Safety – Pedestrians should be protected from motorized vehicles to prevent injuries and fatalities due to crashes. They should be able to walk and cross safely irrespective of age, gender and disabilities.

Security – Pedestrians should be secured from crimes while walking. All pedestrians including women, children and elderly should feel secure while using the facilities.

Continuity – Pedestrians should be provided with continuous walking environment without any obstructions. All pedestrians including persons on wheelchair, visually impaired persons, caregivers with prams and elderly should be able to move seamlessly.

Comfort – Pedestrians should be provided with well-shaded, well-drained, spacious and clean walking environment. They should feel comfortable while walking, waiting at the bus-stop and seating.

Liveability - Pedestrians should be provided with liveable walking environment where they can pause and enjoy the surroundings at their own pace. They should have opportunities to sit, play and socialize.

5. Walking-friendly city

Right street design and urban planning helps to make city walkable. This can be largely achieved through – a. Healthy streets and b. Pedestrian-oriented urban planning.

5.1. Healthy Streets

Urban streets should be designed as ‘Healthy Streets’. Healthy Streets prioritize the movement of greener (emit less per capita) and space efficient (consumes less road space) modes of transport such as walking, cycling, and public transport shown in figure 1. Healthy Streets move people efficiently and safely, and help to reduce congestion by promoting walking, cycling and public transport. This improves air quality. Healthy Streets also provide spaces for citizens to sit and socialize. Studies have shown this has a positive impact on local retail businesses and well-being of citizens. Healthy Streets makes urban environment socially equitable, healthy and liveable.

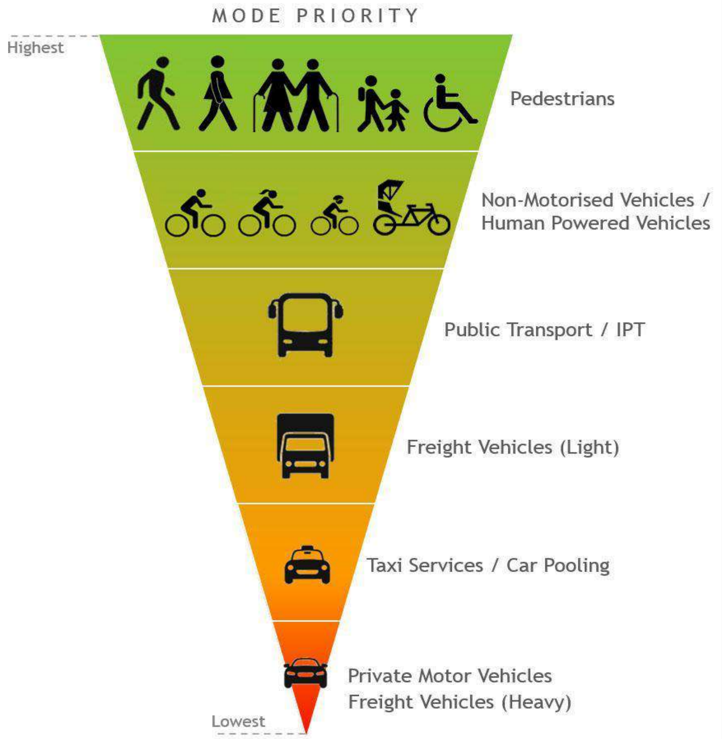

Figure 1: Mode priority diagram for urban street

Healthy Streets provide fair share of road space to all users as shown in figure 2. They are designed with wide and continuous footpaths, safe at-grade pedestrian crossings, segregated cycle tracks (on streets with high vehicle speeds), bus stops designed to enhance convenience and ease of alighting, designated stands for auto-rickshaw, cycle rickshaw and taxis, organised street vending, places for people to sit and socialize, consistent carriageway and organized parking. Where pedestrians have to share road space along with motorized traffic, streets are traffic calmed to ensure safe mingling. It is recommended that the carriageway, service road and parking together should not occupy more than 50% of the total right of way width to ensure space for walking, cycling and other street elements. MoHUA's Complete Streets Design Workbook (2019) can be referred further.

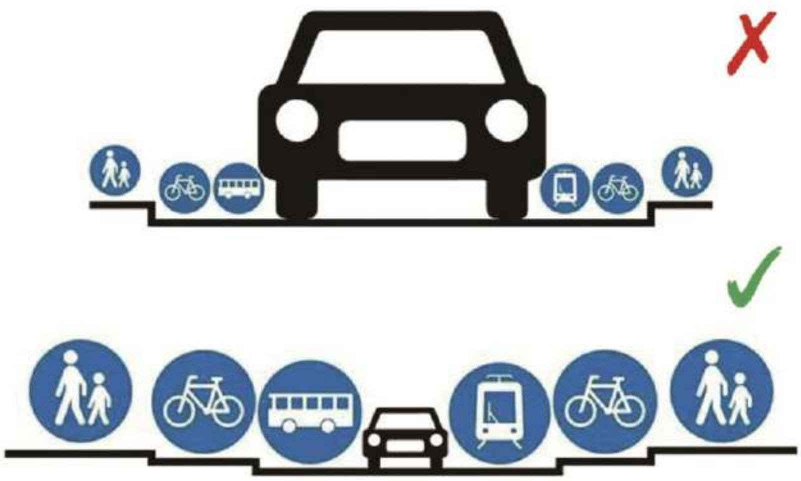

Figure 2: Healthy Street design concept

5.2. Pedestrian-oriented urban planning

Pedestrians and cyclists prefer short routes to reach their destinations. Long walking distance discourages walking. Dense non-motorized transport street network along with mixed-use landuse encourages walking, and reduces dependency on personal motorized vehicles especially for short trips. Dense network provides multiple and direct routes. It also induces safe motorized transport speeds that ensures the safety of all road users.

The pedestrian detour route ratio should be within 1.5. Pedestrian detour route ratio is defined as ratio of actual walking distance to direct route distance. Urban blocks should be designed such that at every 150-200m a non-motorized transport access is available. In case of large urban blocks such as large educational campus, public institutes, commercial complex and others, pedestrian only thoroughfares can be planned to improve walking and cycling. IRC:SP:118 should be referred for planning of urban street network.

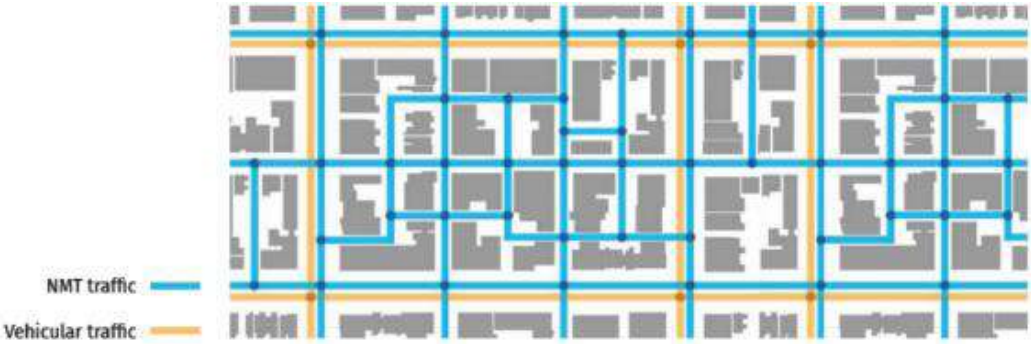

Figure 3: Dense urban road network planning

6. Pedestrian facilities design standards

6.1. Pedestrian level of service

Pedestrian facilities with insufficient space leads to unpleasant and unsafe walking experience. Pedestrian facility should provide enough space for safe and comfortable walking. The width should be provided based on the current and expected pedestrian numbers, street type (arterial, collector or local), and adjoining land-use. Pedestrian facility width should be designed for level of service[1] (LOS) B. LOS C is acceptable only in case of space constraints.

Table 1 gives pedestrian LOS for walking infrastructure in relation to predominant adjoining landuse. Pedestrian flow is given in pedestrian/hour/meter (ped/h/m) width of walking zone.

Table 1: Service volume of pedestrian facility of unit width

LOS considered	**Service volume of pedestrian facility of unit width, pedestrians/hour/meter (ped/h/m) in both direction**				
	Commercial	**Institutional**	**Terminal**	**Recreational**	**Residential**
LOS –B	1285	1145	1360	1360	1430
LOS – C	1800	1600	1900	1900	2000

*Incase of streets with mixed landuse, consider the LOS standard for predominant landuse adjoining the facility.

[1] Level of service is defined as a qualitative measure used to determine how well a facility is operating from a traveler's perspective.

Service volume on facility with pedestrian flow in one direction can be taken as 1.5 times more of the flow given for LOS-B and LOS-C in above table.

6.2. Footpath

Footpaths segregate and protect pedestrians from motorized vehicles on urban streets to provide safe walking, and help to improve vehicle flow. Footpaths must be provided on all street types where vehicular speeds exceed 15 kmph[2]. Walkable footpaths are safe, continuous, secure, comfortable and livable for all including children, elderly, and the persons with physical disabilities. Good footpaths provide places for people to sit, socialize and play.

If footpaths are not provided, then street should be traffic calmed[3] to ensure vehicle speeds are below 15 kmph for safe co-existence of pedestrians and motorized vehicles. This can be considered especially for local streets and narrow crowded commercial streets.

6.2.1. Footpath Design-

Footpath width should be planned in 3 different zones – pedestrian/walking zone, frontage/dead zone and multi-utility zone as shown in figure 4.

Figure 4: A footpath in Chennai showing various zones

Pedestrian/walking zone- It is the clear walking space for pedestrians, clear of any obstructions. It is recommended to provide minimum 2m wide walking zone to ensure two wheelchairs can pass each other. A clear height of 2.4m from the finished footpath floor level should be maintained in walking zone as shown in figure 5. IRC:SP:117 should be further referred for details on the minimum clearances required by different pedestrian groups.

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[2] As per the Global Street Design Guide, it is safe for pedestrians to share the space with motorists at speeds below 15 kmph.

[3] Traffic calming measures ensure pedestrian and vehicle safety by reducing vehicular speed. Traffic calming measures include vertical displacements (for eg. speed humps, tabletop, surface treatment) and horizontal displacement (for eg. Chicane, narrowing of carriageway).

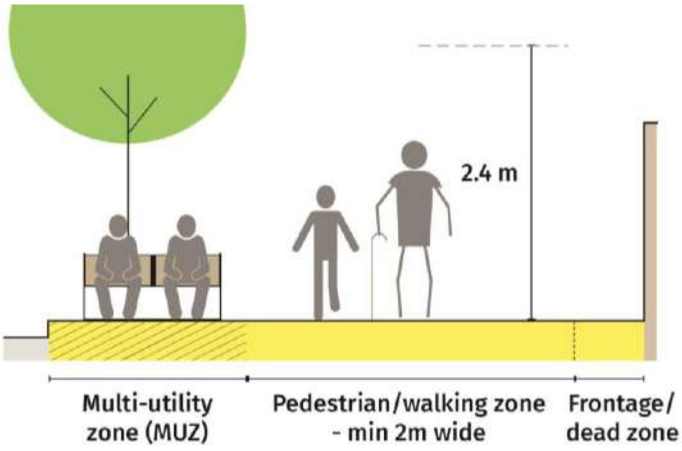

Figure 5: Recommended space requirement in walking zone

Frontage/dead zone – It provides a buffer between the walking zone and the property edge. Minimum 0.5m buffer space should be left from the building compound wall, as pedestrians do not walk touching the wall. Incase of shop front, 1m frontage space is recommended to avoid hindrance from standing customers. Street lights can be placed in dead zone, however, no element of it should protrude inside the walking zone.

Multi-utility zone (MUZ) – It is the space to provide seating, bus stops, IPT (Intermediate Public Transit)[4] stands, landscape, trees, children play elements, street signage, telecom and electric boxes, on-street vending, and on-street parking. Minimum 1.5m wide MUZ should be provided to accommodate tree pits, auto-rickshaw stand, seating and on-street vending. 2m wide MUZ should be provided for on-street parallel parking for 4-wheeler parking and cycle/2-wheeler perpendicular parking. MUZ is usually provided at the footpath kerb edge. More than one MUZs can be provided for wider footpaths to accommodate street furniture, trees and other elements. However, walking zone should not be compromised. Figure 6 shows the provision of seating and landscape in the MUZ of JM road footpath in Pune.
MUZ width can be further reduced below 1.5m on narrow streets with RoW below 15m. However, minimum 0.5m wide MUZ should be provided to accommodate street lights, road signages and bollards.

Figure 6: Seating and landscape located in MUZ

[4] Intermediate Public Transit (IPT) includes auto rickshaws and taxis that can be personally hired or share autos, vans, private minibuses that operate on a shared or per seat basis on specific routes. The service may or may not have a predefined fare structure.

Table 2 recommends minimum clear widths of different zones on footpaths along different landuses. It is also illustrated in figures 8,9 and 10.

Table 2: Minimum clear widths of different zones on footpaths as per adjoining landuse

Adjoining landuse	**a. Minimum walking/pedestrian zone width (meters)**	**b. Minimum dead/frontage zone width (meters)**	**c. Minimum multi-utility zone width (meters)**	**Minimum total footpath width (meters) (a+b+c)**
Residential (Figure 6)	2.0	0.5	2	4.5 (for a 15m wide street with 6m undivided carriageway)
Neighbourhood-level commercial street, (Figure 7)	2.5	1.0	2	5.5 (for a 18m wide street with 7m undivided carriageway)
City-level commercial street, high-street shopping street (Figure 8)	4.0	1.0	2	7 (for a 21m wide street with 7m undivided carriageway)

- Incase of limited Right of Way[5] (RoW) width, optimize the space by first adjusting/removing the parking, then adjusting the carriageway[6] width, and then the MUZ width to ensure walking zone is not compromised. One-side footpath can be considered on narrow local streets with RoW less than 10m as shown in figure 11.
- Walking zone of minimum 2.5m should be considered for streets with schools, hospitals, markets, bus-stops, public parks and gardens (recreation) at the neighbourhood level.
- Streets in areas with high pedestrian footfall such as markets, shopping streets, transit nodes, religious nodes, railway/metro stations, bus terminals, urban historic core can be considered as only pedestrian streets or pedestrian mall that only allows walking, cycling and public transport. Thyagaraja Salai retail street in Chennai is redesigned as pedestrian-oriented street with wide walking space to cater to the high pedestrian footfall. Of the total 30 m RoW width, footpaths occupy 2/3rd of the total right of way space and balance is for vehicular access as shown in figure 7. The street provides spaces to sit, play and socialize. On-street parking is defined and priced.

[5] Right of Way is the total width of the road taken from compound wall/edge on one side of the street to that on the other side.

[6] Carriageway is the space on road meant for vehicles to move.

Figure 7: Thyagaraja Salai, Chennai

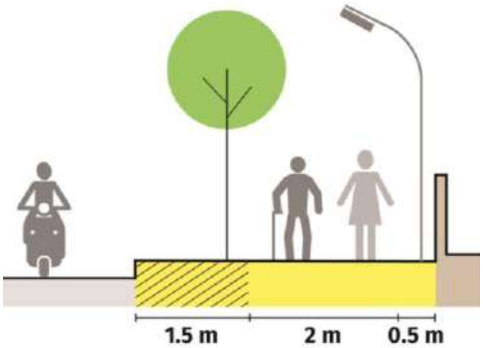

Figure 9: Footpath in residential area

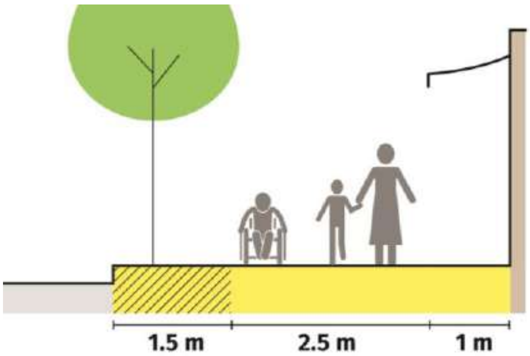

Figure 8: Footpath in neighbourhood-level commercial area

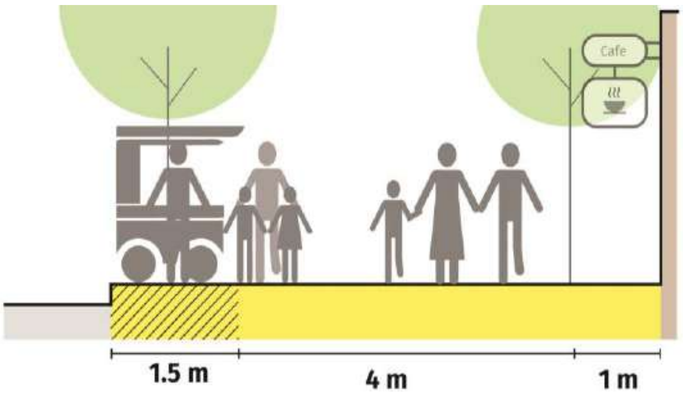

Figure 10: Footpath in high-footfall intensity area

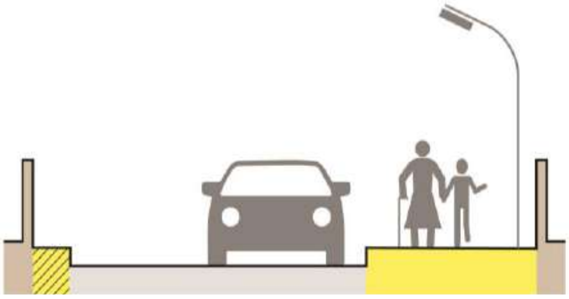

Figure 11: One-side footpath on narrow streets

Height – The height of the footpath should be 150mm from the adjoining finished carriageway level to ensure comfortable access to all pedestrians especially the elderly and children, and prevent illegal parking by not allowing vehicles to mount over the footpath.

Surface – Footpath surface should be even, firm, free from cracks and well-drained. Surface should be of anti-skid material to ensure usability and safety in all-weather conditions. Vitrified tiles should be used for tactile pavers as they have high load bearing capacity and are durable. Footpath surface should have gradient (slope) to prevent accumulation of water. Transverse slope (along the footpath width) can range between 1:50 to 1:100. It should not be steeper than the mentioned slope to prevent fall and rolling back of wheelchair users, however, ensure that the footpath height of 150mm is maintained at the kerb edge. Any break in the surface, such as drainage channels or expansion joints (to prevent cracks in concrete) in the surface should not be greater than 10mm and should cross perpendicular to the direction of movement. This will prevent walking sticks and wheels getting caught in the gaps.

Continuity of the footpath – Footpath should continue at same level across side streets and property entrances for seamless movement.

Vehicle access ramps of 1:8 slope should be provided to access side streets as shown in figure 12. Ramps also slow down vehicles at the intersection, thereby improving safety of pedestrians and other road users. This is recommended where local streets join collector or arterial streets and the intersection is without signal. Bollards should be provided to prevent vehicles encroaching the footpath space as shown in figure 13. Ensure that one bollard spacing provides wheelchair access. Provide tactile pavers before and after the bollards to warn the visually impaired on obstacles.

Figure 12: Footpath continuing at same level along side street in Chennai

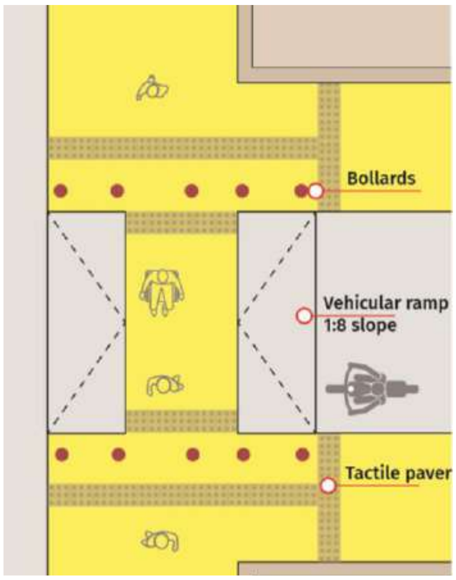

Figure 13: Detail of footpath continuing along side street (top view)

While providing vehicle access ramps to private properties, provide one access ramp in single house dwelling units or small apartment buildings as shown in figure 14. In large commercial, residential and institutional complexes two access ramps may be provided. The access ramp length should not exceed 3.5m as shown in figure 15 to prevent vehicles from mounting over footpath.

Figure 14: Footpath at same level along property entrance in Pune

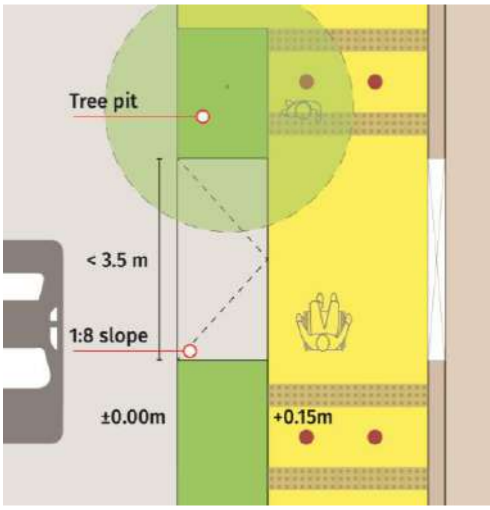

Figure 15: Detail of footpath continuing at property entrance (top view)

Where footpath width is insufficient especially on local streets, footpath should slope down gradually at property entrances as shown in figure 16. Side ramps should slope down at 1:15 slope on both sides from +0.15m to +0.05m as shown in figure 17. The landing space is raised at +0.05m from the finished carriageway level to prevent water logging. A ramp of 1:8 slope should be provided to access landing space and then access property as shown in figure 17.

Figure 16: Footpaths with side ramps at property entrance in Mumbai

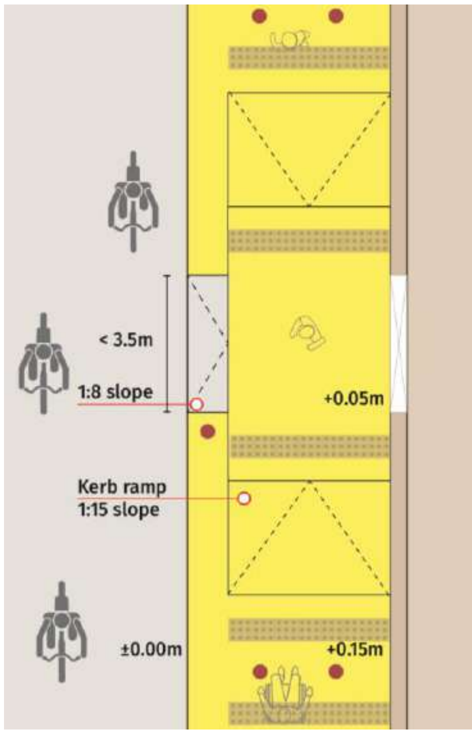

Figure 17: Detail of property access on small footpath widths (top view)

Continuous walking zone should be maintained around the existing trees as shown in figure 18. Where RoW width decreases, provide bulb-out[7] in the MUZ as shown in figure 19 to continue the walking zone.

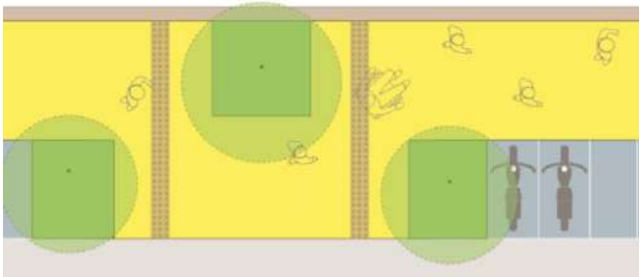

Figure 18: Bulb-out around existing trees

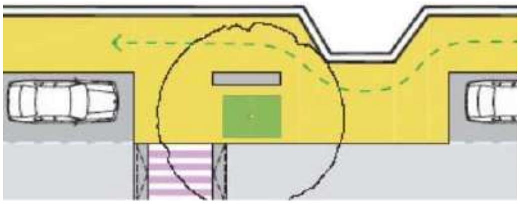

Figure 19: Bulb-out to negotiate decrease in right of way width

Integration of footpath and kerb-side cycle track

Pedestrians can hinder cyclists' movement on kerb-side cycle tracks, if adequate walking space is not available. This will result in cyclists using the carriageway instead of cycle tracks. It is recommended to provide enough walking space and clearly demarcate space for pedestrians and cyclists as shown in figure 20. Walking space can be separated from cycle tracks through a slight level difference. Cycle track finished level should be 50mm lower as shown in figure 21 to prevent water logging on footpath. Cycle track surface can be painted in different colour along with cycle symbol marking. On wider footpaths, various street elements such as seating, landscape, trees and pedestrian lights can be located between walking zone and cycle track as buffer.

Figure 20: Adequate footpath space provided along cycle track in Pune

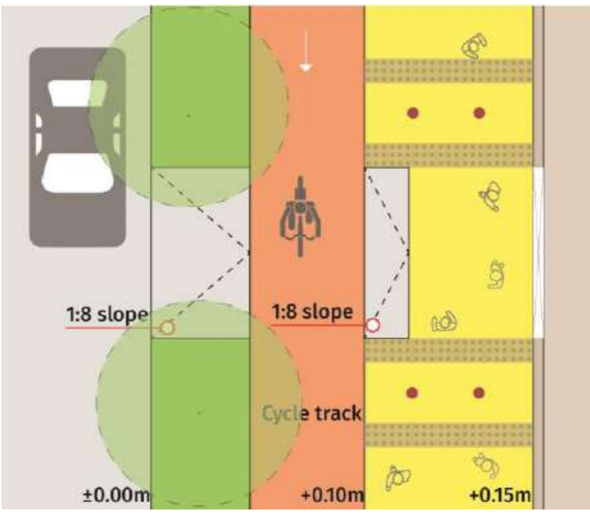

Figure 21: Planning detail between footpath and cycle track (top view)

Minimum 0.5 m buffer is recommended on both sides of cycle track to ensure vehicle overhangs and street elements on footpath such as bus stops, seating and others do not affect the cyclists' movement as shown in figure 22.

[7] Bulbout is a footpath kerb extension into the MUZ.

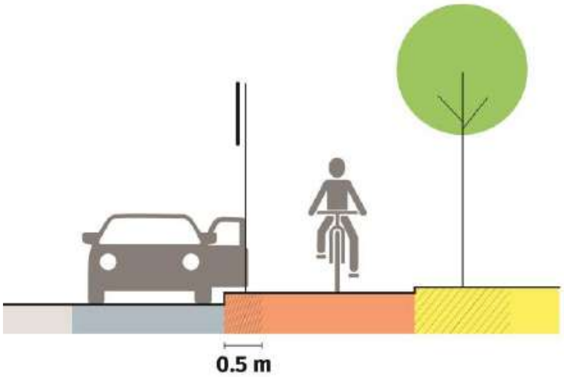

Figure 22: Buffer between on-street parking and cycle track

6.3. Shading on pedestrian facilities

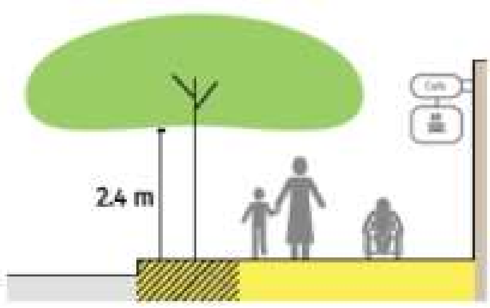

Figure 23: Shade on footpath

All the pedestrian infrastructure including bus-stops, IPT stands, seating spaces, foot-over bridges and skywalks should be well-shaded to ensure pedestrian safety. Footpaths are usually shaded by trees. On narrow streets, abutting buildings provide shade. Ensure minimum clearance of 2.4m between shade and finished footpath floor level to maintain clear walking height and ensure visibility to road signages as shown in figure 23. Other on-street shading elements include colonnades and shaded walkways. Colonnades can be considered along retail commercial streets as shown in figure 24. Shaded walkways can be considered to connect railway/metro station or major building to the nearest bus-stop and/or IPT stand for comfortable transfer as shown in figure 25.

Figure 24: Colonnade walkway in Connaught Place in Delhi, (Source: Flickr)

Figure 25: Shaded walkway connecting bus-stop and transit station in Singapore, (Source: NUS)

It is recommended that bus-stops, IPT stands, foot-over bridges (including staircase) and skywalks be shaded by permanent roofing to protect from heat and rain. All the support systems (post, poles, columns and others) for shading should be located in MUZ or dead zone, and not obstruct pedestrian movement.

6.4. Kerb stone

Kerb stone is placed along the footpath edge. Pre-frabricated concrete kerb stones are preferred as they stronger, easy to install and have uniform finish. However, in some cases in-situ construction of kerb stones can be done if the site needs a lot of variation in the edge. The top level of kerb stone should align with the final finished footpath level. It should not exceed 150mm. A typical bull nose kerb stone is commonly used as shown in figure . Kerb stones are placed over PCC mortar base. Curved and angular kerb stone blocks can be used to create bulb-outs.

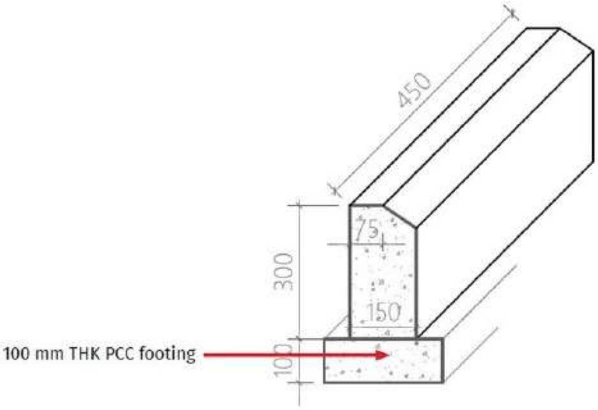

Figure 26: Typical 150mm thick kerb stone block

Saucer drains and openings to catchment pits should be laid along the footpath kerb to channelise and collect stormwater runoff. Saucer drains can also be provided along with the kerb stone as a single unit as shown in figure 27.

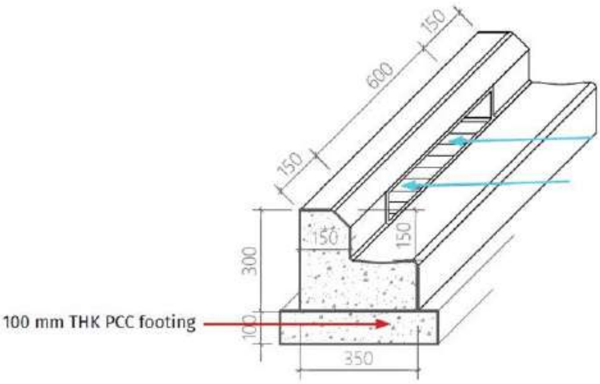

Figure 27: Kerb stone block with saucer drain

Figure 28: Precast rounded kerb stone block

Precast rounded kerb stones of desired radii can be used for intersections and parking bays.

6.5. Tactile pavers

Visually impaired pedestrians need guidance while walking to find their way, overcome obstacles, and cross safely. Two types of tactile tiles are used – guiding and warning tiles as shown in figure 26 and 27. Detail specification of tile design can be referred in IRC:SP:117.

Guiding tiles have straight continuous lines that indicate the route. They are helpful in large areas such as transport terminals, public spaces and wide footpaths (more than 4m) for easy navigation, as the usual guidance given by the edge of the footpath or compound wall is not within the reach of stick used by visually impaired to navigate. Only warning tiles are recommended on footpaths with width less than 4m.

Figure 29: Guiding tile

Warning tiles helps to warn against level difference and obstacles, and further informs on how to navigate. It should be placed at the beginning and end of the ramps and stairs. Warning tiles should be provided at property entrances, intersections and pedestrian crossings. Two sets of pedestrian warning tiles should be provided, so that the pedestrian does not miss it.

Image 30: Warning tile

Tactile pavers should be used in a correct and consistent manner. Figure 28 shows the incorrect laying of tactile pavers that can result in collision. It can result in serious injuries.

Figure 31: Incorrect laying of tactile pavers (Source- walkabilityasia.org)

Tactile pavers should be laid 600mm away from the edge of footpath kerb edge, compound wall and any other obstructions to avoid collision. Pavers should be provided in line of travel avoiding obstructions such as service cover, tree pits/guards, lamp posts, bollards and others. Layout of tactile pavers to indicate turn is shown in figure 29. Unglazed vitrified pavers are preferred over ceramic/cement ones, as they have good load-bearing strength and are durable. Stainless tactile studs can also be used. Tactile paver colour should be contrasting to the surrounding surface. IRC:SP:117 should be referred for more details on tactile pavers.

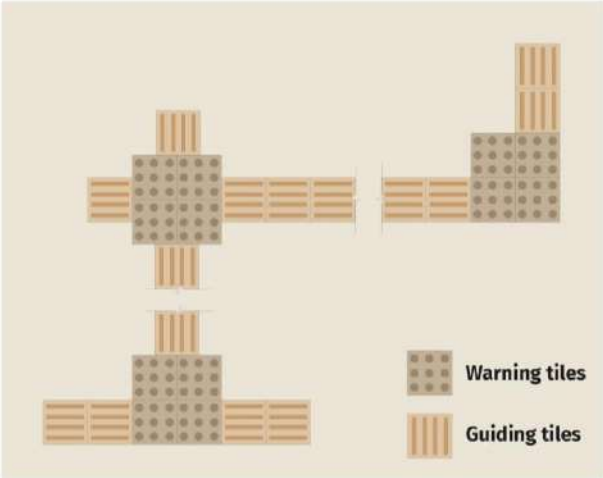

Figure 32: Layout of tactile pavers to indicate turns

6.6. Street furniture

Street furniture includes seating, street light, signage, bollard, wastebin, children play element etc. Street furniture should be located in MUZ, and not obstruct pedestrian movement. All street furniture should be convenient to use, universally accessible, vandal proof, durable and easy to maintain. Installation of street furniture must be accompanied by a maintenance plan. Street furniture should be painted in contrasting colour for persons with low vision. Furniture should be fixed at the same level as surface level. Pedestal-mounted furniture should be avoided. Furniture protruding (for eg. wastebins) inside the walking zone should be avoided. It is recommended that street fixtures like bus shelters, utility boxes, seating, bollards, wastebins, etc. are installed prior to the paving of the footpath.

Seating – Seating enable pedestrian to rest and socialize. It should be well-shaded and comfortable to sit. It should be provided as per the context. Seating in MUZ should be perpendicular to the pedestrian movement as shown in figure 30. Seating may be provided parallel to the pedestrian movement on wider footpaths as shown. Seats may have back rest and armrest. Seat should be at 0.45m in height and depth (not including the back rest).

Wastebins – Wastebins should be provided at regular intervals. It is recommended that wastebins be available at every 50-75m distance. The opening of the bins should not be above 800mm. Dustbins should be placed near all transit stops and vending areas. Dustbins attached to street lights should not protrude into the walking zone. Regular cleaning of dustbins is required to ensure pleasant walking experience. Garbage dump on streets should be prevented, and city-level waste management plan should be implemented.

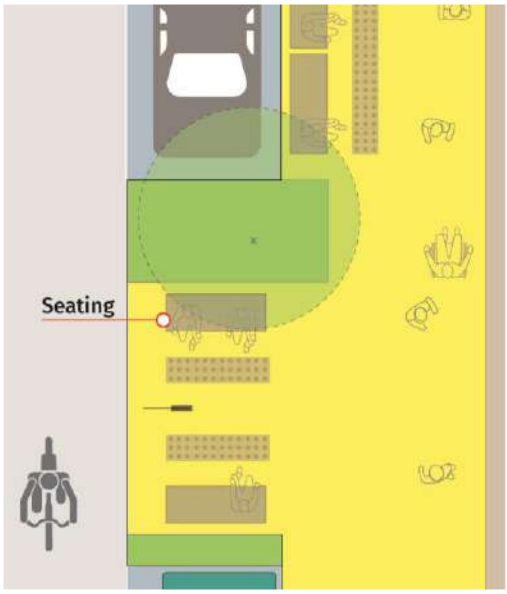

Figure 33: Plan showing location of seating footpath (top view)

Bollards

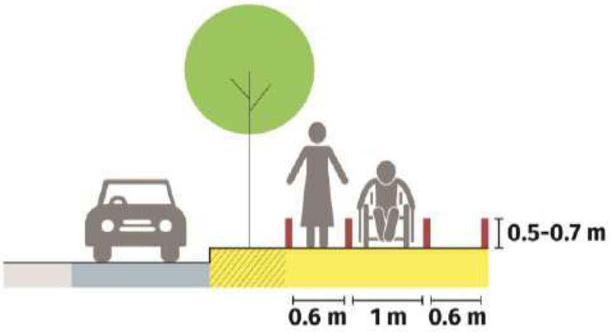

Figure 34: Bollard spacing on footpath

Bollards should be provided at locations on footpath where illegal vehicle encroachment is possible such as around property entrance access ramps, raised pedestrian crossings or kerb edge of footpath. Bollard (outer edge of bollard) should be placed 0.25m away from the footpath kerb edge to ensure proper fixing of bollard after kerb stone, and prevent mounting of vehicles. Bollards should be 0.5-0.7m high with a clear spacing of 0.6m between them and one with 1m clear width to ensure movement of wheelchair users, caregivers with pram and persons with luggage. Bollards can be placed on footpath kerb edge at 3m center to center distance to prevent mounting of vehicles. Bollards can also be designed as seating at a height of 0.45m as shown in figure 32. Bollard material should be of good quality material and fixed well to avoid breaking as shown in image 33. Refer Annexure 4 for more details on bollard material.

Figure 36: Bollards designed as seating

Image 35: Broken bollards due to poor implementation

Pedestrian guardrails

Continuous guardrails on footpath without frequent opportunities to enter and exit makes pedestrians feel trapped inside, and they begin to walk on carriageway. In the absence of frequent crossing opportunities or crossings at preferred locations, pedestrians tend to jump over median guardrails. Pedestrian guardrails if not provided thoughtfully, adds to the discomfort of pedestrians. Hence, pedestrian guardrails should be only used where there is evidence that pedestrian safety can only be achieved by providing guardrails. Pedestrian guardrails may not be required in most cases if sufficient walking space, and frequent and safe crossings are available. It is recommended to avoid kerb-side guardrails on streets with undivided carriageway, where crossing is frequent and vehicle speeds are under 40kmph. Guardrails may be considered at -

- Around intersections on arterial roads to direct pedestrians towards safe crossings. However, ensure crossings are planned along pedestrian desired lines to avoid increase in walking length.
- Around school and aanganwadi entry/exit to protect children.
- Streets or locations that have high pedestrian volumes and fast-moving vehicles, and there are chances that pedestrians may spill over carriageway.

Following design considerations to be incorporated in pedestrian guardrails-

- The guardrails to be around 0.7-0.9m high to deter pedestrians from climbing over it and ensure visibility.

- The balusters should be placed such that the pedestrians cannot pass through the gap.
- Guardrail (outer edge) should be located 0.25m away from the footpath kerb edge.
- They should be aesthetically designed to enhance the street character.
- Provide appropriate entry and exit points along the pedestrian desired line to prevent pedestrians from climbing over the guardrails.
- If a continuous guardrail is provided along the stretch, it is recommended that a gap be provided at every 20m to allow exit during emergency – for instance, pedestrian can escape any unfortunate event that may be threat to their personal security.

Signage

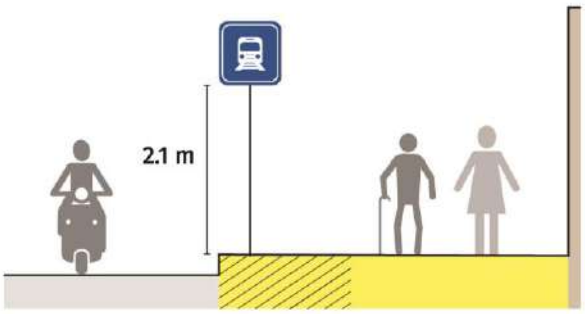

Figure 37: Signage placement on footpath

Signages inform pedestrians and other road users to navigate on urban streets. There should be no clutter of signages, unnecessary signages should be avoided. Signages on directions, parking, and others that helps to navigate and induce safe driving should be provided. A clear height of 2.1m should be maintained between the signage bottom and the finished footpath floor level as shown in figure 34. Signage should be placed perpendicular to the line of traffic, on the left side of the road with clear visibility except for 'Parking' and 'No Parking' signs which shall be placed parallel to the carriageway as per IRC:67. Signages should be placed in the MUZ. Multiple informatory signs and advertisements can be combined on a single pole to reduce clutter. IRC:67 on road signages should be referred. Braille signboards should be located between 1.4-1.6 meters from floor level for persons with visual impairments as shown in figure 35.

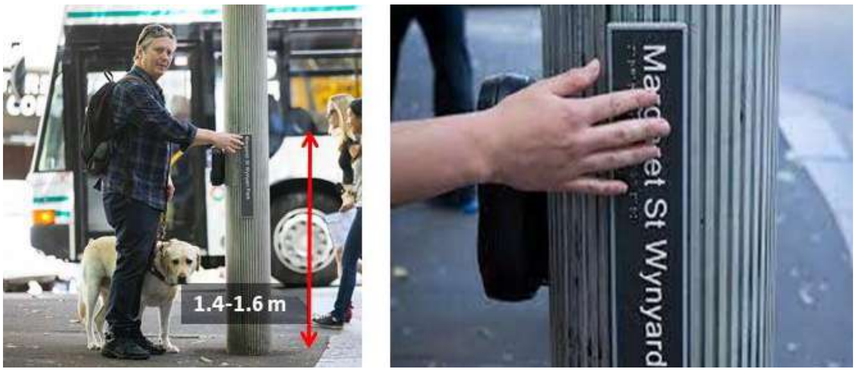

Figure 38: Tactile sign for wayfinding in Sydney, (Source: govnews.com.au)

Contrasting colour should be used to differentiate signage content from the background. Typically, white is used for the content and blue for background. The colour combinations red/green and yellow/blue should not be used to avoid confusion to persons with colour blindness. IRC:SP:117 should be referred for details. Periodical testing of retro reflective sign boards to be done as mentioned in IRC:67 to assure the performance of the sign boards. Non-performing sign boards (not meeting the minimum Ra values) which are under the warranty period should be replaced, and damaged sign boards to be replaced on immediate basis.

Street lights

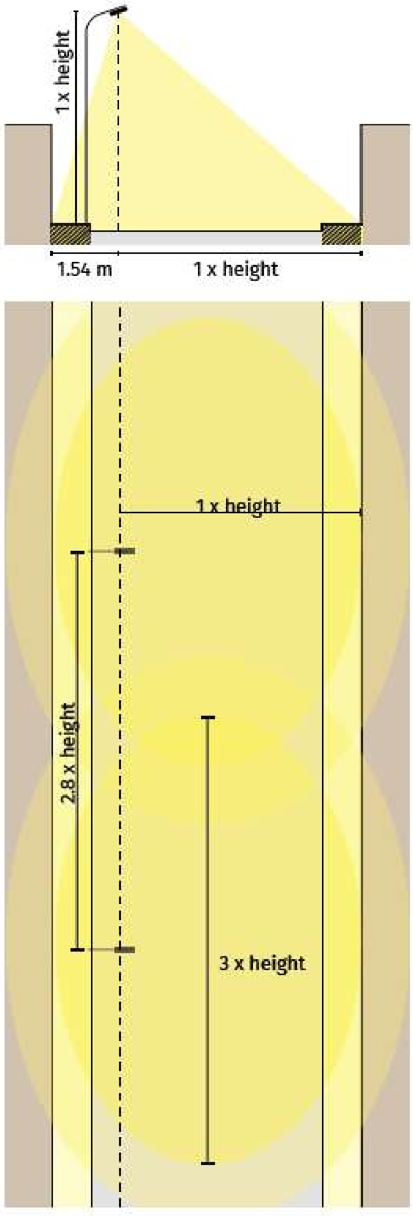

Figure 39: Spacing between street lights

The entire RoW width should be well-lit. Warm white LED light is preferred. 25-30 lux level of lighting should be available on footpath. Spacing between two light poles should be approximately three times the height of the fixture to ensure complete lighting as shown in figure 36. Light poles should be no higher than 12m to reduce undesired illumination of private properties. It is recommended to have flexible and reboundable type retro-reflective sheets of Type IV on street light poles. Pedestrian lights on footpath and cycle track should not exceed beyond 6m. Table 3 recommends the height and spacing of street lights.

Table 3: Street light height and spacing as per street type

Street type	**Pole height (m)**	**Spacing (m)**
Footpath or cycle track	3-6	9-16
Local street (less than 12m width)	8-10	25-27
Arterial or Collector (more than 12m width)	12	30-33

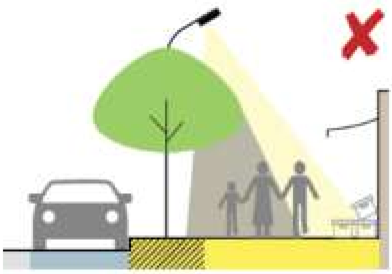

Figure 40: Trees obstructing the street light

Placement of street lights should be coordinated with trees to avoid dark spots as shown in figure 37. An integrated plan of trees and street lights location should be prepared.

A single row of light is sufficient for streets upto 12 m wide. Dual lights can be mounted on a single central post as shown in figure 24, if lighting is insufficient.

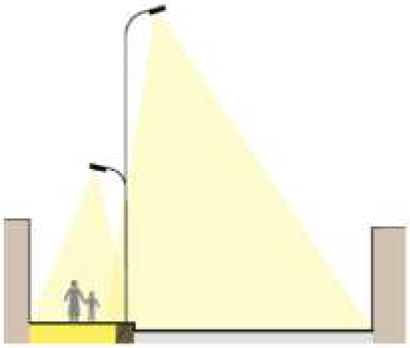

Figure 41: Street lighting on narrow streets

For wider streets, multiple rows of posts can support lights at different levels as shown in figure 39.

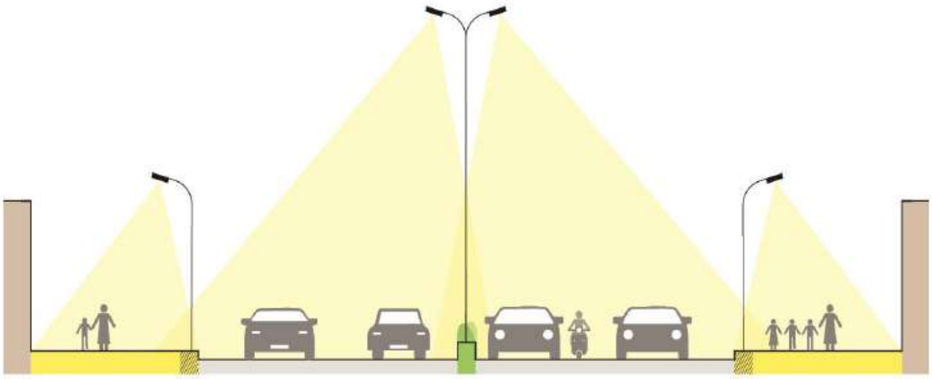

Figure 42: Street lighting on wide streets

Utilities

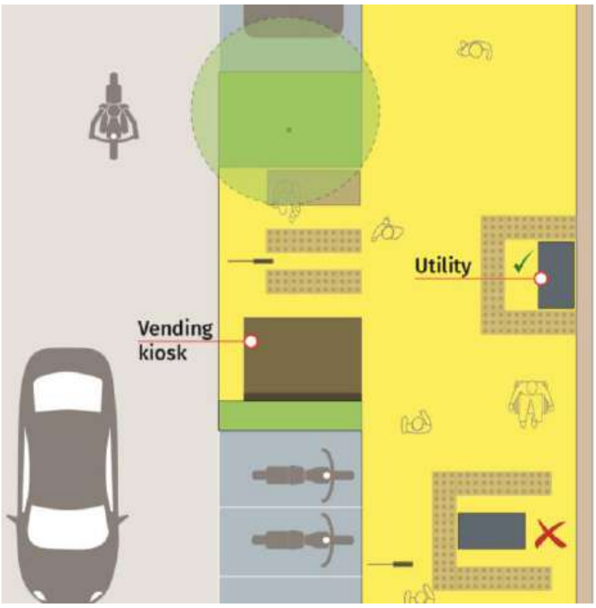

Figure 43: Placement of utilities on footpath (top view)

Improper placement of overground utilities such as utility boxes and uneven service covers impedes pedestrian movement. Utility boxes should be placed in MUZ or dead zone without disrupting the pedestrian movement as shown in figure 40.

Any service covers on the footpath should be placed in MUZ as shown in figure 41. They should be avoided on cycle tracks. However, if they come on walking zone or cycle track, the covers should be in level with footpath surface. Warning tiles should be provided to indicate the visually impaired persons to change the direction as shown in figure 42. The gratings of the service covers should be perpendicular to the movement of wheels of a wheelchair. Openings of grating should not be more than 10mm wide.

Figure 44: Service covers should be located in MUZ

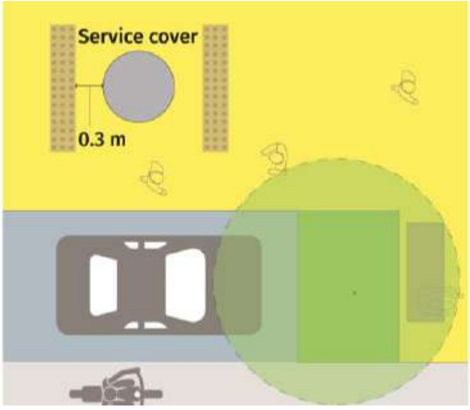

Figure 45: Detail of service cover when provided on walking zone (top view)

Mapping utilities

- While retrofitting existing footpaths, mapping of all utility lines running underground is necessary for precise excavation so as to prevent damage to these lines.
- While excavation, atleast 2 m around tree trunk should be left unexcavated to prevent damage to the roots. Precautions should be taken to avoid damaging of existing utility lines.
- Ducts are recommended for all underground utilities than trenches. Ducts may be conduits, tubes or pipes such as RCC, PVC hume pipes. Ducts are cost effective and provide flexibility. Where trees obstruct the continuous passage of utility lines, the lines should be continued around the trees via flexible ducts. Manholes should be provided at regular intervals for maintenance. IRC:98 should be further referred for guidelines on accommodation of utility services on urban streets.

Public toilets and drinking water facilities

It is recommended that public toilets be located off-street. Walking along public toilets should be pleasant. They should be universally accessible. IRC:SP:117 should be referred for details on universally accessible toilet design. They should be safe for women and children to use. Hygienic public toilets and drinking water facilities should be available within 5-minute walking distance of major destinations such as transit stations, markets, public parks etc.

6.7. Pedestrian crossings

Pedestrians of all age groups, gender and abilities should be able to cross streets safely and conveniently. Pedestrians cross at mid-block and at intersections. Frequent opportunities for at-grade crossings should be available on urban streets. Crossings that are located far apart increases the walking distance which leads pedestrians to cross randomly. Similarly, if the waiting time to cross increases, the pedestrians tend to become impatient, and cross in an unsafe condition subjecting themselves to the risk of road crash. Table 4 recommends LOS for pedestrian crossing as per the Indian Highways Capacity Manual. Pedestrian delay is defined as the waiting time a pedestrian has to invest before crossing.

Table 4: Pedestrian Crossing Level of Service

LOS	Pedestrian Delay (in seconds)
A	≤ 5
B	5 – 10
C	11 – 25
D	26 – 45

Pedestrian crossings are of two kinds – at-grade and grade-separated. At-grade pedestrian crossings provide crossing at the street level, whereas grade-separated infrastructure provide crossing above or below the street level. Foot-over bridges and subways are grade-separated pedestrian crossings. At-grade pedestrian crossings are recommended over grade-separated ones, as they provide quick, short and comfortable crossing. Pedestrian crossings should be provided at every 80-150m in urban areas. On undivided streets where pedestrians tend to cross at any points, such streets should be traffic calmed to ensure vehicles speeds are below 20kmph. Pedestrian crossings should be minimum 2 m wide. 4m wide crossings are recommended on streets with high pedestrian volumes such as schools, transit stations, shopping complex etc. Pedestrian crossings should be clearly visible to all road users by appropriate markings as per IRC:35.

6.7.1. At-grade pedestrian crossings

At-grade pedestrian crossings are mainly of two kinds – tabletop / raised crossing, and painted zebra crossing.

Tabletop crossing

Figure 46: Tabletop crossing in Connaught Place, Delhi

Tabletop or raised crossings are recommended at all unsignalized crossings, as it provides comfortable and safe crossing to all road users including persons on wheelchair, elderly and caregivers with pram. It allows pedestrians to cross at the same level as the footpath as shown in figure 43. It also acts as a traffic calming measure that ensures road safety to both pedestrians and motorists.

As shown in figure 44, crossing is raised at the same level as the adjacent footpath finished level. Ramps of 1:8 slope is provided for vehicle access. Crossing should be minimum 2m wide. Bollards should be provided at both ends of the crossing and at median, to prevent vehicles from (especially two-wheelers) taking U-turns and entering the footpath. Atleast one bollard spacing should ensure access to wheelchair users. It is recommended to provide traffic calming measure (speed hump) 10-20m before the crossing as per IRC:99. This will help to slow down the vehicle in advance and ensure pedestrian safety. Tactile pavers should be provided to guide visually impaired persons. Provision for storm water drainage before the ramp should be provided. Asphalt concrete may be used for the table-top surface.

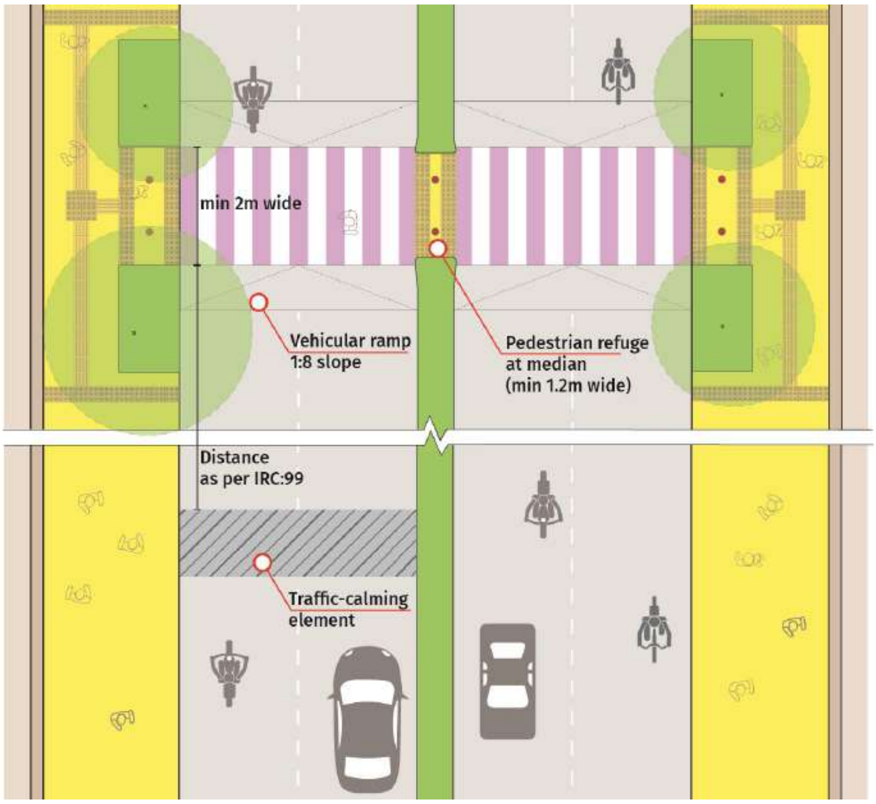

Figure 47: Table-top pedestrian crossing detail (top view)

Painted zebra crossing

Zebra crossings are painted at the level of carriageway. Kerb ramps on footpath should be provided at both the ends of the zebra crossing for access to wheelchair users, caregivers with prams and elderly. Following design guidelines should be followed for kerb ramp-

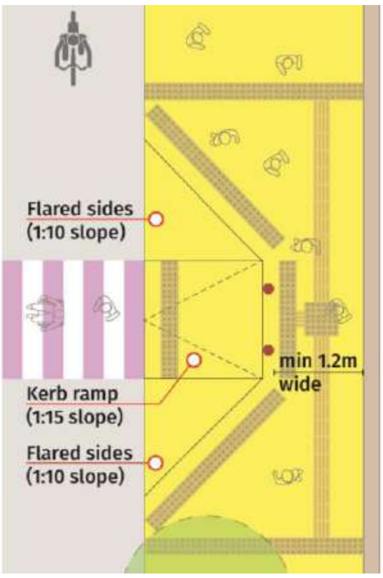

Figure 48:Kerb ramp detail (top view)

- The kerb ramp slope should not be steeper than 1:15 and slope on flared sides should be 1:10 as shown in figure 45.
- The width of kerb ramp should be equal to the width of the pedestrian crossing.
- Ensure minimum clear 1.2m wide walking space is available after bollards.
- Warning tactile pavers should be provided at the ramp top and bottom as shown in figure 45 to warn a visually impaired person on the level difference due to ramp slope and the beginning of the carriageway.
- The carriageway surface at the ramp bottom should be well drained.

‘STOP’ line should be provided before the zebra crossing as per IRC:35, if the crossing is signalized. Stop line provides buffer space between zebra crossing and waiting vehicles.

Pedestrian refuge at median

Pedestrian refuge at median provides safe space for pedestrians to wait while crossing the divided carriageway. It is recommended that the minimum median width be 1.2m as shown in figure 44. 2m median width should be provided for a cyclist to wait. For wheelchair and pram access, median level should be at the same level as tabletop crossing or as carriageway level incase of zebra crossing. Pedestrian median refuge should be properly highlighted with the help of road markings, delineators, median markers or solar studs based on the site requirement.

Bulb-outs

Where on-street parking is provided, bulb-out should be provided at pedestrian crossing as shown in figure 46. Bulbout is a footpath kerb extension into the MUZ to reduce the crossing distance for pedestrians and provide visibility to motorists and pedestrians at the crossing. Bulb-out enhances the pedestrians safety. Bulb-out length before the crossing should be long to ensure higher visibility.

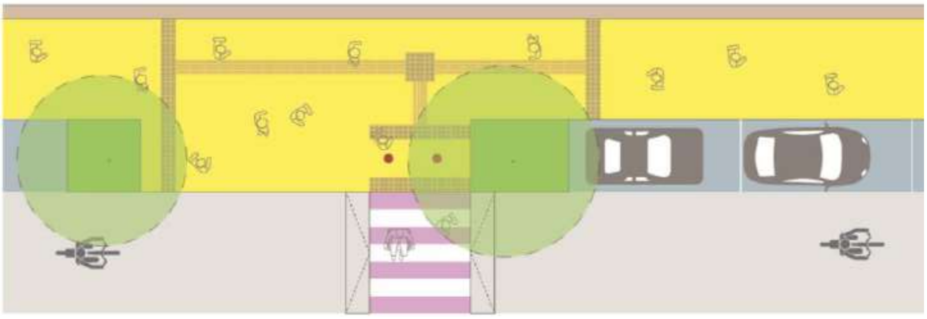

Figure 49: Bulb-out at pedestrian crossing (top view)

Transverse Bar Marking

Incase if signalized crossings are not feasible on high-speed corridors such as highways and urban expressways, it is recommended to provide transverse bar markings before crossings for pedestrian safety as shown in figure 47. Transverse bar markings slightly reduce the vehicle speeds and warn drivers as they approach the crossing. Markings reduces confusion while crossing and help pedestrians to make a better judgement before crossing. IRC:99 should be referred for the details on the specification of transverse bar marking, its location and its distance from crossing.

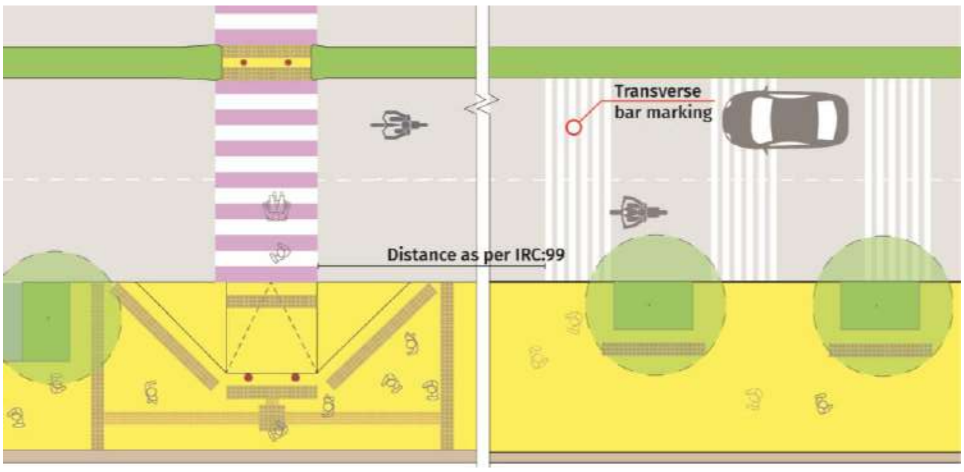

Figure 50: Transverse road markings before pedestrian crossing (top view)

Signalized Crossings

Signalized crossings improve the pedestrian safety at intersections and midblock. Following warrants, can be considered if -

a. Pedestrians have to wait more than 45 seconds to cross the street.
b. Traffic speed increases above 40 km/h, 60 km/h or 80 km/h for 2-lane undivided road, 4-lane or 6-lane divided road respectively.
c. Psychological gap size (PGS)[8] becomes less than 1.65s, 2.0s, or 2.55s for 2-lane undivided road, 4-lane or 6-lane divided road respectively.
d. Vehicular flow on a 2-lane undivided road, 4-lane or 6-lane divided road respectively increases beyond 940, 1250 or 1860 PCU/hour respectively.

It is recommended to consider signalized crossings on 6-lane divided streets or one-ways streets with more than 2 lanes in one direction, as it is difficult to cross more than two lanes. Crossings and intersections that have shown history of road crashes in the black spot data of the city.

The nomographs depicting the relationships between pedestrian flow[9], vehicular flow[10], vehicle speed and pedestrian psychological gap size are given in annexure 2. These can be used to decide a type of crossing facility which shall be provided at a location (Jain & Rastogi, 2018).

Traffic signals with pedestrian phase

Traffic signals should have exclusive pedestrian phase. Pedestrian phase timing should consider the walking speeds of all age groups, gender and persons with different abilities. Walking speeds of various pedestrians is given in annexure 1. Following pedestrian walking speeds should be considered for the design of signal timings -

- 15th percentile speed (approximately 0.95 m/s)
- If older pedestrians are high in volume, a walking speed of 0.8 m/s should be used.
- If young children accompanied by caregivers are high in volume, a walking speed of 0.5m/s should be used. This will be also helpful to persons with disabilities. School, recreation and hospital zones should consider a walking speed of 0.5m/s.

Pelican signals may be used on streets with high vehicle volumes. Pelican signals are activated by the pedestrians using a push button are useful on midblock crossings. Signals should have audible device for the benefit of visually impaired pedestrians and children. IRC:SP:117 should be referred for further details.

6.7.2. Grade-separated crossings

Grade-separated pedestrian crossings are often inconvenient for pedestrians, as it increases the walking length and involves high effort of climbing up and down. It is not suitable for the elderly, and those with disabilities. Access to persons on wheelchair is impossible without a lift. Grade-separated crossings especially subways are often perceived unsafe by women, due to the fear of crimes. If present grade-separated crossings are not usable or unsafe as found in the audits, feasibility of at-grade crossings should be considered. Grade-separated crossings to be only provided under the following conditions-

- On urban expressways or high-speed corridors where vehicle speeds are very high.

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[8] Pedestrian psychological gap size (PGS) is defined as the time gap perceived safe by a pedestrian, who feels confident to cross the potential pedestrian-vehicle conflict area including the width of the vehicle.

[9] Number of pedestrians passing a given point per unit time expressed as pedestrians per hour or pedestrian per minute or pedestrians per 15 minutes.

[10] Total number of vehicles that pass over a given point of a street in a given interval of time. It is expressed as PCU/hr.

- To cross the railway corridor.
- Psychological Gap Size (PGS) is less than 0.77s or 0.98s on a 4-lane or 6-lane divided road respectively.
- When vehicular flow on a 4-lane or 6-lane divided road increases beyond 4200 or 6300 PCU/h respectively.

Where pedestrian grade-separated facilities are built, they should ensure universal accessibility, and convenience to pedestrians by providing lifts, escalators, and ramps for cyclists. Tactile pavers should be provided for the visually impaired persons. They should be well-lit, shaded and safe to use. Additional design details of grade-separated pedestrian crossings are given in annexure 3.

6.8. Bus-stops

Bus-stop should be placed at the kerb edge in MUZ on footpaths above 4.5m width as shown in Figure 48 (a) to ensure continuous movement. For footpaths below 4.5m width, bus-stop should be placed along the property edge to provide sufficient space for pedestrians to walk as shown in Figure 48 (b). Bus-stop should be well-lit and well-shaded. Bus-stop should have a clear waiting space of minimum 1.2m and seating should be provided especially for elderly, caregivers with young children, pregnant women and persons with disabilities. Bus-stop waiting area should be at the same level as the footpath.

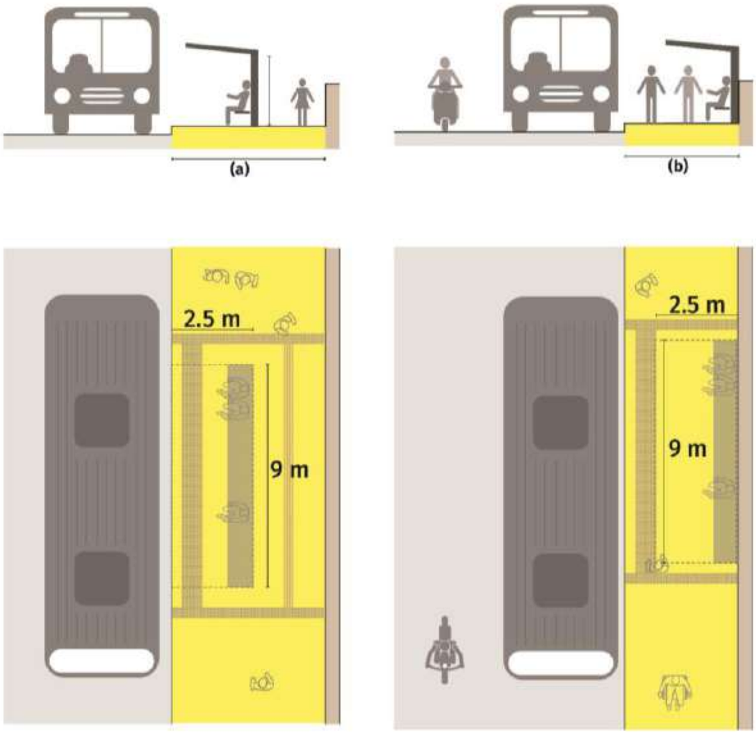


Figure 51: Placement of bus-stop on footpath (top view)

The area around the bus stop should be planned as shown in figure 49. Vendors, signages, advertisements and trees should be located in a way that they do not hinder the vision of the passengers waiting at the bus-stop and pedestrian movement. Bus-stop marking should be provided as per IRC:35. The back-side of the bus stop should be visually transparent to ensure personal security while waiting. Dustbin and drinking water facilities may be provided. Pedestrian crossings should be before the bus-stop to ensure passengers cross safely at the rear end of the bus. IPT stands should be provided near bus stops for multi-modal integration. Passenger information system in terms of static information and real time information should be made available. Static or schedule information should be made available in printed sign board with route network map, bus number information, emergency helpline numbers etc. Real time information on estimated arrival of bus will increase the dependency of public bus transport.

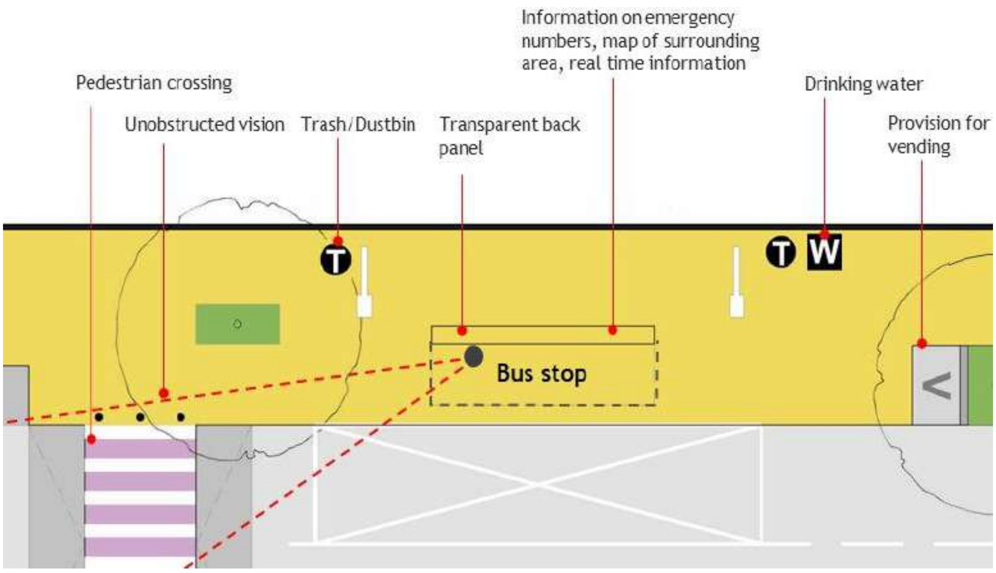


Figure 52: Bus-stop area planning (top-view), Source: Safety audits and walking assessment around bus terminals in Delhi, 2018

It is recommended that bus-stops should be placed 40-45m away from the pedestrian crossing at the intersection. IRC:70 should be further referred for guidelines on planning of bus stops.

6.9. Landscaping

Landscaping improves the livability on streets and enhances walking experience if planned properly. Trees provide shade to pedestrians and other road users, and keep the street environment cool. Trees and shrubs should be planted in MUZ. Existing trees should be retained, and footpath should be planned around it. Trees that suit the local climatic conditions should be planted. Narrow columnar trees should be used where footpath space is limited. Vertical clearance of 2.4 m should be maintained. Branches should be pruned to ensure visibility of signages. An integrated plan of street lights and trees should be prepared to ensure they do not block the streetlight.

Tree pits of around 1.8 m x 1.8 m (area without concrete) should be provided around trees to accommodate roots. On narrow footpaths, the same surface area can be achieved with tree pits of size 1.25 m x 2.6 m as shown in figure 50. IRC:SP:119 should be referred for details on landscaping on urban streets.

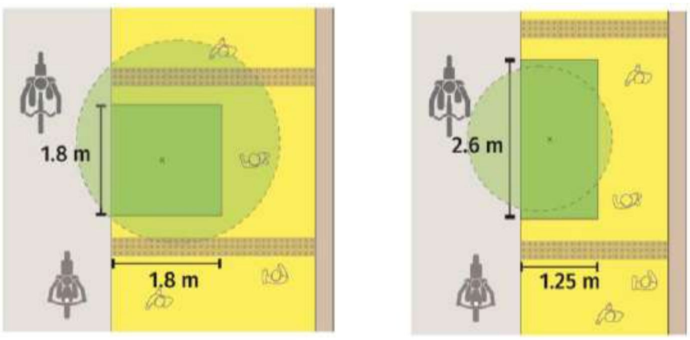


Figure 53: Tree pit detail (top view)

Surmountable tree gratings should be used over tree pits to increase the effective walking zone width especially on narrow footpaths as shown in figure 51. Tree gratings should be at the same level as footpath. Precast concrete gratings may be used. Tree grating gaps should be perpendicular to the movement of wheels of a wheelchair,

Figure 54: Tree grating detail

6.10. Street vending

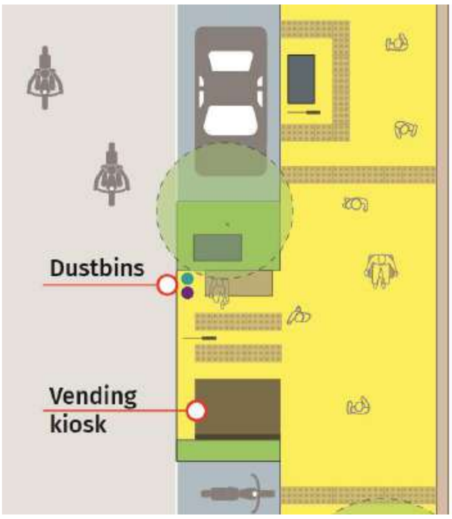


Figure 55: Planning of on-street vending on footpath (top-view)

Well-planned on-street vending provides for a vibrant social space and passive personal security especially for women, children and elderly. The Street Vendors (Protection of Livelihood and Regulation of Street Vending) Act, 2014 makes it mandatory to integrate vending areas in the street design. On-street vending should be managed to ensure vendors and buyers do not hinder the pedestrian movement. Vending spaces to be provided in the MUZ as shown in figure 52.

Vending spaces should be clearly demarcated. An on-street vending management plan should be prepared. Supporting infrastructure like water taps, electricity points, waste bins, and public toilets should be provided.

6.11. On-street parking

Street space is meant to move people efficiently and allow people to sit, play and socialize. Parking is a sub-optimal use of limited street space. More and more on-street parking (except cycle parking) should move to off-street to ensure all road users have fair road space. On-street parking should be limited and priced. On-street parking on urban streets should be provided as per the following hierarchy as shown below:

First	Non-motorized vehicle parking (cycle)
↓	Non-motorized IPT vehicle stand (cycle rickshaw stand)
	Motorized IPT vehicle stand (auto rickshaw, share auto rickshaw and taxi stand)
	Parking for persons with disabilities
	Loading/unloading bays for light commercial vehicles
	Private motor vehicle parking (2-wheelers)
Last	Private motor vehicle parking (4-wheelers)

On-street parking is not desired on arterial streets for better traffic flow. However, it can be provided on service lane. On-street parking may be provided on collector and local streets. On-street parking should be parallel, instead of angular or perpendicular as shown in figure 53. Parallel parking occupies less space. It also allows flexibility between four-wheeler and two-wheeler parking. Angular and perpendicular car parking should be avoided since they occupy more road space and hamper visibility to drivers on approaching vehicles while reversing. Parking bay for four-wheeler (car) should be 2 x 6m, two-wheeler and cycle parking should be 2 x 1m. Parking space for one auto rickshaw, e-rickshaw and cycle rickshaw should be 1.5 m x 3 m and for taxis should be 2 m x 6 m. Each parking bay should be clearly defined and marked to avoid haphazard parking. Appropriate parking signages giving information on timings, vehicle type parking and price should be provided. Parking signages and markings should be provided as per IRC:67 and IRC:35 respectively.

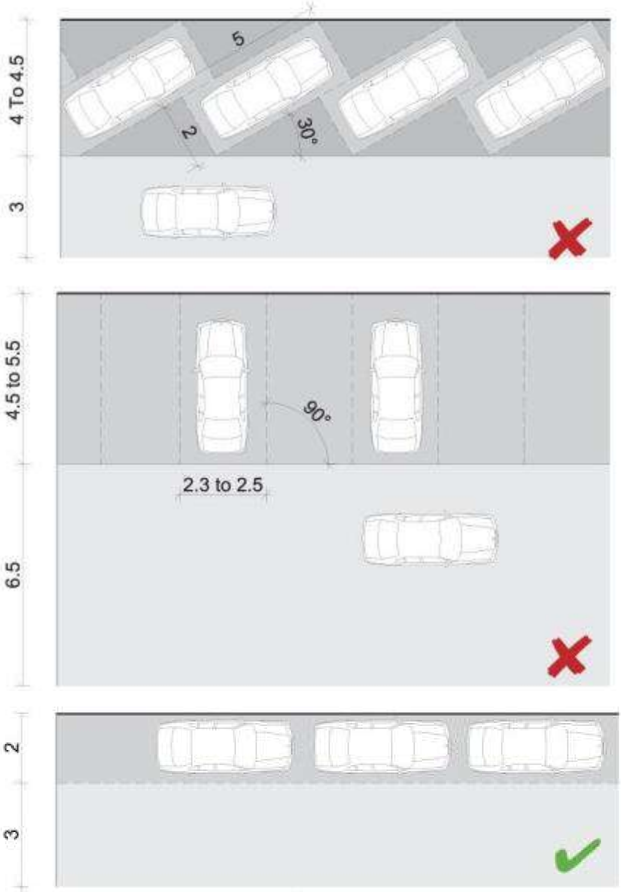


Figure 56: Parallel parking is preferred for all 3&4 wheeler vehicles

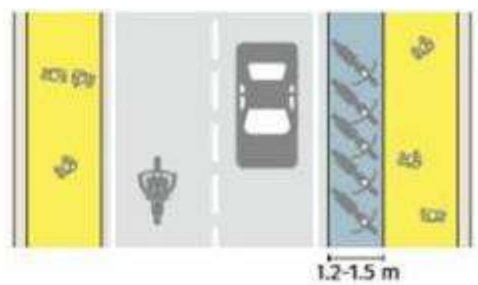


Figure 57: Angular 2-wheeler parking on narrow street (top view)

Parking for two-wheelers and cycles should be perpendicular. On narrow streets with high density of two-wheeler parking, angular two-wheeler parking may be considered as shown in figure 54.

Intersections should be free of on-street parking. Parking should not be provided within 50m from the intersection on collector streets and 10m from the intersection on local streets. Parking should be interrupted by bulb-out after every 5 car parks as shown in figure 55, to provide other amenities such as seating, trees, utilities and other footpath elements. The kerb edge of parking can be at right angle as vehicles enter and exit parking bays at different times, whereas the kerb end for an IPT stand may have 45-degree splayed edge as the vehicles move in rotation.

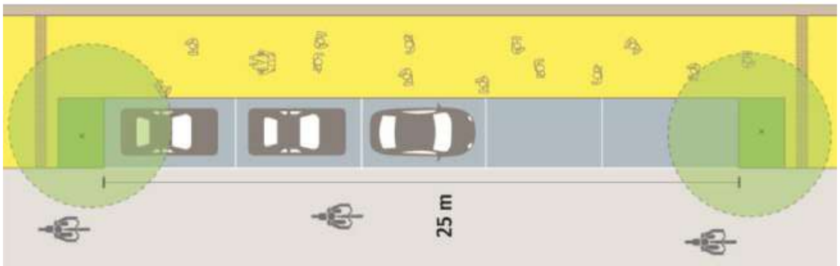


Figure 58: On-street parking planning detail

Dedicated on-street and off-street cycle parking should be provided. On-street cycle parking can be accommodated in the MUZ. IPT stands should preferably be located near bus stops, transit stations, hospitals, markets and other major destinations. Appropriate signages for IPT stand should be provided. Usually, 5-6 IPT waiting bays may be provided in one stand. However, at transit stations and other major destinations, the number of waiting spots can be provided as per the context.

Accessible car parking for persons with impaired mobility

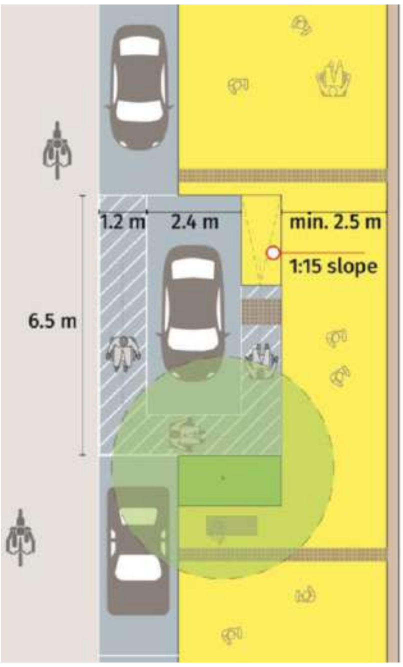


Figure 59: On-street accessible parking (top-view)

Designated car and tri-cycle parking spaces for persons with impaired mobility should be provided. It is recommended to provide off-street accessible parking spaces. On-street accessible parking space numbers should be provided in discussion with the disability groups. On-street accessible parallel car parking of size 3.6 x 6.5m should be provided. 1 m wide ramp should be provided for wheelchair user to access the footpath as shown in figure 56. The ramp slope should be 1:15. Parking bay should have the international symbol of accessibility painted on the ground, along with a signpost around it. IRC:SP:117 should be further referred.

6.12. Shared Streets

Shared streets are designed in a way where pedestrians and motor vehicles use the same street space in safe conditions as shown in figure 57. There is no segregation in the form of footpaths. The concept of shared streets is to ensure that each street user becomes more aware and considerate of the others on the street. The speeds are regulated below 15kmph through various traffic calming measures such as speed bumps and chicanes. Chicanes are angular deflections created in streets to break the linear travel movement. This can be created by strategically placing diversions in the form of bollards, planters, parking and other street elements as shown in figure 58.

Shared streets can be considered on narrow local residential streets (RoW > 9 m) where physical segregation through footpath may not be feasible. They can also be considered on crowded commercial streets, or in urban historic core. They are not meant to carry through traffic.

Figure 60: Shared street in Brighton, UK (Source: pps.org)

Figure 61: Chicane in Netherlands (Source: Street films)

6.13. Consistent carriageway width

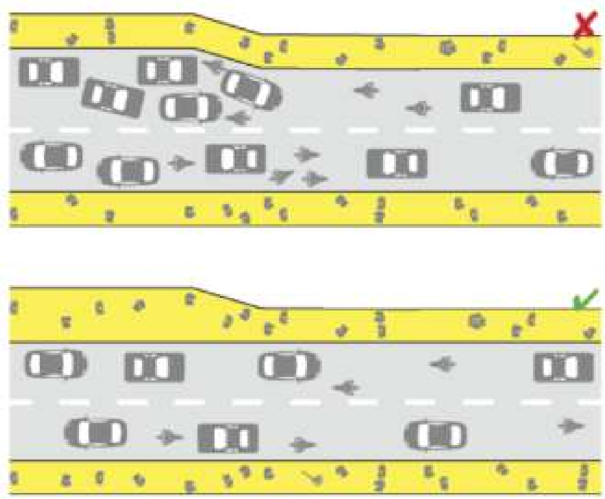


Figure 62: Consistent carriageway

Often urban streets in Indian cities have inconsistent right of way width. While designing such urban streets, it is important that the carriageway width be consistent throughout the length of the street as shown in figure 59 to avoid bottlenecks and ensure smooth traffic flow. Footpath widths should be increased in portions where a wider RoW width is available to maintain consistent carriageway.

7. Pedestrian facilities at intersection

Intersection design involves two important goals of efficient vehicle throughput and safety of pedestrians crossing the intersection. This can be achieved by compact intersection design. Compact intersections bring the stop line and pedestrian crossing as close as possible to the intersection. This improves the throughput of vehicles. This section briefly introduces the various elements that make intersection safer for pedestrians. It is illustrated in figure 60.

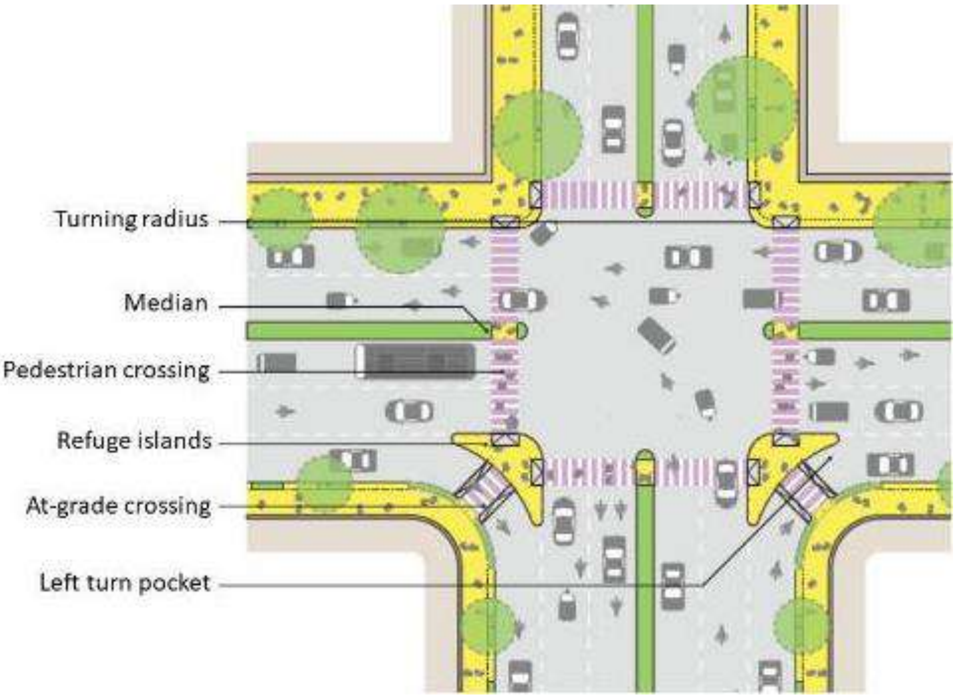


Figure 63: Safe intersection design

Turning radius

Small turning radius slows down vehicles while turning and increases pedestrian safety while crossing. Turning radii at intersections should be 4m on local and collector streets, and maximum 9m on arterial and sub-arterial streets. Figure 61 shows how a large vehicle will turn on the small turning radius by driving ahead in the farthest carriageway lane.

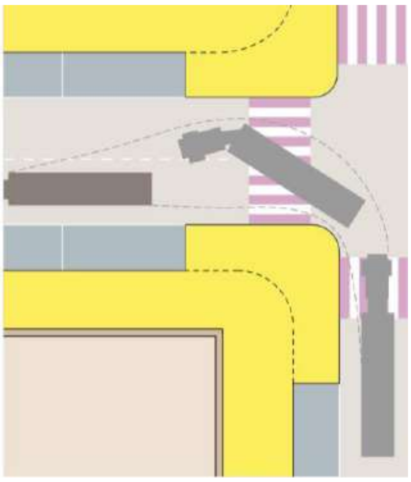


Figure 64: Large vehicle making a turn on small kerb radius, (Original source: globaldesigningcities.org)

Pedestrian crossings

Pedestrian crossings should be provided along pedestrian desired lines to prevent pedestrians from walking longer lengths. Pedestrian crossings should be provided as per section 6.6.1. Traffic calming measures should be provided before the unsignalized crossings to ensure pedestrian safety. Kerb ramps should be provided when crossings are not raised.

Pedestrian Refuge at Median

Pedestrian refuge at median provides intermediate resting point for pedestrians while crossing a divided carriageway. It breaks the pedestrian crossing length in small segments. Pedestrian refuge at median should be provided as per section 6.6.1. Shrub height on median should be restricted to 0.7m height from carriageway level to ensure visibility to pedestrians and vehicles.

Pedestrian Refuge Islands

Refuge islands provide easy crossing and safety to pedestrians at large intersections. It provides intermediate resting point for pedestrians while crossing a large intersection. It breaks the crossing length in small segments. The unused carriageway space at intersections should be converted to pedestrian refuge for safe crossing and efficient vehicle throughput. Refuge islands should be free of landscaping and fencing to ensure usability. Advertisements on pedestrian refuge islands should not impede the pedestrian movement and visibility. Refuge islands should be properly highlighted with the help of road markings, delineators, median markers or solar studs based on the site requirement. It should provide access to wheelchair.

Left turn pockets

At large intersections, often free or signalized left turns are provided to increase vehicle throughput. However, free left turns are not desired for safety of pedestrians and cyclists as it becomes difficult to cross due to high vehicular traffic. Left turn pockets should be avoided on intersections up to right of way of 30m. In case where they exist, vehicular speeds at left turn pockets should be reduced with the help of tabletop crossing and small turning radius as shown in figure 60.

Roundabouts

In unsignalized intersections, a roundabout can improve safety by consolidating intersection movements and reducing speeds. Roundabouts also simplify the conflict associated with right turns, which are a major cause of intersection crashes. In small intersections, the roundabout itself as well as the islands in the centre of the four street arms may be constructed with truck aprons that are surmountable by trucks and buses, but not by cars and two-wheelers. Such a design accommodates the larger turning radius of heavy vehicles while maintaining a smaller turning radius for other vehicles as shown in figure 61.

Figure 65: Intersection with roundabout, (Source: msa-ps.com)

8. Non-motorized transport only streets and Greenways

Many cities such as Gangtok and Amritsar have pedestrian-only streets as shown in figure 63. These are market streets and streets around transit zones with high pedestrian footfall. These streets are designed as vibrant public spaces with ample seating, landscaping, children play elements and other street furniture for people to enjoy. Access to emergency vehicles and loading/unloading of goods should be planned. Parking management[11] is crucial. All facilities should be universally accessible. Temporary street closures can be considered for on-street weekly markets, recreation and concerts. Local stakeholders such as shopkeepers, residents and traffic police should be involved during the planning and design process.

Figure 66: Pedestrian only street in Amritsar

Greenways are exclusive walking and cycling facilities along natural features such as water bodies, lakes and parks with a variety of public spaces and natural features. Motor vehicle traffic is prohibited on this network. It is recommended that greenways have a minimum clear width of minimum 8m to accommodate two-way movement of cyclists and pedestrians. The city of Coimbatore is developing a network of greenways around its lakes in the city.

9. Placemaking

Figure 67: Seating space on JM road footpath in Pune

Streets are not only meant to move, but also to pause and enjoy. Providing places to sit, play and socialize enhances the walking experience of a pedestrian. Placemaking makes streets a vibrant public place. Placemaking also improves the local retail business by attracting higher pedestrian footfall. It also makes a street active and lively, which improves the perception of security amongst women, elderly and children. Streets when designed as vibrant public spaces improves the physical and mental well-being of citizens.

10. Skywalks

Skywalks are grade-separated walking paths as shown in figure 65. They are built with the intention to provide quick and unhindered entry/exit to major buildings in high crowded zones such as railway stations, metro stations, malls, airport

[11] Parking management implies managing existing parking, instead of creating more parking. On-street parking supply is limited and priced as per demand. On-street parking is distributed and demarcated.

terminals and office complexes. However, it is important to note that skywalks are not a replacement to footpaths. Pedestrians will require footpaths to access shops and other buildings at street level. Skywalks, if planned well, can help in managing crowd in high crowded zones. Following points should be considered for planning and design of skywalks-

- Skywalks should not be a standalone facility, but integrated with building entry/exit at same level for seamless and convenient walking.
- Skywalk length and entry/exit points should be planned carefully to ensure pedestrians find it purposeful and convenient to use.
- Skywalks should be well-shaded with roof to provide protection from heat and rain.
- They should be well-lit and visually transparent to improve passive personal security. Patrolling should be done especially during late evening time.
- Lifts, escalators and tactile pavers should be provided for access to persons with disabilities and elderly.
- The sub-structure of an elevated skywalk should not hinder the pedestrian movement on footpath below.
- Seating may be provided along the skywalk corridor.
- They should be clean and well-maintained.

Figure 68: Skywalk, source: flickr.com

11. Pedestrian facilities around school zone

Infants, toddlers and children travel along with their caregivers to aanganwadis (pre-primary school) and schools. Many walk, cycle or take public transport to reach the above facilities. Children are one of the most vulnerable road users. Streets that are designed to prioritize the road safety of children, prove safe for all road users. Following guidelines should be considered to ensure children and their caregivers' safety-

Planning recommendations-

- It is recommended that the streets around schools should be traffic calmed to ensure vehicle speeds are below 20kmph. The city of Dublin in Ireland has a city-wide 30kmph zone plan which includes streets around schools and local streets in residential areas in the city. Street stretches 50m before and after the entry/exit gates should be traffic calmed.
- A dense street network should be available around schools to facilitate easy movement of crowd during peak school hours.
- Streets should provide wide footpaths and priority to bus movement.
- Streets should have protected cycle tracks if vehicle speeds are above 30kmph.
- On-street parking should be avoided 50m before and after the entry/exit gates.
- On-street and off-street cycle parking should be provided.

- It is recommended that the nearest bus-stop and IPT stand be available within 50m distance of entry/exit gate.

Pedestrian Facilities-

- Footpaths should be provided and designed as per section 6.1.
- Tabletop crossings should be provided in case of unsignalized crossing. If the institution is located on an arterial or sub-arterial street, signalized crossings should be provided. The width of the crossing should be atleast 4m to ensure comfortable crossing of high pedestrian volumes during school peak hours.
- The pedestrian signal time should be provided as per the walking speed of 0.5m/s.
- It is recommended to have guardrails near the school entry/exit gate to ensure children's safety.
- Seating and wastebins should be provided near schools.
- Children-friendly art installations and play elements may be provided on streets.
- Appropriate road signs and markings should be provided as per IRC:67 and IRC:35 respectively. Annexure 6 should be referred for signages.

Management-

- Traffic wardens should be deployed during peak hours to manage pedestrians and vehicular traffic. Traffic wardens to be equipped with necessary personnel protective equipment such as hand-held Stop signs and reflective jackets.
- On-street parking especially of school bus and vans should be managed to ensure smooth traffic flow and comfortable walking experience.
- On-street vending should be managed around schools.

12. Pedestrian facilities around transit stations

Transit stations include railway station, metro station, bus terminal and depot, bus rapid transit station and bus-stop. Transit stations see a high footfall of pedestrians entering and exiting the stations. Transit stations see a variety of modes such as autorickshaws, cycle system and bus system waiting to provide last-mile connectivity. Transit station should ensure multi-modal integration of different modes to facilitate seamless and fast transfers. Following recommendations to be followed for pedestrian facilities around transit stations -

Planning recommendations-

- Streets around 500m entry/exit of railway station, metro station, bus rapid transit station and bus terminal should prioritize walking, cycling and movement of other intermediate public transport such as autorickshaws and others.
- Streets around transit stations should be traffic calmed to 30 kmph.
- Pedestrian only streets or streets that only allow non-motorized transport and public transport may be considered. Temporary pedestrianization may also be considered.
- Dense street network should be provided to facilitate easy distribution of crowd.
- Bus-stop, cycle rental stations, cycle parking and public toilets should be provided within 50m walking distance of the entry/exit to the mass rapid transit station such as railway, metro and bus rapid transit station.
- IPT stands should be planned within 100m walking distance of the entry/exit to the station.
- Provision of way-finding maps of a 1km radius area around transit station should be provided.
- It is recommended to avoid on-street parking in the transit zone for smooth traffic flow.
- Off-street car parking facility in the transit station and zone should not be provided to discourage private vehicle use, and avoid traffic congestion.
- Any grade-separated pedestrian facilities like skywalk should be integrated with the station exit/exit points.

Pedestrian facilities-

- Wide footpaths should be provided as per high intense footfall zones in section 6.1.
- Frequent at-grade pedestrian crossings should be provided every 80-150m.
- Appropriate way-finding signages should be provided.

Management-

- Traffic wardens should be deployed at critical locations during peak hours to manage pedestrians and vehicular traffic.
- On-street parking and on-street vending should be managed to ensure smooth traffic flow and comfortable walking experience.
- Traffic circulation and traffic management plan (including freight) should be prepared.

13. Implementation and Maintenance

Poor execution reduces the usability of pedestrian facilities and increases the risk of safety while walking. It also increases the maintenance cost. Poor execution may be due to the use of low-grade materials, lack of adherence to design details, defective construction and lack of supervision.

Along with the right design standards, it is important to adopt high quality implementation standards. Good materials provide high usability of the design. When materials are not selected properly, the facility becomes unfit for use in a short time, either due to difficulty in maintenance or due to wear and tear. Materials used should be durable, easy to install, easy to maintain, slip resistant, resistant to vandalism and provide universal accessibility. Details on various materials is given in annexure 4. Coordination of all different government departments and utility agencies is important during implementation and maintenance. MoHUA's Complete Streets – Implementation Workbook should be further referred for guidelines on implementation.

Test on-site

It is recommended to first test the proposed design before making it permanent. Testing can be done through a 'tactical urbanism' method which involves using low-cost, temporary and easy to install materials. Testing helps to evaluate the performance and impact of the design on road users movement and safety. The learnings from testing can help modify the design before making it permanent. It is recommended to test the trial run for atleast 1-2 weeks at a stretch.

The proposed design is marked on the road using chalk, traffic cones, and other temporary objects. It is tested for functionality and safety. Necessary instructions, barricades and signages shall be put in accordance to inform the road users. During the process of testing, involve traffic police and other relevant local stakeholders such as residents, shop owners and others for their support and feedback. Image 66 shows the testing of an intersection design in Coimbatore.

Figure 69: Intersection trial in Coimbatore

14. Management and Enforcement

Often well-designed pedestrian infrastructure is encroached by parking, shop and residential extensions and street vendors. Sometimes, two-wheelers are seen riding on the footpath especially when the streets are congested. This reduces the usability, and harms the safety of pedestrians. Along with right street design and implementation, effective management and enforcement is needed. On-street parking, vending, utility and waste collection should be managed to ensure usability of the footpaths.

Strict enforcement is required to prevent encroachment, wrong-side driving and other nuisance that obstruct pedestrian movement. Any encroachment by adjoining shopkeepers or residential unit on footpath in the form of display, storage, security cabins, flower pots etc. should be avoided. On-street vendors should not be allowed to extend outside their dedicated vending space. The city Traffic Police Department, Urban Local Bodies, Shopkeepers' association, Residents' Welfare Association etc. can play an important role in safeguarding the functionality of public pedestrian facilities.

During implementation, city should have work zone management plan to ensure all road users can move and cross safely, and access private properties. Any digging work that happens for utility management should be well-levelled and finished.

15. Audits

Audits during the testing and final implementation helps to revise and rectify the design in a timely manner. Audits include evaluation of pedestrian infrastructure to know if they are walkable, universally accessible and safer for women and children. The findings from audits help to identify gaps and provide solutions to ensure its usability. This would provide clear data to the authorities on what factors need immediate attention and improvement. A detailed checklist for audit can be found in Appendix 1 of IRC:SP:117.

Calculating walkability score for pedestrian infrastructure

'Walk Score' is a qualitative method to evaluate the walking experience of pedestrians. It helps to give insights on the satisfaction level of pedestrians. A greater score implies that the pedestrian facility is safe and attractive to use. 'Walk Score' is derived against various attributes that impacts one's walking experience. The factors affecting Walk Score are provided below:

- Traffic volume: High traffic volume especially at residential and commercial areas results in noise, air, unsafe urban street conditions and affects the quality of life. This deters pedestrians to walk or spend time on streets.

- Traffic speed: Vehicles plying at high speeds makes walking unsafe.

- Shade: Availability of shade while walking and waiting at the bus stop makes walking comfortable.

- Police patrolling: Police patrolling enhances pedestrians' sense of security against crime or theft.

- Street lighting: Street lighting provides visibility to both pedestrians and motorists, and improves personal security of pedestrians against crimes.

- CCTV cameras: Installation of CCTV cameras along streets improves surveillance and helps to enhance the perception of security.

- Width: Wider footpaths provide pedestrians with sufficient space to move and enjoy the surroundings at their pace.

- Surface: Even, firm and anti-skid walking surface provides continuous movement to pedestrians and persons with physical disabilities.

- Obstacles: Footpaths that are unhindered due to obstructions (wrongly placed overhead utilities and street furniture in the walking zone) provide continuous movement to pedestrians.

- Encroachments: Footpaths that are free of encroachments (illegal parking, shop spillover, residential extension, unmanaged on-street vending) provide continuous walking experience.

- Continuity: Frequent up and downs while walking makes walking difficult for pedestrians and impossible for persons on wheelchairs and elderly.

- Cleanliness: Cleaner pedestrian facilities that are free from garbage and litter provides pleasant walking experience.

- Amenities: Availability of amenities such as toilets, drinking water provisions, etc. enhances the attractiveness of pedestrian environment.

- Facilities for disabled persons: Tactile pavements and ramps provide provides universal accessibility.

The perception of walk score factors produce different reactions in each pedestrian. The above information on factors was gathered through questionnaire surveys. Respondents were asked to state their level of satisfaction with all the above factors on a 5-point Likert scale ranging from one (strongly disagree) to five (strongly agree). For example, statements like "*There is so much traffic along the street where I work/live which makes it difficult to walk*" is used for assessing pedestrian satisfaction on the factor "Traffic speed".

Factors are categorized under safety, security, movement and comfort.

Grouping of attributes

Latent Variables	Attributes	
Safety	x_1	Traffic volume
	x_2	Traffic speed
Security	x_3	Police patrolling
	x_4	Street lighting
	x_5	CCTV Cameras
Movement	x_6	Width
	x_7	Continuity
	x_8	Encroachments
	x_9	Surface
	x_{10}	Amenities
	x_{11}	Shade
Comfort	x_{12}	Cleanliness
	x_{13}	Facilities for disabled persons
	x_{14}	Obstructions

Following methodology is followed to calculate walk score (Bivina & Parida, 2019) -

The pedestrian attributes level of service indicator has been calculated from the model results on the basis of weights estimated for latent variables. The values assigned to each latent variable were obtained by using the estimated weights for each observed indicator and the corresponding average satisfaction rate expressed by pedestrians, as explained by equations 1 to 5.

Accordingly, Walk Score is calculated as per the following steps.

1- Walk score = 0.50 walk (safety) + 0.60 walk (security) + 0.39 walk (movement) + 0.52 walk (comfort)

2- Walk (safety) = 0.841 x_1 + 0.842 x_2

3- Walk (security) = 0.793 x_3 + 0.531 x_4 + 0.481 x_5

4- Walk (movement) = 0.699 x_6 + 0.635 x_7 + 0.528 x_8 + 0.760 x_9 + 0.514 x_{10} + 0.577 x_{11}

5- Walk (comfort) = 0.850 x_{12} + 0.460 x_{13} + 0.651 x_{14}

where, x_1 = traffic volume, x_2 = traffic speed, x_3 =, police patrolling, x_4 = street lighting, x_5 = CCTV, x_6 = width, x_7= surface, x_8 = continuity, x_9 = pedestrian amenities, x_{10} = encroachments, x_{11} = shade, x_{12} = cleanliness, x_{13} = obstructions, x_{14} = facilities for persons with disability.

6- Walk Score $_{max}$ = Maximum possible Walk Score
(if average satisfaction ratings for all the factors scoring the maximum scores)

Converting in the scale of walkability types from A to F (1 To 6)

7- Walk Score index = (Walk Score / Walk Score $_{max}$) * 6

Walkability Type	Index Values
A	>4.5
B	<4.5-4.2
C	<4.2-3.8
D	<3.8-3.5
E	<3.5-3.1
F	<3.1

An illustration to calculate Walk Score is given in annexure 5

Annexure

Annexure 1 - Pedestrian walking speeds

User group	Speed (meters/second)
Adult men (as per Indian Highway Capacity Manual (INDO-HCM), 2017)	1.3
Adult women (as per INDO HCM, 2017)	1.1
Persons with assistance in form of canes, walkers, crutches (as per NACTO's Global Street Design Guide)	0.3-0.5
Person on wheelchair (as per NACTO's Global Street Design Guide)	1.4
Caregiver with an infant (0-2 years) on stroller/pram (as per MoHUA's Infant, Toddler, Caregiver friendly neighborhood design guidelines, 2019, adopted by Smart Cities Mission)	0.5-0.6
Caregiver with a toddler (2-3 years) holding hands (as per MoHUA's Infant, Toddler, Caregiver friendly neighborhood design guidelines, 2019, adopted by Smart Cities Mission)	0.3-0.5
Caregiver with a toddler (3-5 years) not holding hands (as per MoHUA's Infant, Toddler, Caregiver friendly neighborhood design guidelines, 2019, adopted by Smart Cities Mission)	0.25-0.3

Annexure 2 – Nomographs for planning pedestrian crossing

The nomographs depicting the relationships between pedestrian flow, vehicular flow, vehicle speed and pedestrian psychological gap size are given below (Jain & Rastogi, 2018). These can be used to decide a type of crossing facility which shall be provided at a location. The procedure to be adopted is outlined in the nomograph itself. These are given for a 2-lane undivided carriageway, 4-lane and 6-lane divided carriageways.

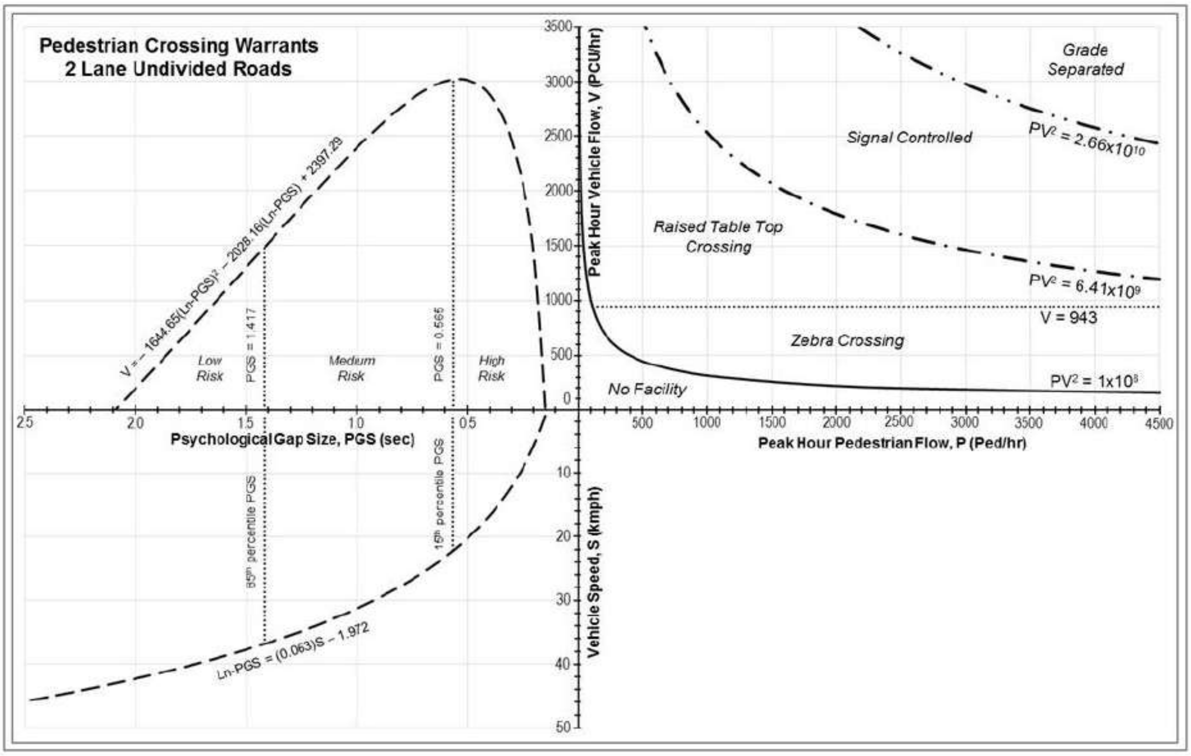
Crossing facility**	**PV^2 value ranges***		
	2-lane undivided	**4-lane divided**	**6-lane divided**
No facility	< 1.00×10^8	< 2.00×10^8	< 2.00×10^8
Zebra crossing	$1.00 \times 10^8 - 6.41 \times 10^9$	$2.00 \times 10^8 - 1.14 \times 10^{10}$	$2.00 \times 10^8 - 2.78 \times 10^{10}$
Signalized crossing	$6.41 \times 10^9 - 2.66 \times 10^{10}$	$1.14 \times 10^{10} - 4.92 \times 10^{10}$	$2.78 \times 10^{10} - 1.17 \times 10^{11}$
Grade separated crossing	> 2.66×10^{10}	> 4.92×10^{10}	> 1.17×10^{11}
*Where 'P' is the peak hour pedestrian flow & 'V' is the peak hour vehicle flow of both directions for 2 lane undivided roads and of one direction for 4 lane and 6 lane divided roads. Pedestrian flow is defined as the number of pedestrians passing a given point per unit time expressed as pedestrians			

per hour or pedestrian per minute or pedestrians per 15 minutes. Vehicle flow is defined as the total number of vehicles that pass over a given point of a street in a given interval of time. It is expressed as PCU per hour.

**It is recommended that the design specifications of these facilities should be as per section 6.6

Pedestrian crossing warrants for 2-lane undivided roads

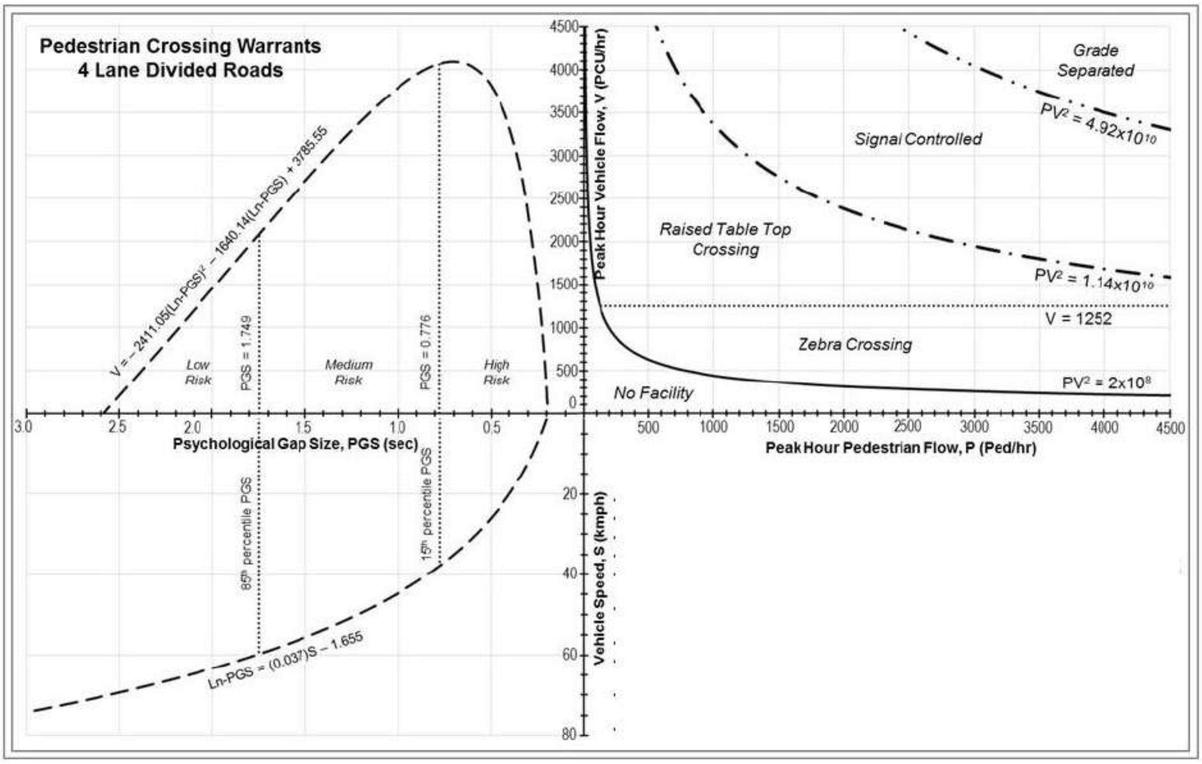
- Calculate vehicle flow 'V' in both directions for 2 lane roads and in one direction for all other roads.
- Calculate peak hour pedestrian flow 'P' for both directions of pedestrian crossing movements.
- Use V v/s P graph to identify the appropriate pedestrian crossing facility for the location.
- V=943 represents pedestrian delay of 45 sec beyond which zebra crossing should not be provided.
- Signal controlled crossing may be upgraded to grade separated crossings before $PV^2 = 2.66X10^{10}$ if the signal reaches capacity after regulating the cycle time.
- Calculate PGS using either vehicle flow or vehicle speed.
- If PGS > 1.417. pedestrians are at low risk of being in a road accident and no intervention is needed.
- If 1.417 > PGS > 0.565, pedestrians are at medium risk, in this case, provide appropriate crossing facility using V v/s P graph.
- If PGS < 0.565, pedestrians are at high risk. In this case, the location should be upgraded to signal controlled or grade separated, irrespective of the pedestrian and vehicle flows on site.



Pedestrian crossing warrants for 4-lane divided roads

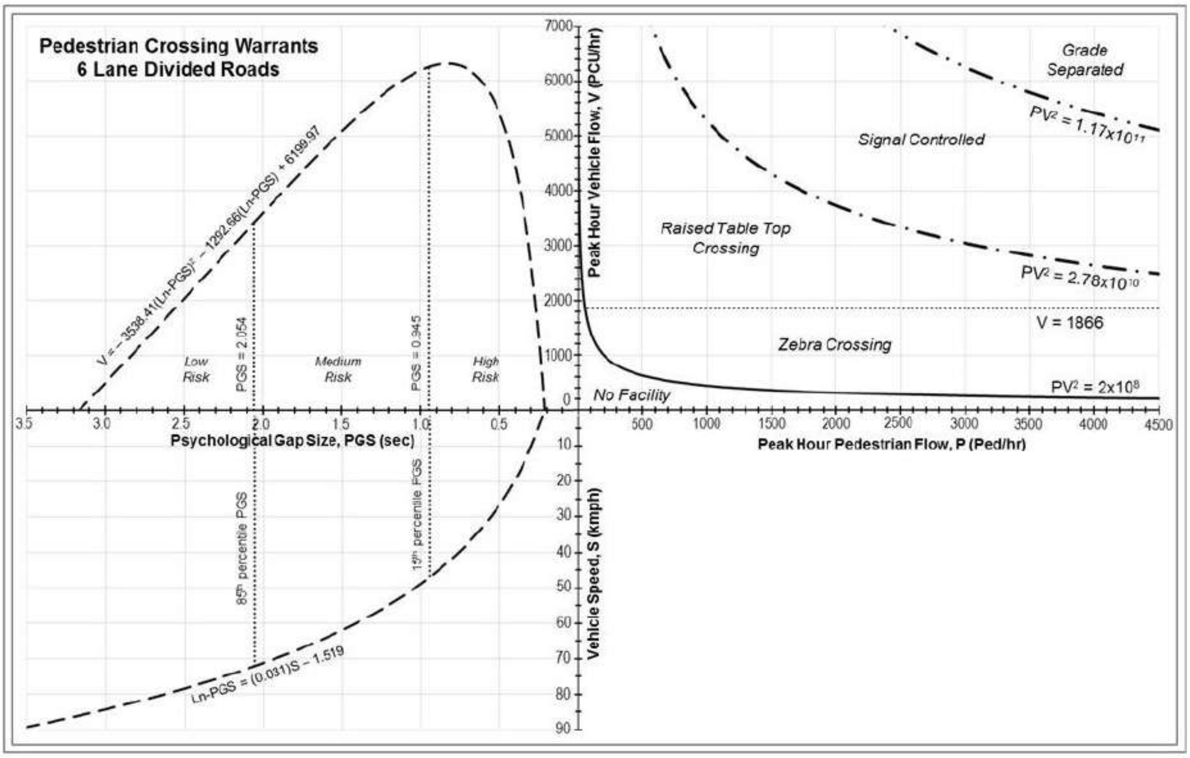
- Calculate vehicle flow 'V' in both directions for 2 lane roads and in one direction for all other roads.
- Calculate peak hour pedestrian flow 'P' for both directions of pedestrian crossing movements.
- Use V v/s P graph to identify the appropriate pedestrian crossing facility for the location.

- V=1252 represents pedestrian delay of 45 sec beyond which zebra crossing should not be provided.
- Signal controlled crossing may be upgraded to grade separated crossings before $PV^2 = 4.92X10^{10}$ if the signal reaches capacity after regulating the cycle time.
- Calculate PGS using either vehicle flow or vehicle speed.
- If PGS > 1.749. pedestrians are at low risk of being in a road accident and no intervention is needed.
- If 1.749 > PGS > 0.776, pedestrians are at medium risk. In this case, provide appropriate crossing facility using V v/s P graph.
- If PGS < 0.776, pedestrians are at high risk. In this case, the location should be upgraded to signal controlled or grade separated, irrespective of the pedestrian and vehicle flows on site.



Pedestrian crossing warrants for 6-lane divided roads

- Calculate vehicle flow 'V' in both directions for 2 lane roads and in one direction for all other roads.
- Calculate peak hour pedestrian flow 'P' for both directions of pedestrian crossing movements.
- Use V v/s P graph to identify the appropriate pedestrian crossing facility for the location.
- V=1866 represents pedestrian delay of 45 sec beyond which zebra crossing should not be provided.
- Signal controlled crossing may be upgraded to grade separated crossings before $PV^2 = 1.17X10^{11}$ if the signal reaches capacity after regulating the cycle time.
- Calculate PGS using either vehicle flow or vehicle speed.
- If PGS > 2.054. pedestrians are at low risk of being in a road accident and no intervention is needed.
- If 2.054 > PGS > 0.945, pedestrians are at medium risk. In this case, provide appropriate crossing facility using V v/s P graph.
- If PGS < 0.945, pedestrians are at high risk. In this case, the location should be upgraded to signal controlled or grade separated, irrespective of the pedestrian and vehicle flows on site.



Annexure 3 – Guidelines for safe and accessible grade-separated crossings

Foot-over bridges

Following guidelines should be considered -

- Tread and riser of the staircase should be 0.3 m wide and 0.15 m high respectively. The riser should not be open.
- The clear walking zone width of the staircase should be minimum 2 m.
- There should be no more than 12 risers in one flight run.
- Handrails should be circular in section with a diameter of 38-45mm. It should have a firm grip. It should be positioned at two levels – 0.76 m and 0.9 m above the pitch line of a flight of stairs.
- Along with escalators, elevator should be provided for wheelchair access. Minimum size of elevator should be 1.4 x 1.4 m to accommodate person on wheelchair.
- A ramp along the staircase should be provided for cycle access.
- Tactile pavers should be provided 0.3 m at the beginning and at the end of the stairs.
- All steps should be fitted with a permanent colour and tone contrasting at the step edge for the visually impaired persons. It should extend the full width of the step, reaching a minimum depth of 50mm on both tread and riser.
- The facility should be well-covered including the stairs.
- It should be well lit with illumination levels between 100-150 lux.
- The foot-over bridge should not be covered entirely with advertisement panels to ensure visual connectivity.

Subways

It is recommended to avoid subways keeping in mind the issues of personal security especially for women, children and elderly. However, if provided, following guidelines may be followed-

- The subway clear width should be 4.8 m and vertical clear height of 2.75 m should be provided. 50 lux of lighting is required.
- Small shops should be encouraged to increase passive safety.

- Subway with over 40 m length should be provided with mechanical ventilation. Natural lighting and ventilation through skylights may be provided.

Annexure 4 - Material details

PCC Stamped Concrete

Pros

- Variety of stencils available
- Monolithic surface; does not start dismantling like pavers
- Uniform finish
- Easy to clean and maintain

Cons

- Stamping too deep may disrupt wheelchair movement
- Expansion joints should be provided to prevent cracking
- Has to be demolished in case of future repairs of underground utilities
- Need additional care during curing to avoid paw-prints

Figure 70: PCC stamped concrete at D.P Road, Pune

Application

It can be applied on footpaths, plazas; intricate stencils not recommended for cycle track. Colour pigment can be added to the concrete to differentiate between functions.

PCC Broomed Finish

Pros

- Relatively quick to install
- Grooves provide sufficient grip
- Cheaper than other PCC finishes
- Monolithic surface; does not start dismantling like pavers
- Uniform finish

Cons

- Finish has to be even to avoid poor cycling experience
- Has to be demolished in case of future repairs of underground utilities
- Need additional care during curing to avoid paw-prints

Image 71: PCC broomed finish at J.M Road, Pune

Application

It can be applied on footpaths, cycle tracks, parking bays, and carriageways. Colour pigment can be added to the concrete to differentiate between functions. They are preferred over all other surface finishes.

Rubberised floor finish for play area on footpath

Pros

- Rubber surface helps in impact absorption
- Reduces the risk of permanent injury by cushioning the fall
- Highly durable, less prone to weathering
- Offers permeability

Cons

- Comparatively expensive
- Prone to staining

Application

It is suitable for play areas for children.

Figure 72: Rubberised flooring at J.M Road, Pune

Stone blocks

Pros

- Highly durable, less prone to weathering; 0.08 m thick stone blocks can be used for bearing vehicular load as well
- Can be laid in variety of design patterns
- Easy to dismantle for future repairs

Cons

- Expensive; heavy to transport
- Results in uneven surface and sinking if sub-base is not prepared with care
- Prone to dismantling if kerbs are not installed properly

Figure 73: Stone block paving in Calicut

Application

It is suitable on carriageways for slowing traffic, landscaped zones, shared streets, at entries for gates and ramps; not suitable for footpath due to its highly undulated surface.

Stone slabs/tiles

Pros

- Thicker slabs are durable; less prone to weathering
- Can also be used as cladding for seating to compliment the pavement finish

Cons

- Expensive and heavy
- Thinner slabs prone to breakage if mishandled or dropped
- Labour-intensive to install
- Slippery during rains if polished
- Results in uneven surface and sinking if sub-base is not prepared with care

Figure 74: Stone slab tiles on Harrington road footpath, Chennai

Application

It is generally applied in selected projects; not recommended on cycle tracks and heavy load-bearing areas. The stone is sand blasted or leather finished stone for footpath surface.

Concrete blocks

Pros

- Variety of sizes, colours, and patterns available
- Cost-effective
- Easier to install than stone slabs
- Anti-skid due to rough surface

Cons

- Results in uneven surface and sinking if the base is not prepared with care
- Un-chamfered edges may lead to chipping of blocks
- May become pigmented and slippery due to growth of moss on constant exposure to water

Figure 75: Concrete blocks used in J.M road footpath, Pune

Application

It is applied on footpaths, parking bays, and carriageways to control speed; not recommended on cycle tracks. Porous concrete blocks are also available which help in water percolation which are recommended in parking bays. It requires regular cleaning to avoid blockage due to dust and oil.

Cement tiles

Pros

- Cost-effective
- Lighter than stone tiles, stone/concrete pavers
- Available in different textures, colours, designs, patterns, and shapes

Cons

- Prone to breakage if mishandled or dropped
- More labour-intensive to install than PCC finish
- Slippery during rains if without anti-skid studs
- Results in uneven surface and sinking if the base is not prepared with care
- Prone to dismantling

Figure 76: Cement tiles on a footpath in Chennai

Application

On footpaths, especially tactile flooring; not recommended on parking bays and cycle tracks.

Interlocking tiles / Paver blocks

Pros

- Variety of sizes, colours, and patterns available
- Cost-effective
- Easy to install and replace
- Anti-skid due to rough surface

Cons

- Results in uneven surface and sinking if the base is not prepared with care
- More labour-intensive to install than PCC finish
- Prone to dismantling
- May become pigmented and slippery due to growth of moss on constant exposure to water

Figure 77: Interlocking tiles used in footpath in Chennai

Application

It is applied on footpaths and parking bays; not recommended on cycle tracks. They are not recommended on footpaths as they often come out if not implemented properly, and makes it difficult to walk.

RCC Bollards

Pros

- Cost-effective
- Can be cast in different shapes as per design

Cons

- Tends to chip off with time Two white color,

Figure 78: R.C.C bollards with reflector strips

Retro reflector strips with width 100mm of Type IV grade, flexible reboundable sheeting that meets the required parameter as per ASTM D 4956 Clause S2 should be provided on bollards. M 40 grade concrete mix is recommended.

Galvanised Iron Bollards

Pros

- Can be fabricated in different shapes as per design

Cons

- More expensive than RCC bollards

Image 79: GI bollards used at J.M road, Pune

Stainless Steel Bollards

Figure 80: Stainless steel bollards

Pros

- Lighter and easier to handle

Cons

- Limited in shape - generally available only as pipes.

Stone seating

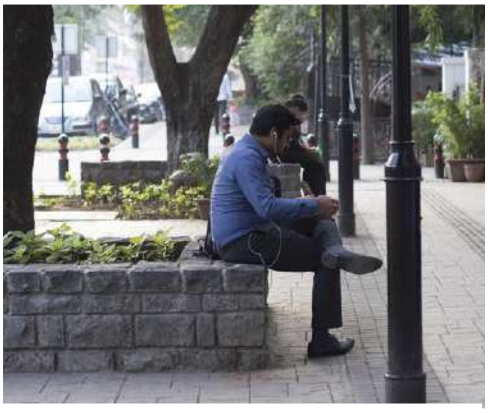


Figure 81: Stone seating at D.P road, Pune

Pros

- Highly durable, less prone to weathering
- Does not chip away easily

Cons

- Expensive
- Labour-intensive to install

Precast Concrete seating

Image 82: Precast concrete seating at J.M road, Pune

Pros

- Cost-effective
- Can be cast in different shapes as per design
- Pigmented concrete mixture results in homogenity, as opposed to painted seats

Cons

- Tends to chip off with time
- If painted, colour chips off with time

Metal Bench

Pros

• Can be fabricated with varying degrees of ornamentation- highly suited for traditional design themes
• Durable
• Less prone to weathering

Cons

• Becomes easily hot or cold depending on outside temperature, making it uncomfortable to use
• Hard and not comfortable to use for long - preferred to avoid squatters
• Prone to vandalism

Figure 83: Metal bench

Fibre Reinforced Plastic

Pros

• Can be cast in different shapes as per design
• Pigment added to FRP mixture results in homogenity, as opposed to painted seats
• Can be made translucent, providing for embedded lighting options
• Durable, being plastic in nature

Cons

• Expensive
• Relatively difficult to source, owing to fewer FRP vendors dealing with seating

Figure 84: Fibre reinforced plastic bench

Annexure 5 – To evaluate qualitative level of service for pedestrian infrastructure (Walk Score)

Problem Statement: Footpath width of 2 m in a commercial area is to be redesigned and improved based on pedestrian needs and satisfaction on various qualitative footpath characteristics. Pedestrian movements are restricted by the on-street parking that also invades into the footpath. The street configuration is such that it does not allow good vigilance by police and other pedestrians, also, absence of street lights at many areas making the area highly prone to threats for pedestrians. At some places, footpaths are neither segregated nor raised from the road level. Estimate the walk score of the footpath.

Step 1: A field assessment is done by transport planner. Satisfaction ratings (1 = Strongly Disagree to 5 = Strongly Agree) for each of the qualitative footpath characteristics are collected using questionnaire surveys from pedestrians. Average pedestrian satisfaction ratings for attributes from the questionnaire are provided in table below.

Factor Notation	Factors	Average Satisfaction Ratings
x_1	Traffic volume	3
x_2	Traffic speed	4

x_3	Police patrolling	3
x_4	Street lighting	3
x_5	CCTV cameras	2
x_6	Width	3
x_7	Continuity	3
x_8	Encroachments	3
x_9	Surface	3
x_{10}	Amenities	3
x_{11}	Shade	3
x_{12}	Cleanliness	3
x_{13}	Facilities for disabled persons	3
x_{14}	Obstructions	3

Step 2: Calculate constructs identified from the study such as safety, security, comfort and movement by substituting corresponding values of footpath factors in the following equations:

$\xi_{1\ safety} = 0.841\ x_1 + 0.842x_2$

$\xi_{2\ security} = 0.793x_3 + 0.531x_4 + 0.481x_5$

$\xi_{3\ movement} = 0.699x_6 + 0.635x_7 + 0.528x_8 + 0.760x_9 + 0.514x_{10} + 0.577x_{11}$

$\xi_{4\ comfort} = 0.850x_{12} + 0.460x_{13} + 0.651x_{14}$

Obtained values for constructs are provided in the following table:

Safety	Security	Movement	Comfort
5.891	4.934	11.139	5.883

Step 3: Substituting the above values of constructs for PLOS in calculation using the following equation.

$\eta = 0.50\xi_1 + 0.60\xi_2 + 0.39\xi_3 + 0.52\xi_4$

$\eta = 0.50 \times 5.891 + 0.60 \times 4.934 + 0.39 \times 11.139 + 0.52 \times 5.883$

$\eta = 13.309$

Maximum score of PLOS (if average satisfaction ratings of all factors =5)

$\eta_{max} = 21.961$

Step 4: Converting in the scale of PLOS index range from A to F (1 To 6)

$$\eta_{index} = \frac{13.309}{21.961} * 6 = 3.63$$

The walk score came out to be 3.63, which is at LOS D from the table as shown below.

Level of Service	Index Values
LOS A	>4.5
LOS B	<4.5-4.2
LOS C	<4.2-3.8
LOS D	**<3.8-3.5**
LOS E	<3.5-3.1
LOS F	<3.1

Problem Statement: Footpath stretch of width 2.5 m with good pedestrian infrastructure except for some part of the stretch where pedestrian movement is affected by encroachment. Pedestrians' security is highly ensured by police & presence of CCTV cameras. Street lighting and clear line of sight with low concealment that reduces the risks of criminal activities. Vehicles ply with a high-speed threating pedestrian as there is no guard rails or buffer between footpath and road stretch. Also, pedestrian amenities such as toilets, drinking water facilities, etc. and facilities for persons with physical disability such as ramps, tactile tiles, etc. are not provided. The possible improvement measures need to be suggested by analyzing walkability score of the footpath.

Answer

Step 1: A field assessment is done by transport planner. Satisfaction ratings (1 = Strongly Disagree to 5 = Strongly Agree) for each of the qualitative sidewalk characteristics are collected using questionnaire surveys from pedestrians. Average pedestrian satisfaction ratings for attributes from the questionnaire are provided in table below.

Factor Notation	Factors	Average Satisfaction Ratings
x1	Traffic volume	3
x2	Traffic speed	2
x3	Police patrolling	4
x4	Street lighting	4
x5	CCTV cameras	4
x6	Width	5
x7	Continuity	4
x8	Encroachments	3
x9	Surface	4
x10	Amenities	3
x11	Shade	3
x12	Cleanliness	4
x13	Facilities for disabled persons	2
x14	Obstructions	3

Step 2: Calculate score for each construct identified from the study such as safety, security, comfort and movement by substituting corresponding values of footpath factors in the following equations:

$$\xi_{1\,safety} = 0.841\,x_1 + 0.842x_2$$

$$\xi_{2\,security} = 0.793x_3 + 0.531x_4 + 0.481x_5$$

$$\xi_{3\,movement} = 0.699x_6 + 0.635x_7 + 0.528x_8 + 0.760x_9 + 0.514x_{10} + 0.577x_{11}$$

$$\xi_{4\,comfort} = 0.850x_{12} + 0.460x_{13} + 0.651x_{14}$$

Obtained values for constructs are provided in the following table:

Safety	Security	Mobility& Infrastructure	Comfort & Convenience
4.207	7.22	13.932	6.273

Step 3: Substituting the above values of constructs for PLOS is calculation using the following equation.

$$\eta = 0.50\xi_1 + 0.60\xi_2 + 0.39\xi_3 + 0.52\xi_4$$

$$\eta = 0.50 \times 4.207 + 0.60 \times 7.220 + 0.39 \times 13.932 + 0.52 \times 6.273$$

$$\eta = 15.130$$

Maximum score of PLOS (if average satisfaction ratings of all factors =5)

$$\eta_{max} = 21.961$$

Step 4: Converting in the scale of Walk Score index range from A to F (1 To 6)

$$\eta_{index} = \frac{15.130}{21.961} * 6 = 4.13$$

The Walk score came out to be 4.13, which is LOS C from the table as shown below.

Level of Service	**Index Values**
LOS A	>4.5
LOS B	<4.5-4.2
LOS C	<4.2-3.8
LOS D	**<3.8-3.5**
LOS E	<3.5-3.1
LOS F	<3.1

Improvement 1: Reducing traffic speed limits by strict enforcement and adopting traffic calming measures would improve pedestrians' perception on safety factor. Speed humps and rumble strips should be provided on road stretch. Road markings, signage and lighting are mandatory within areas of.

Improvement 2: Pedestrian amenities in the form of toilets, drinking water facilities, benches, etc. need to be provided along the footpath. These improvement measures would improve pedestrians' perception score on comfort construct which would ultimately improve the walk score.

Annexure 6 – Signages and Markings

All the sign boards (except indoor exit signs) shall be retro reflective with type XI retro reflective sheeting as per IRC 67-2012 and ASTM D 4956-19 standards which performs better in both short and medium distance. To differentiate vulnerable areas like school zones and pedestrian crossing which need utmost attention even during daytime special style of signs of given design (Figure 82 & 83) with fluorescent yellow green type XI retro reflective materials to be used. Typical design of signs is shown below.

Figure 85: School ahead signage

Figure 86: Pedestrian crossing ahead

Figure 87: No free left signage

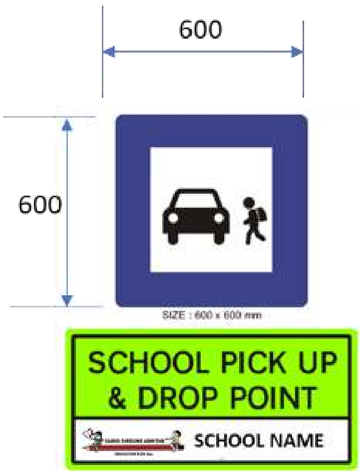


Figure 88: Pick-up and drop point signage in school zone

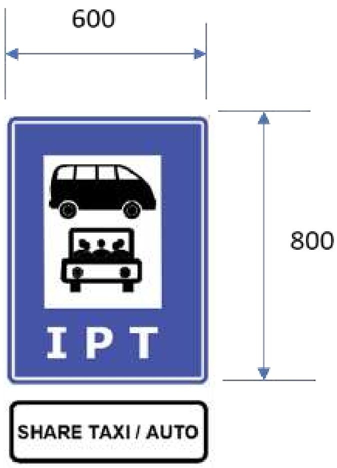


Figure 89: Informal public transport stop signage

Figure 90: Tow away zone signage

IRC:SP:55 should be followed for all the signages during construction.

Pavement Marking

All the pavement marking shall be as per IRC 35 standards. For symbols and legends/arrows preformed adhesive tapes shall be used. Transverse bar marking to be provided as per IRC:99 with the inclusion of road studs to have a better visibility and rumbling effect.

Delineators

All the delineators, median markers and object markers shall be as per IRC:79.

LED Type Smart VMS (Variable Message Signboard) for realtime passenger information system

Real time information intelligent variable message sign should be placed atleast at a height of 3.5 m with a size of minimum 0.95 m x 1.9 m. These Intelligent VMS boards shall be with full color (RGB) DIP LED boards with 10mm pitch and have CE, FCC, CB, RoHS, EN12966 (Display Parameters) certifications. These Intelligent VMS boards shall have the facility to switch to low power mode screens in case of mains power failure. Maximum power consumption per cabinets should not exceed 400W/sq meter. These screens should be monitored remotely for pixel level failure detection via a dashboard at the control room and generate real time information of traffic data i.e. journey time, congestion data live weather and air quality information automatically using a thin client windows embedded system. The solution should have capability to be integrated with 3rd party applications to display real time bus arrival schedules and estimated journey time for nearest buses. The solution should also provide mobile application for disaster management and emergency messages. This solution should support 128-bit encryption along with dongle-based access control to ensure secure access and communications with server.

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