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Bus Rapid Transit
Planning Guide
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Part IV – Integration

CHAPTER 13

Modal integration

CHAPTER 14

TDM and land-use integration

13. Modal integration

"At first it may appear that pedestrian space is a frivolous issue in a developing country; but the privations of low income people are not really felt during working hours—it is during leisure hours that the differences are felt. While higher income people have cars, clubs, country houses, theatres, restaurants and vacations, for the poor, public space is the only alternative to television. Parks, plazas, pedestrian streets and sidewalks are essential for social justice. High quality sidewalks are the most basic element of respect for human dignity, and of consideration for society's vulnerable members such as the poor, the elderly and children."

—Enrique Peñalosa, former Mayor of Bogotá

BRT systems should not be designed and implemented in isolation. BRT systems work best when they are part of an integrated network of transport options that allow safe and convenient access to all parts of the city. Even private motorists have to walk to their cars, and therefore are pedestrians for part of their trip. The best BRT systems provide a seamless set of linkages from the doorstep of the home to the door of the office or shop, using many other transport modes for parts of the trip. By maximising the BRT system's interface with other options, system designers are helping to optimise the potential customer base. The BRT system does not end at the entry or exit door of the station, but rather encompasses the entire client capture area. If customers cannot reach a station comfortably and safely, then they will cease to be customers.

The contents of this chapter include:

13.1 Corridor integration

"The one thing we need to do to solve our transportation problems is to stop thinking that there is one thing we can do to solve our transportation problems."

—Robert Liberty, 1000 Friends of Oregon

Before a public transport system can consider integration with other transport modes, a basic first step is to ensure that the system is integrated with itself. System integration of this type refers to ensuring that physical and fare integration exists between the different corridors, routes, and feeder services. Unfortunately, many busway systems fail this simple test of integration. In many lesser BRT systems such as Kunming, Porto Alegre, Recife, and Taipei, there is no free transfer between the different bus lines sharing a BRT corridor. In Quito, the three major BRT corridors share corridor space at several different junctions (Figure 13.1). However, the three corridors do not even share common stations. A customer wishing to transfer from one corridor to another must physically endure a difficult walk between different stations and then must pay again for entering the new corridor.

Systems operating as individual corridors are forgoing the many synergies from forming a full integrated network. Since customer mobility needs are likely to include destinations on several corridors, the system is sacrificing a portion of its potential customer base. Rather than endure several different transfers each involving an additional payment, customers will likely seek alternative means of transport.

As noted previously in Chapter 7 (*Network and service design*), cities often choose open, non-integrated systems for political expediency.

Fig. 13.1
In Quito, the "Trolé" line shares the same roadway as the "Ecovía" line, but the passengers can not transfer between the two without walking to separate stations and paying another fare.
Photo by Lloyd Wright

Rather than potentially upset the existing transport cartels, political figures will choose a system structure that does not entail any great operational changes for the fleet owners. In such instances, the city is essentially serving the desires of a few private operators over the needs of the customers. As has been stressed throughout this guidebook, basing public transport design around the customer almost always guarantees success. Basing public transport design around a few special interests almost always results in a compromised system. Integration begins with a focus on a system's internal routes and corridors. An internally integrated system can then expand its reach and customer base considerably by permitting other modes to form a seamless interconnection with the BRT system.

13.2 Pedestrians

"Traveler, there is no path. Paths are made by walking."

—Antonio Machado, Spanish poet, 1875–1939

A key component of BRT station planning and design is the provision of safe, convenient and secure access for pedestrians. If it is not convenient or easy to walk to a BRT station, then customers will be discouraged from using the system. Providing a Safe Route To Transit is therefore a basic step to providing an effective BRT service.

While station locations vary by the origin-destination patterns to be served and local context, fundamental pedestrian factors remain constant. To evaluate the quality of pedestrian access to public transport, an evaluation framework has been devised (Table 13.1). Specifically, effective public transport access is achieved with infrastructure that is affordable, attractive, comfortable, direct, legible, safe, and secure. If any one of these elements is not adequately

Table 13.1: Evaluation framework for public transport access

Category	Description
Accessibility	"Accessibility" refers to the viability of individuals with physical disabilities in using the system and reaching destinations.
Affordability	The "affordability" of providing public transport access is greatly affected by the need for pedestrian bridges, underpasses, and other significant infrastructure.
Aesthetics	The "aesthetics" of the pedestrian access area encompasses the attractiveness of the walkway, the street furniture, and the congruence between street design and local architecture.
Directness and connectivity	"Directness" involves a pedestrian path that minimises the distance travelled to access the public transport station. "Connectivity" refers to the ability of pedestrians to readily access a broader network of destinations.
Ease of access	"Ease of access" refers to the pedestrian's comfort level in walking along a corridor; this issue encompasses steepness of inclines, weather protection, condition of the walking surface, and protection from noise and air pollution.
Legibility	The "legibility" of an area refers to the ease in understanding the street environment. The availability of maps and signage can help legibility.
Safety	A "safe" pedestrian pathway implies that pedestrians are well protected from road hazards such as vehicles.
Security	"Security" refers to providing an environment where pedestrians are not susceptible to robberies or other crimes.

Fig. 13.2
The quality of access around and within stations greatly determines whether the system is used by the public.
Photo by Lloyd Wright

addressed, then the entire viability of public transport access can be undermined.

These qualities are not necessarily always mutually compatible. For example, the most direct path may involve conflicts with vehicles, or the safest route may imply using a difficult set of stairs. The design challenge is to prioritise competing interests while balancing the outcome.

Pedestrian access to public transport stations involves considering ease of movement at three critical points: 1. From the neighbourhood area to the corridor; 2. Crossing the corridor to access the station; and, 3. Movement within the station area (Figure 13.2). An effective pedestrian access plan will address each one of these trip segments in accessing the system. Ignoring just one of these pedestrian trip components can mean that the system is effectively non-accessible for a percentage of the customer base.

A well-designed pedestrian access plan will provide a natural flow of walking customers from the surrounding area. System planners should ask a few basic questions regarding the quality of pedestrian access. Are the pedestrian walkways leading to the station well maintained? Are they sufficiently broad to comfortably handle the expected pedestrian traffic? Are they safe and well lit? Is there adequate signage to lead individuals easily to the stations? Are there logical pedestrian connections between major origins and destinations such as shops, schools and work places?

13.2.1 Pre-existing pedestrian conditions in developing-nation cities

"Any town that doesn't have sidewalks doesn't love its children."

—Margaret Mead, anthropologist, 1901–1978

Public transport ridership in developing nations is frequently compromised by a general lack of acceptable pedestrian facilities. Pedestrians typically run a gauntlet of challenges that directly contribute to the high injury and fatality rates witnessed in these countries. These challenges include the following:

- Complete lack of pedestrian pavements;
- Poor quality of pavements, often dirt or mud;
- No physical separation from high levels of traffic and from high-speed traffic;
- Extreme levels of noise and air pollution;
- Intersection designs aimed at facilitating high vehicular turning speeds at the expense of safe pedestrian crossing;

Fig. 13.3
Communities like Alexandra in Johannesburg (South Africa) often lack proper pededestrian infrastructure.
Photo by Lloyd Wright

Fig. 13.4
The lack of formal pedestrian crossings in Dhaka (Bangladesh) create significant risks.
Photo by Karl Fjellstrom

- Obstructed pavements due to parked cars (illegal or legal), poor design, utility poles and signs, uncollected rubbish, vendors, etc.
- No protection from harsh climatic conditions;
- Lack of sufficient lighting;
- Pedestrian overcrowding due to narrow or below-capacity pavements;
- High levels of robbery, assault and other crime befalling pedestrians.

Adapted from Vasconcellos (2001, p. 113) and Hass-Klau *et al.,* (1999, p. 105)

The complete lack of formal pedestrian pavements in developing nations is relatively common. Hook (2003) notes that: "Over 60 percent of the roads in Jakarta, for example, have no sidewalks, and those that exist are heavily obstructed by telephone poles, trees, construction materials, trash, and open sewer and drainage ditches." Likewise, in African cities, poor districts will rarely be provided with pedestrian infrastructure, even though virtually all of the population of such areas do not own a motorised vehicle (Figure 13.3). Vasconcellos (2001) also notes that even when crossings are provided, they rarely give priority to the pedestrian:

> "Crossing facilities are also inadequate; zebra crossings are rare, and signals rarely consider pedestrian needs; in such cases, pedestrians are seen as something that might be 'stacked' until some gap is available in the traffic stream: 'second class citizens' have to wait until first class ones exert their rights to use roads."

Crossing a street can be particularly difficult in developing-nation cities due to a lack of formal crossings and restrictions on informal crossings, with the latter typically based on driving and not walking patterns (Figure13.4).

Lack of direct routes for cyclists and pedestrians between their homes and public transport stations can also encourage people to drive cars and motorcycles. Because walking speeds are so slow, even modest detours in the directness of a walking access route can have a dramatic negative impact on total travel time. Hook (2000) documents how sidewalk barriers and other detours in Surabaya result in substantially longer journeys for pedestrians:

> "…pedestrian barricades and one way streets have been used to facilitate long distance motorised trips but which simultaneously impose huge detours for short distance cycling and pedestrian trips. People wishing to cross a main shopping street often find it easier to take a taxi two kilometres than to walk across the street. In Surabaya, the World Bank estimated that these measures generate an additional daily 7,000 kilometres of needless vehicle traffic."

For this reason, many cities developing BRT systems simultaneously develop pilot pedestrian improvement schemes along and adjacent to the new BRT corridor.

One of the first questions typically raised by engineers designing a new BRT system is "how are the passengers going to get to the BRT stations if they are in the centre of the carriageway?" While carefully designing safe station access is one of the most important elements of a BRT system, and it is discussed at length in the following section under 'safety,' it should be kept in mind that safe pedestrian access is just as much of an issue for standard bus systems. Even without a BRT system, bus passengers need to cross streets, often at very dangerous intersections, in order to take buses going in the opposite direction. Competition for passengers along a curb lane bus stop is also frequently an important cause of death for pedestrians; a problem that BRT can solve. Therefore, BRT brings with it no special difficulties with regard to pedestrian access, but it does provide a strategic opportunity to significantly improve pedestrian safety and access for bus passengers.

The second most frequently asked question is whether pedestrian crossings should be at grade, elevated, or below ground. As a general rule, at grade pedestrian crossings are more convenient for pedestrians and disabled people, and can generally be made safe by various traffic calming measures. Where possible, at grade facilities are preferable. In most instances, pedestrian overpasses or underpasses are designed primarily with the aim of getting pedestrians out of the way of vehicular traffic and not with the safety and convenience of pedestrians in mind. Such facilities frequently fail to protect pedestrians, who often eschew such infrastructure because it is poorly located, overly steep, badly maintained, filled with informal merchants, inherently dangerous from a crime and safety standpoint, or otherwise generally inconvenient. The safety benefits of an overpass will not be realised if most people (in all parts of the world) choose to take their chances crossing through the chaotic and dangerous maze of traffic. Nevertheless, there are conditions where full grade separation between pedestrians and motorised modes is preferable, and the following section provides some guidelines for making better informed decisions on this matter.

Fig. 13.5
Pedestrian Infrastructure of the new BRT System in Jakarta.
Photo courtesy of ITDP

A new BRT system offers the opportunity to re-evaluate pedestrian conditions and develop a vastly improved pedestrian environment. However, if no attention is paid to the pedestrian environment, pedestrian conditions could actually be made worse. Initially, the Jakarta BRT system failed to properly address pedestrians (Figure13.5), and pedestrian access bridges fully obstructed the existing footpath. However, Jakarta has now learned from this experience, and is now modernising the footpaths in all of the new TransJakarta BRT corridors.

13.2.2 Street audits

"The pedestrian remains the largest single obstacle to free traffic movement."
—Los Angeles planning report (Engwicht, 1993)

As most pedestrians will be approaching a BRT station from within one kilometre, and as stations tend to be roughly 500 metres apart, the catchment area for BRT walking access trips is generally between 500 metres and 1,000 metres. Surveys from TransJakarta indicated that 58 percent of the passengers walked less than 500 metres to the station, and an additional 31 percent came from locations within 500 metres and 1000 metres. Longer distance walking trips are rare, unless there is a distinct corridor such as a path along a river.

Usually, in developing countries, the street grid is not very dense. Small local streets tend to have fairly slow operating speeds, so these smaller streets may already possess effective

Fig. 13.6 and 13.7
Pedestrian conditions connecting Mexico City's metro system to nearby municipal offices.
Photos by Michael King

pedestrian facilities. The locations where major pedestrian improvements are likely to be needed are on arterials and intersections where vehicle speeds are likely to exceed 40 kph, so identifying these roads and intersections within the service area and assessing the quality of the pedestrian environment is the next step. To analyse facilities at this level of detail, precise maps, ideally at a minimum of 1:2000 scale, should be utilised.

The ease of walking from one's home or office to the BRT station depends on the street design and the overall urban form. Some of the design factors that will affect the decision to undertake this walk include:

- Quality of pavement materials;
- Amount of trees, vegetation, verandas, etc. providing climate protection;
- Quality of street lighting;
- Pedestrian priority at intersections;
- Absence of major barriers / severance issues.

Additionally, the aesthetic value of the walking environment will play a role in the potential customer's disposition towards the walk. If the walk is pleasant and intriguing, then more customers will be attracted to the BRT system. If the walk is an unpleasant experience punctuated by excessive noise, pollution, and risk to personal safety, then a significant portion of the system's customer base can be lost (Figures 13.6 and 13.7). System developers thus should assess the quality of pedestrian corridors connecting the BRT stations with major origins and destinations.

At this stage, the project developers have identified the major pedestrian corridors linking the stations to origins and destinations. An audit to evaluate the quality of the existing pedestrian infrastructure along and serving these corridors will be useful in highlighting potential problem areas. With this data in hand, priority areas for improving pedestrian conditions can be identified and included in the BRT development budget.

Several auditing protocols have been developed for evaluating the condition of pavements, curbs, and other roadway features. These protocols are available for download from several organisations[1].

The principal tools for conducting a pedestrian infrastructure audit are a map, a camera, and a distance measuring wheel (Figure 13.8). As the audit team walks along the pedestrian corridor, photographic images are collected approximately

1) http://www.bikewalk.org/vision/community_assessment.htm
http://www.walkinginfo.org/walkingchecklist.htm
http://www.falls-chutes.com/guide/english/resources/pdf/WalkChecklistJuly29ForWeb.pdf

every 30 metres and/or whenever a major feature or problem is noted. Once this information is collected, the street environment can be ranked based upon its suitability for providing public transport access. An example of this type of ranking scheme can be found in Figure 13.9. In this illustrative view of the quality of streets in Surabaya (Indonesia), the pedestrian environment has been colour-coded according to the footpath's usability: 1. Usable (green); 2. Partially usable (yellow); and 3. Unusable (red).

13.2.3 Directness and connectivity

"All truly great thoughts are conceived by walking."

—Friedrich Nietzsche, philosopher, 1844–1901

The directness of the route between the customer's starting point and the public transport station plays a central role in the amount of walking time required. The connectivity afforded by the street infrastructure determines the ease of movement between two points. Connectivity also discusses the placement of the station within the larger context of the urban fabric.

13.2.3.1 Analysing connectivity

Improving the accessibility of the public transport station for pedestrians is not complicated, and a quick visual scan of the area around the station can usually determine whether good quality footpaths exist, whether good quality crossing facilities have been provided, whether proper lighting for night time crossing exists, or whether certain popular access points are obstructed by barriers, unsafe conditions or temporary obstructions that could cause significant inconvenience to pedestrians. While a site visit by a trained non-motorised transport (NMT) planning team is generally sufficient, a more detailed analysis is called for if engineers have no specific background in planning for pedestrians, or if intersections or stations have complex pedestrian movements.

Mapping pedestrian movements in the area of the proposed BRT station provides the baseline data that will help shape the optimum design of the supporting pedestrian infrastructure. Just as traffic counts were an important input element to the BRT modelling process, pedestrian counts and pedestrian movements are important parts of understanding issues around station access. Tools such as walking origin-destination (O-D) studies, walking time maps, and tracking surveys allow planners to understand pedestrian movements at the local level. By identifying the likely origins and destinations of pedestrians and the most travelled walking routes, planners and designers can prioritise infrastructure improvements in the most effective locations.

If the most common walking routes are not inherently clear, it is sometimes helpful to do a small localised OD survey of passengers disembarking at a BRT station and their local destinations. The impact zone might be divided up into small 250 metre square zones around the BRT station with popular destinations such

Fig. 13.8
A pedestrian infrastructure audit in Zurich.
Photo by Lloyd Wright

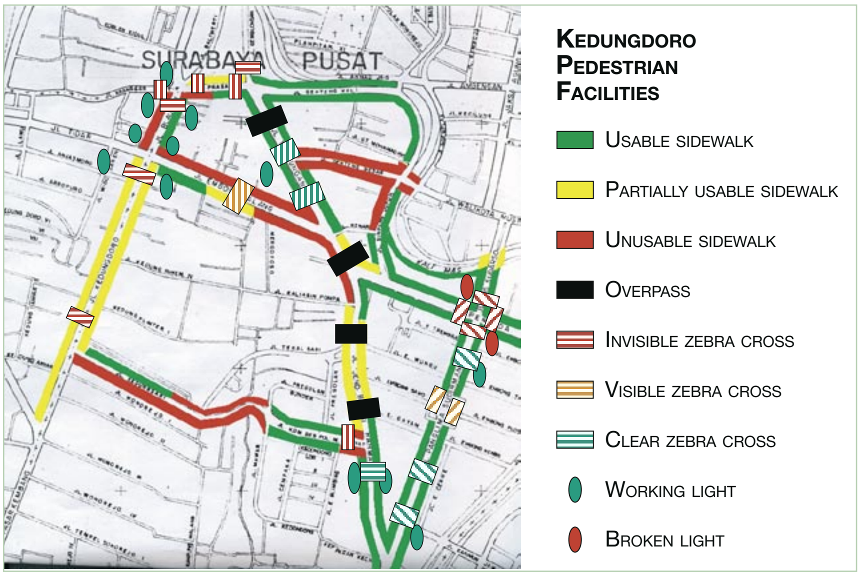


Fig. 13.9
Results of street audit for Surabaya.
Image courtesy of GTZ and ITDP

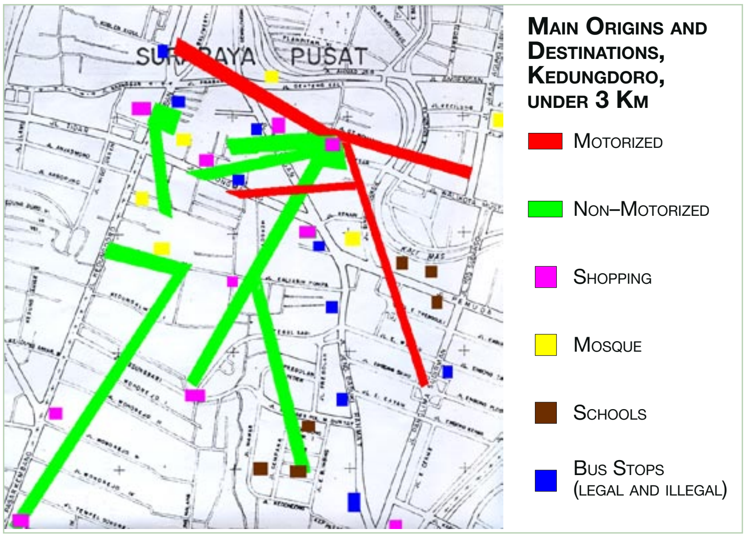


Fig. 13.10
Origin-destination map from Surabaya (Indonesia).
Image courtesy of ITDP

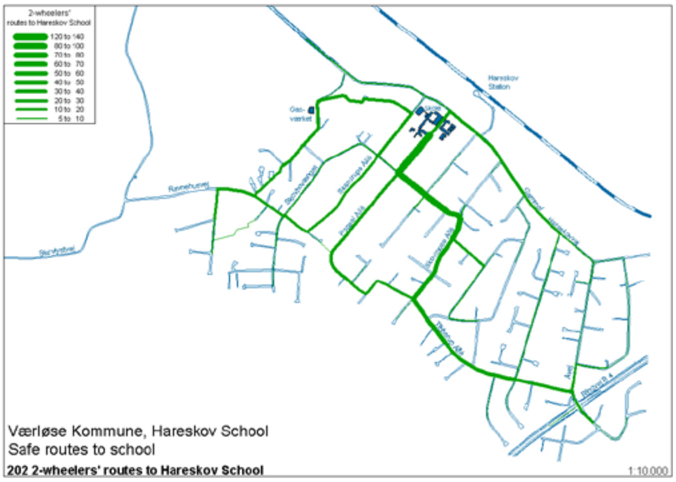


Fig. 13.11
Mapping of actual walking routes for school trips in Copenhagen (Denmark).

as schools, shopping areas, and office buildings identified. If there is a major trip attractor in the destination zone (*e.g.,* a shopping centre, school or hospital), this location can serve as the destination point. If a clear major attractor is not present, the destination can be represented by a central point in each zone.

On this map it would be useful to highlight any roads or streets where bicycles or other modes are forbidden (*i.e.,* pedestrian-only streets and other traffic restrictions). Particular focus should be given to all trips up to 1,000 metres from the station, regardless of the mode currently being utilised. If certain OD pairs show a very high proportion of short motorised trips, it may be because the pedestrian facilities are of very poor quality. Often, popular short OD pairs currently dominated by motorised modes can indicate locations where pedestrian improvements might be prioritised.

In Figure 13.10, popular short OD pairs between a major commercial centre, bus stops, and other high demand destinations are shown in red if the majority of trips are by motorised modes and in green if by non-motorised modes. Bus stops are shown in blue, schools in brown, mosques in yellow, and shopping areas in purple. The red lines indicate trips that are so difficult to make safely by walking that most people are taking motorised modes. This mode preference indicates there may be a severance problem. The green lines indicate trips that are already being made by walking. While this map indicates nothing in terms of the quality of the walking trip, the map does indicate that these trips are possible.

It is also generally possible to conduct a survey of public transport passengers alighting at a particular station and ask the passengers to map the specific route that they normally use. If a random sample is taken, each trip can be placed on a map and simply added up. The second image (Figure 13.11) shows a compilation of the actual routes that a sample of students takes from their homes to school. The same methodology would be used for a public transport station. If specific route data has not been collected, it is usually possible to assign the OD pairs to specific streets using the shortest route possible if the routes are observed to be safe for pedestrians.

Another type of mapping that can provide useful insights into severance problems is to record travel times from the station. Maps showing areas covered in such intervals as one minute, five minutes, ten minutes, twenty minutes, and thirty minutes not only indicate the potential catchment area for the station, but may also highlight potential barriers to pedestrian access. For example, a busy roadway near the station may create severance issues for approaching pedestrians. Other impediments such as blocked or non-existent pavements will become evident in a time-based mapping. Also, long signal cycles for pedestrian crossings will increase walking travel times. This type of analysis can often show areas where distances are relatively short but pedestrian travel times are lengthy.

Figure 13.12 shows a 1/3-mile (roughly 500 metres) circle around the main train station in Trenton, New Jersey (USA). In yellow is the distance that a person walking at 1.5 metres per second walked in five minutes. The person followed all traffic laws. This type of analysis is useful in planning station environs. Note that the person was able to walk further where the street network is denser, so it would be useful to create passages within blocks. Note also that crossing larger streets took longer, so the person was not able to walk as far. Here it would be useful to minimise delay at signals.

13.2.3.2 Detour factors

Once these actual trips are mapped, one can generally tell whether there are a lot of people walking a long way out of their way to reach a popular destination. This actual route mapping can be used to calculate detour factors. Detour factors are the most systematic way of identifying major severance problems. Severance problems can be created by unsafe, high-speed roads, by restrictions on non-motorised vehicles on specific streets, by barriers to crossing streets, by a one-way street system, and by large canals, railroad tracks, and other impassable infrastructure.

Detour factors are the distance that the average pedestrian, cyclist, or pedicab operator needs to travel out of their way in order to reach their destination, relative to the straight line distance. In a typical European or American traffic grid with no restrictions on non-motorised vehicle travel, the detour factors are generally very low. A detour factor of 1.2, as observed in Delft, Holland, is extremely low. This level means that the average cyclist only needs to travel 20 percent farther than a straight-line distance in order to reach the destination. Mapping of some detour factors in Surabaya indicates that Asian cities with many one-way streets, few intersections, a weak secondary and tertiary street system, and unsafe high-speed roads can have fantastically high detour factors.

It is fairly typical in developing countries for distances between intersections to be one kilometre or greater. Normally pedestrians are able to cross reasonably safely at-grade at intersections, but sometimes traffic planners even discourage at-grade crossings at intersections in order to allow free left or right hand turns without any pedestrian conflicts. Traffic planners also like to erect barricades that try to force pedestrians to cross major roads only at designated pedestrian overpasses, and frequently, these overpasses as much as one kilometre apart. In these typical conditions, if a pedestrian simply wants to cross a 50 metre wide street, and the nearest overpass is 250 metres away, the pedestrian will have to walk 500 metres to go a straight line distance of 50 metres. This distance represents a detour factor of 1:10. This situation is fairly typical in developing countries, and is a frequent reason why pedestrians refuse to use pedestrian overpasses.

In these cases, adding safe at-grade or even elevated pedestrian crossing facilities at BRT stations either at mid-block or at the intersection will not only help to improve safe access to the public transport system, it can also help to improve pedestrian safety and convenience for pedestrians not using the BRT system. When the new pedestrian facilities along the TransJakarta system were opened, taxi drivers in the corridors complained of losing a considerable number of short fares.

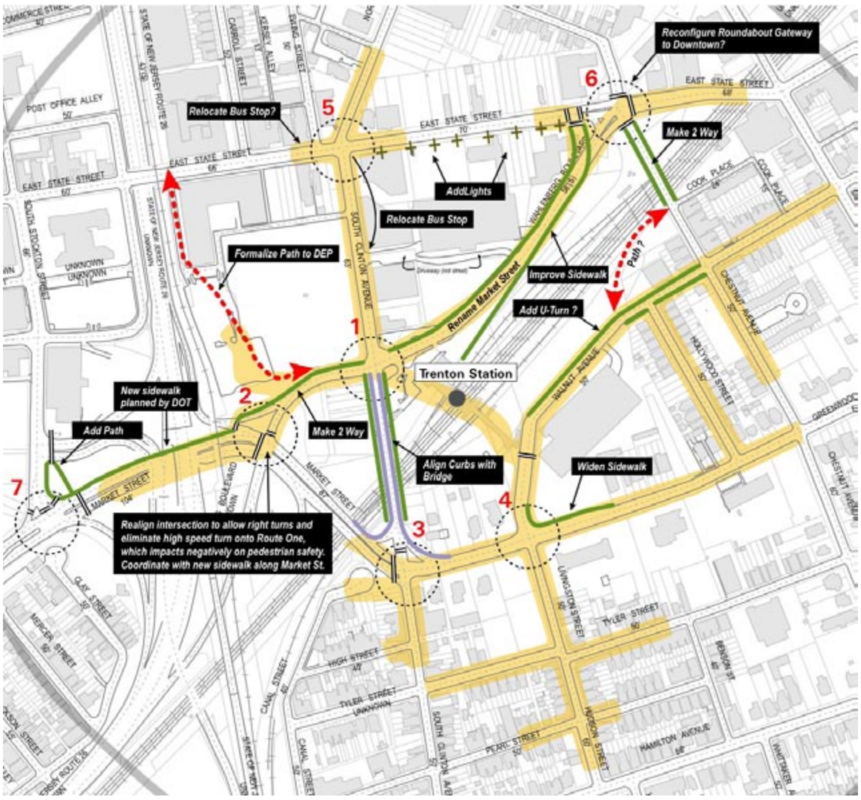


Fig. 13.12
The yellow lines represent areas that are accessible within a five minute walk of the transit station.
Image courtesy of Nelson/Nygaard

Pedestrian connectivity to a BRT station is also a function of the layout of area roads and paths. It is fairly typical in developing countries for the secondary street system to be extremely weak. Residential areas frequently connect to major arterials only at a very limited number of access points, and these local streets rarely connect to other residential areas except via the major arterials. Street networks which rely on a high number of minor roads which do not connect with each other severely limit the pedestrian's ability to reach the BRT station. This pattern reduces the functionality of the BRT station, since it requires longer trips to reach destinations. Conversely, networks developed on an interconnected grid system provide greater accessibility because streets are more connected, which allows pedestrians to travel directly to BRT stations. A grid street system also tends to be more resilient, because the system will not fail if one link is blocked. It is sometimes possible to find locations for small pedestrian shortcuts to reduce high detour factors caused by the lack of a secondary street system.

13.2.3.3 Station location

On the macro level, stations should be located so that they best serve the general population and maximise ridership potential. While there are many, non-pedestrian issues in the location of stations, there are a few particulars which directly relate to pedestrian access and safety. Normally, locating stations near to popular trip origins and destinations like shopping malls, large office complexes, or popular intersections, will minimise pedestrian walking times. However, there are many important reasons from overall traffic flow point of view that a slight offset of stations from these popular destinations is generally desirable, as is described in detail in Chapter 8 (*System capacity and speed*), where a methodology for determining station spacing and location is outlined. Clearly, customer safety and ease of access are additional considerations that should help define the exact location of a station.

13.2.4 Tracking pedestrian movements

"The place where you lose the trail is not necessarily the place where it ends."

—Tom Brown, Jr., naturalist, 1950–

On the micro scale, pedestrian tracking surveys are a useful way to document exactly how people use a street, intersection, or plaza. These surveys have been used to redesign complex intersections, to show how the space is used throughout the day, in order to prioritise the locations where improved pedestrian facilities are needed. As the role of the pedestrian facilities designer is to facilitate pedestrian travel, it is normally advisable to keenly observe existing pedestrian behaviour and then determine what infrastructure interventions can be designed to ensure these trips are made safely, rather than designing pedestrian facilities that try to force pedestrians to behave in ways that are highly inconvenient to them.

13.2.4.1 Tracking surveys

Tracking surveys are usually conducted at complex intersections and public transport facilities,

Fig. 13.13 and 13.14
Despite efforts to force pedestrians to take alternative routes at Jakarta's Blok M, most customers still prefer to enter by the direct, at-grade approach.
Left photo by Lloyd Wright
Right photo by Michael King

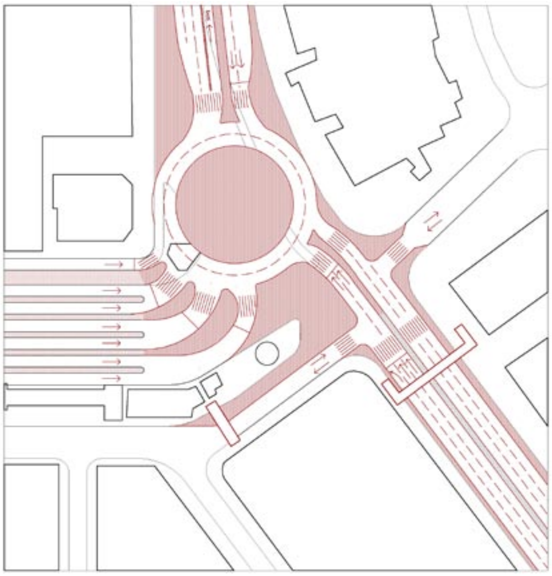


Fig. 13.15
A design was developed with multiple pedestrian islands in order to improve conditions.
Image courtesy of Michael King

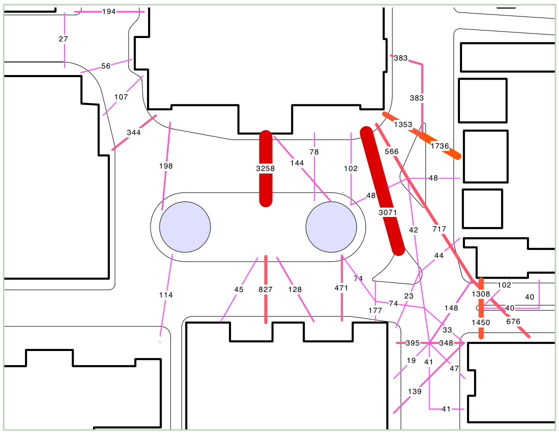


Fig. 13.16
Walking routes at a Jakarta public transport station in the morning.
Figure courtesy of ITDP

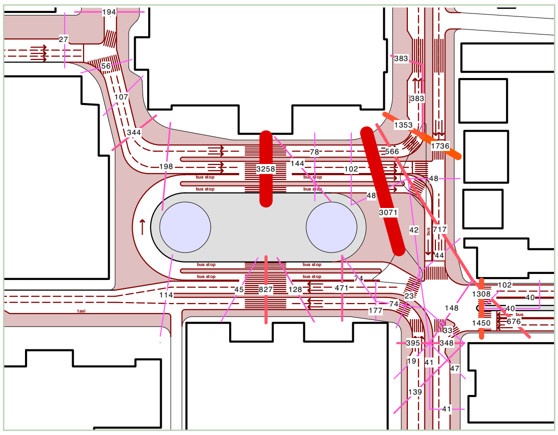


Fig. 13.17
Proposed solution based on the observed audit of walking routes.
Figure courtesy of ITDP

particularly if these facilities or intersections have been identified as having a high number of pedestrian injuries and fatalities, in order to show where pedestrian improvements are needed.

When TransJakarta was built, the Phase I corridor terminated at the Blok M bus station. At the time that the system opened, the expectation was that pedestrians accessing Blok M from the North and East would all use the provided pedestrian bridge and underpass. In fact, only 210 passengers were using the pedestrian overpass at the morning peak, and none of the passengers

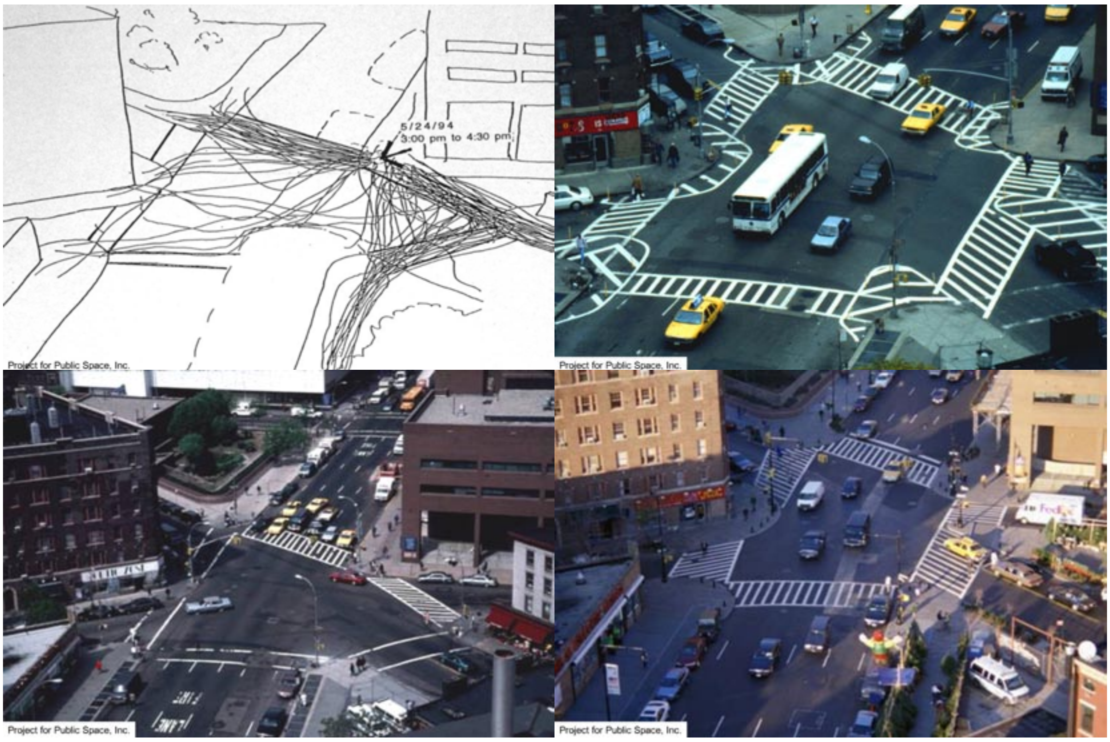


Fig. 13.18
Tracking survey as intersection redesign tool for Mulry Square in New York City.
Photo courtesy of Project for Public Spaces

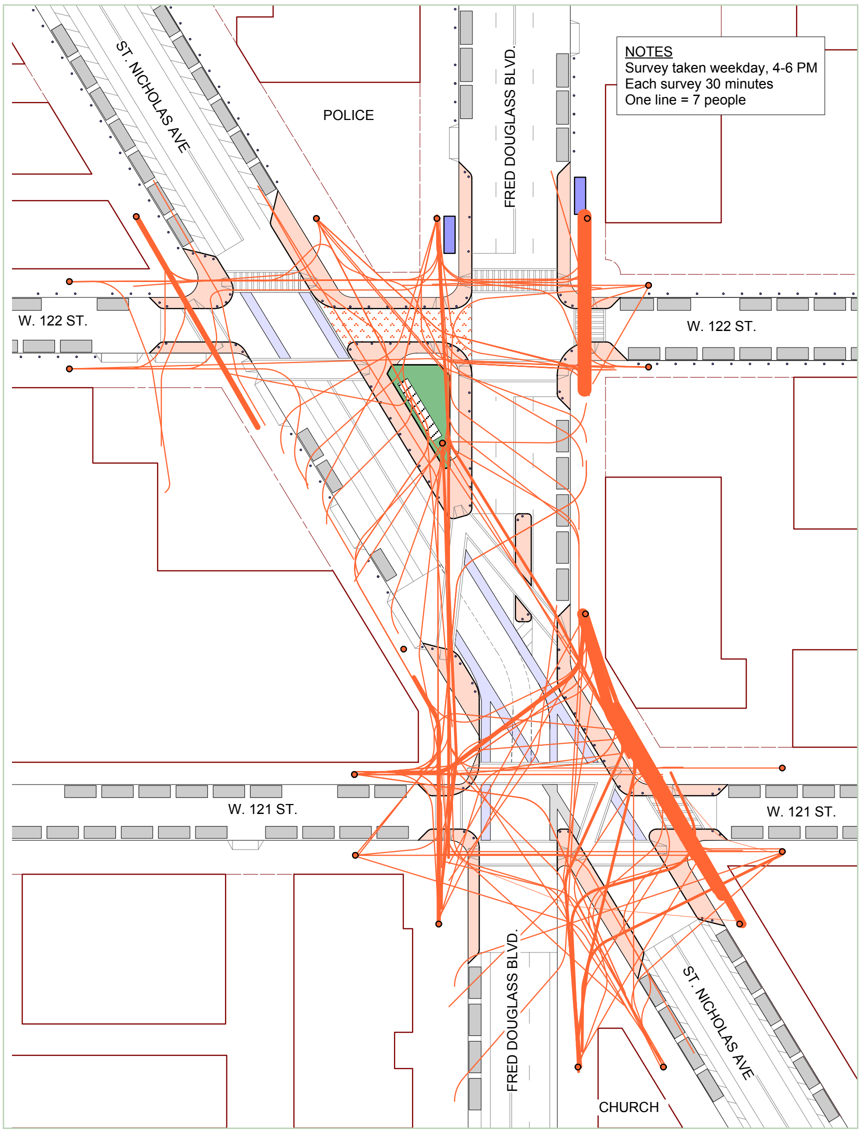
from the North and East were using the pedestrian underpass to the south. The remaining several thousand passengers were all entering or exiting the Blok M terminal at-grade, despite the efforts to station designers to make such access impossible, as shown in Figures 13.13 and 13.14.

An initial design concept of the Blok M intersection was attempted (Figure 13.15). However, designing an intersection of this complexity in order to optimise pedestrian safety and convenience without compromising mixed traffic throughput and BRT operating speeds is a highly complex matter. In developed countries, where traffic flows are far less complex, it would not be unusual to spend over US$10 million to redesign an intersection of this complexity, using highly specialised micro-simulation modelling tools.

Fig. 13.19

Composite of tracking surveys conducted in Tubman Triangle, New York City.

Drawing courtesy of Michael King



The basic technique for tracking pedestrians is to position surveyors at the entries of the location. At a typical four-leg intersection, there are eight sidewalks that lead to the intersection, and hence there are eight entry points. As people walk past, the surveyors record on a plan of the area exactly where they walked, where they crossed the street, where they turned around, etc. The surveyors do not actually follow anyone. The survey can last from 30 minutes to two hours, depending on how long it takes to establish the walking patterns. However, the survey should be conducted across different periods since use patterns will likely vary by the time of day. For example, morning flows and evening flows are likely to be reversed. The optimum design accommodates the peak flows in both directions. Evaluation of rush hour volumes may be the key to maximising pedestrian convenience at transfer points (Figures 13.16 and 13.17). Whether alignments run east/west, north/south or any combination, most locations will have dominant flows.

Figure 13.18 of Mulry Square in New York shows how a tracking survey can be used to redesign an area. The lower left of Figure 13.18 shows the previous condition. In the upper left of the figure is the tracking survey. The upper right shows temporary curb extensions (in paint). The lower right of the figure shows the final built condition.

In complex environments, several individual tracking surveys can be drawn together to form a composite few of the area. This composite view is particularly useful in understanding how multiple intersections, plazas, and footpaths can interact to serve the customer. Figure 13.19 provides a composite tracking study from 19 different points in Tubman Triangle in New York City.

While it is possible to predict walking patterns, humans are highly adaptable. After the public transport station is opened it is good to re-analyse the area and see if the design works.

13.2.4.2 Aerial photos and video

Tracking surveys are highly specific and require a certain amount of personnel to perform. Another way to obtain similar information, although not as exact, is through aerial photographs. It is often easy to see from aerial photos where most

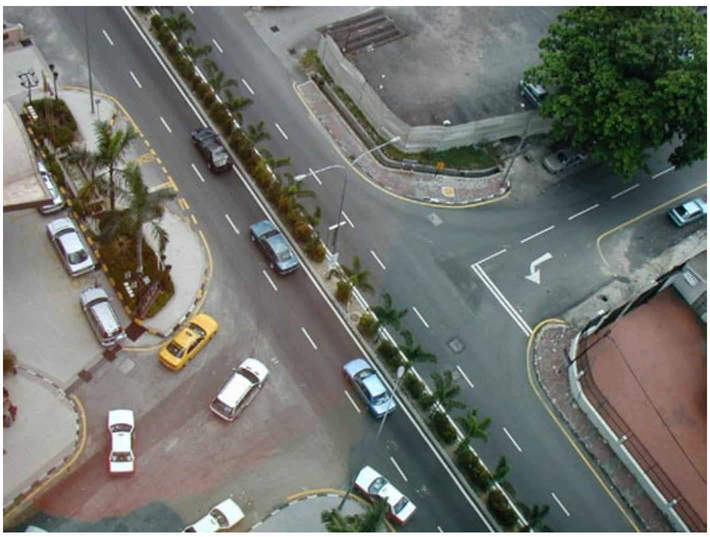
Fig. 13.20
Aerial image showing where people cross the street in a neighbourhood of Cape Town (South Africa).
Photo courtesy of ITDP

pedestrians want to go based on the tracks left in the grass of median strips. Aerial images can show actual pedestrians, say at a market or along a sidewalk, or the paths in unpaved ground. Figures 13.20, 13.21, and 13.22 present examples of aerial photos being used to assist in tracking pedestrian routes and movements.

The rise of video technology offers much promise to improve the accuracy of pedestrian tracking. Rather than rely upon a team of surveyors to catch pedestrian movements as they occur, a video of an area can capture the scene for a more studied analysis. Movements can be replayed in slow motion to catch nuances not seen in a single moment.

Fig. 13.21
Aerial image recording how people access a bus stop in Brasilia (Brasil).
Photo by Michael King

Fig. 13.22
Aerial image showing where people cross the street in Kuala Lumpur (Malaysia).
Photo by Michael King



13.2.5 Safety

"The car is a luxury that is apt to degenerate into a nuisance." (1907)

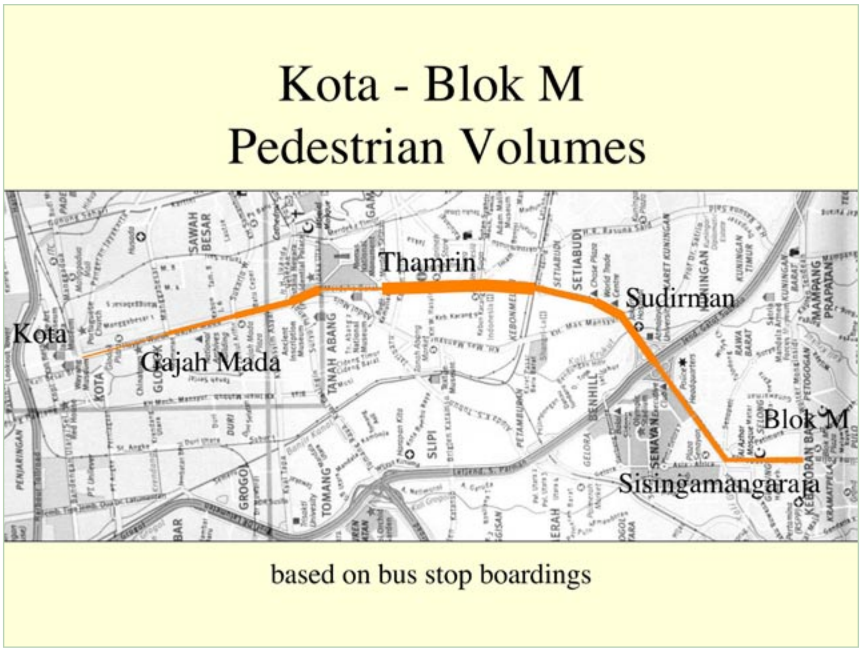
—Herbert Asquith, former UK Prime Minister, 1852–1928

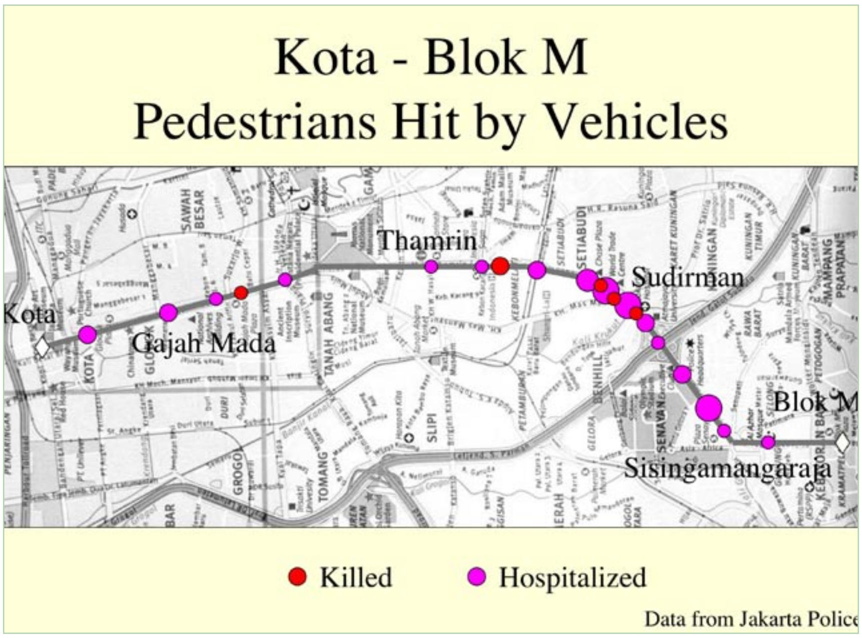
Improving pedestrian access for the BRT system most importantly requires designing facilities for pedestrian safety. While most of the pedestrian safety measures that will be recommended for a BRT corridor could be implemented with or without a BRT system, the introduction of a BRT system is often a strategic opportunity to implement these much needed measures anyway.

While analytical tools and measures suggested below are generic to safe pedestrian facilities design more generally, they are necessary for the specific application of safe station access, which is critical to the success of a BRT system.

Most of the road design measures used to increase pedestrian safety follows fairly standard rules that do not require in-depth analysis. However, analysis of existing safety conditions can greatly help prioritise interventions, and sometimes can dispel a lot of misunderstanding about road safety, much of which is quite counter-intuitive.

Fig. 13.23 and 13.24
Pedestrian volumes, injuries and deaths along a BRT Corridor in Jakarta.
Images courtesy of ITDP





13.2.5.1 Accident mapping

Determining where pedestrians and other vulnerable road users are hit by vehicles is a fundamental step in safety analysis in general, and for planning a transit station in particular. Planners should first collect traffic accident (crash) data for incidents involving non-motorised road users from the police and map the locations as precisely as possible. Differentiating between intersection and non-intersection accidents can be quite useful. Even though the numbers are likely to be significantly underreported (Box 13.1), this simple mapping exercise should make it possible to identify particularly dangerous locations.

Box 13.1:
The limits of crash statistics

Vehicle-vehicle incidents and incidents involving fatalities are typically reported with reasonable accuracy and need not be adjusted. However, research indicates that only 35 to 85 percent of vehicle-bicycle and vehicle-pedestrian incidents involving injury are included in typical crash statistics. A study of California children estimated that police reports only cover 80 percent of hospital admissions (Agran *et al.*, 1990). A British study found that only 67 percent of slight injuries to pedestrians were reported while 85 percent of serious injuries were (James, 1991). In Germany the figures are 50 percent for major injuries and 35 percent for minor ones. Based on this research, it is appropriate to adjust vehicle-bicycle and vehicle-pedestrian injury statistics upwards by at least 50 percent (Hautzinger, 1993).

Once a particularly dangerous location or a future station area has been identified, more detailed analysis of the location should be conducted. Researchers at Lund University in Sweden have developed a "conflict-analysis" technique where a location is observed and conflicts between various roadway users are recorded. These "conflicts" could be near misses, evasive manoeuvres or simply a reduction in speed. The idea is that this type of information paints a more complete picture of the safety at a particular location than do accident statistics. The technique is especially useful in contexts where most traffic incidents go unreported.

Figures 13.23 shows pedestrian volumes along the first BRT corridor in Jakarta and figure 13.24 compares these volumes with injury locations.

Careful analysis of these locations showed that by far the largest number of serious pedestrian accidents and fatalities occurred in the slow lane of the higher-speed section of the BRT corridor, and determined that the primary cause was competition for passengers among bus drivers and other commercial vehicles in the curb lane (Table 13.2). The next most dangerous location was high-speed access and egress ramps onto highways. The next most dangerous location was at poorly lit underpasses where many people were crossing to catch buses and motorcycle taxis going in the opposite direction. Next were accidents in the fast lane, caused by pedestrians illegally crossing the roadway due to the inconvenience of walking to the nearest pedestrian overpass. As is consistent with research from India, but inconsistent from developed-nation research, very few accidents were taking place at intersections or roundabouts.

Table 13.2: Location of serious pedestrian accidents in Jakarta

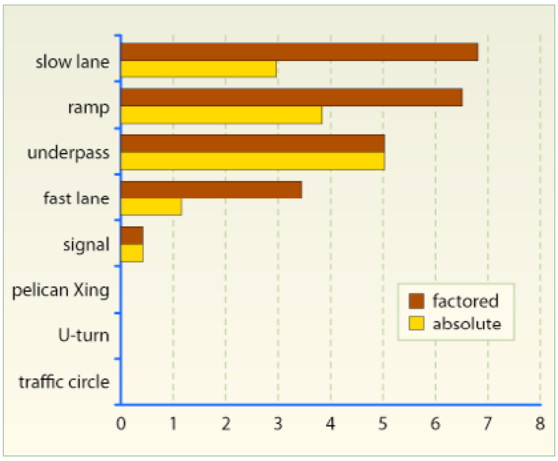


Fig. 13.25
The addition of higher-quality pedestrian crossings in Jakarta has done much to reduce pedestrian accidents.
Photo courtesy of ITDP

This comparison showed that higher pedestrian volumes are not necessarily accompanied by more deaths and severe injuries. In fact, vehicle speed was the most representative indicator of injury severity. Pedestrian volumes usually mean more absolute numbers getting hit, but generally with less severe outcomes. This "safety in numbers" argument is gaining currency within the pedestrian safety community.

Based upon these results, if pedestrian safety is to be improved along a BRT corridor, the first step is to end the competition for passengers amongst bus operators. This change can be accomplished through the business and operational structure of the system. Specifically, operator revenues should be based upon vehicle-kilometres travelled rather than the number of passengers. Secondly, the provision of high-quality pedestrian crossings at a wide variety of points along the corridor will do much to avoid pedestrians entering unmarked crossings. In Jakarta, the construction of higher quality, gradual gradient, pedestrian overpasses to largely mid-block BRT stations helped significantly in this respect (Figure 13.25).

13.2.5.2 Key factors contributing to accidents

Table 13.3 lists weight factors which can be used to determine the relative safety of a location or area. This list includes direct costs (property

Table 13.3: Factors to determine the relative safety of a location

Factor	Severity
1,300	Fatality
90	Incapacitating injury
18	Evident injury
10	Possible injury
1	Property damage only

Source: Homberger *et al.,* (1996)

damage, emergency medical services, medical treatment, lost productivity, insurance payouts) and indirect costs (insurance premiums, automobile safety features). These multipliers can be applied to existing crash data to show the approximate annual cost of the existing roadway configuration. This list can also be used to estimate potential cost savings of a proposal relative to the cost of construction.

Dangerous conditions can be mitigated by addressing the root causes of the danger, which can be grouped into three basic categories:

1. Vehicle speed and volume
   Vehicle speed is a significant determinant of crash severity but not their frequency. Vehicle volumes tend to correlate with frequency of accidents but not their severity. Both vehicle volume and vehicle speed are controllable, and ultimately determined by the decisions of road designers and policy makers who should be held accountable for these decisions, as people's lives are at stake. While mechanisms to reduce vehicle volumes will be discussed in Chapter 14 (*TDM and land-use integration*), many design options for reducing vehicle speeds, most of which do not compromise vehicle throughput, are discussed below.
2. Pedestrian "exposure" risk
   The time that pedestrians are exposed to traffic varies based on the distance between secure pedestrian facilities, the way traffic signals are phased, and the type of facility segregation. It has both a temporal and spatial component. To reduce exposure risk is to increase safety.
3. Driver and pedestrian predictability
   Drivers are constantly making decisions, and if other street users—walkers, cyclists and other drivers—can better predict those decisions, then the street will be safer. Reducing the number of options for drivers at key junctions is the simplest way to improve driver predictability.

13.2.5.3 Reducing vehicle speeds

Speed and risk

The relationship between vehicle speeds and the risk of death or injury has been well documented in a range of settings (Figure 13.26). At speeds of less than 32 kph there are almost no pedestrian deaths; at 80 kph almost all vehicle-pedestrian incidents result in death. There is good reason why residential speed limits in countries with good traffic safety records are set at 30 kph or less.

Similarly, research from Australia suggests that a drop in speed of only 5 kph will result in:

- 10 percent fewer pedestrian fatalities; and
- 20 percent less severe pedestrian injuries (Anderson, 1997).

There are many techniques to lower traffic speeds, from lowering and better enforcing speed limits to changing road design. Camera enforcement of speeding vehicles and changing police incentives to crack down on speeding motorists can be effective. The focus here, however, will be on road design issues, as they are self enforcing and easy to implement as part of a BRT project.

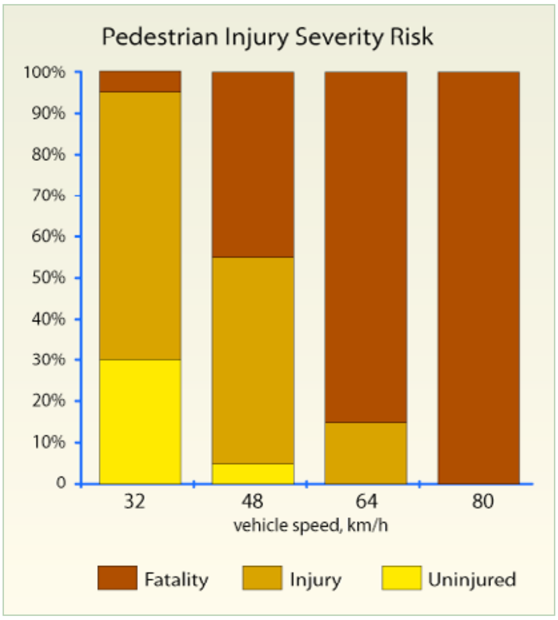


Fig. 13.26
Relationship between vehicle speed and pedestrian safety (UK DOT, 1993)

There are two basic approaches to slowing vehicle speeds through road design: "traffic calming" and what has been called "shared space" or "post traffic calming". While in some cases slowing vehicle speeds through these methods will also compromise mixed traffic throughput, recent Dutch research has shown that it can frequently increase mixed traffic capacity through a process known as "traffic smoothening", which ends the accordion-action that can lead to traffic bottlenecks.

Traffic calming

The most familiar family of interventions to slow down motor vehicle speeds for pedestrian safety are called "traffic calming". At any locations critical to pedestrian access to the BRT system, or at any location where numerous accidents have been recorded, traffic calming measures should be considered. Box 13.2 summarises many of the most common forms of traffic calming.

Several other measures that both reduce motor vehicle speeds and increase pedestrian refuge space are discussed in the following section. Figures 13.27 through 13.30 illustrate some of these traffic calming techniques.

Shared space

Where a BRT system goes through a city centre or on smaller access roads, there may be opportunities to implement one of the most innovative concepts in recent years: the idea of "shared space", also known by several other names including "post-traffic calming",

Box 13.2: Traffic calming measures

Speed humps – Rounded raised area across the vehicle lane with typical dimensions of 3-4 metres in length and 50–100 mm in height.

Speed table – Flat topped speed humps that are often constructed with brick or textured materials and are usually long enough for the wheel-base of a standard car to rest entirely on the flat surface

Raised sidewalks – These are speed tables outfitted with crosswalk markings and signage to channelise pedestrian crossings, providing pedestrians with a level crossing. Additionally, by raising the level of the crossing, pedestrians are more visible to approaching motorists.

Raised intersections – Flat raised areas that cover the entire area of the intersection, with ramps on all approaches and typically constructed of brick or other textured materials.

Realigned intersections – Changes in intersection alignment which converts a "T" shaped intersection with straight approaches into curving streets.

Textured and/or coloured pavements – Pavement materials are used to create a coloured or uneven surface for vehicles to traverse across an intersection, crossing, or even an entire city block.

Traffic circle – Raised islands in the centre of intersections, around which traffic circulates.

Chicanes – Curb extensions that alternate from one side of the street to the other, forming S-shaped curves.

Neckdowns – Curb extensions at intersections that reduce the distance required for a pedestrian to cross a street.

Chokers – Curb extensions at mid-block locations that narrow the street and widen the footpath area.

Pedestrian islands – A raised island located in the centre median area; also known as pedestrian refuges.

Traffic cells – A street enclosure that permits a direct link for a pedestrian or cyclist but force a longer trip by car.

Source: Adapted from Institute of Transportation Engineers, 2005

Fig. 13.27
Before curb extension is installed (Salem, Oregon, USA).
Photo courtesy of Michael Ronkin

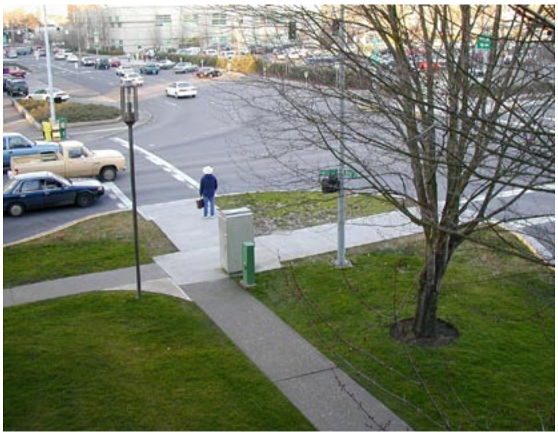


Fig. 13.28
After curb extension installed.
Photo courtesy of Michael Ronkin

Fig. 13.29
Raised intersection in Quito.
Photo by Lloyd Wright

Fig. 13.30
A fence in the centre of the road keeps drivers from swinging wide during a turn in Shenzhen (China).
Photo by Michael King

"second-generation traffic calming", "psychological traffic calming", "context sensitive design" and even "naked streets". In some respects "shared space" represents the antithesis to traffic calming, and yet, both share the ultimate goals of slower vehicle speeds and reduced accidents. With shared space, all physical differentiation between car space and pedestrian space is removed (Figure 13.31).

In shared space, the roadway is designed to look not like a road but like a public plaza where motor vehicles do not belong, sending a visual signal to motorists that they are in a space not intended for high speeds. Often, simply redesigning a street to look like a pedestrian zone alone, with no restrictions on motorist access, will fundamentally change driver behaviour in this environment. In such an environment, neither pedestrians nor motorists have explicit signage to dictate who has priority. People must resort to eye contact and other forms of subtle communication to navigate the roadway.

Whereas traffic calming might put traffic lights at every intersection and remove all green-waving to force vehicles to stop at every intersection, shared space removes all the traffic signals. When the driver does not have a clear right-of-way at an intersection, in most cases they will instinctively slow down. The end result is that motorists naturally reduce speeds in order to engage in a subtle communication process with pedestrians and other motorists. In other words, there are no lane markings, crosswalks, signals, or curbs. For many, the idea of shared space seems counter-intuitive: "Build roads that seem dangerous, and they'll be safer" (McNichol, 2004). The idea is that the lack of signage and road markings increases the uncertainty for motorists, who will then be more cautious within an undefined road environment. Through intrigue and uncertainty motorists become more engaged in their surroundings (Engwicht, 1999).

By eliminating specific designations for motorised road users the total amount of usable public space for non-motorised transport increases.

Fig. 13.31
Shared space concept as applied in Guangzhou.
Photo by Karl Fjellstrom

Fig. 13.32
Alameda Jimenez in Bogotá only allows BRT and non-motorised access.
Photo courtesy of Diego Velazquez

Fig. 13.33
Public transport, pedestrians, and cyclists amicably share space in Biel (Switzerland).
Photo by Lloyd Wright

Vehicles still use the street, albeit at a slower speed. Moreover, since driver speed is entirely self-enforced, shared space can be seen as the ultimate form of context sensitive design. Drivers' speed is determined not by arbitrary speed limits, but rather the presence of pedestrians, cyclists and public furniture in the "roadway".

The origins of shared space are attributed to Hans Monderman of the Netherlands who has taken his designs to roadway intersections of such Dutch cities as Drachten and Oosterwolde. In a short amount of time, these concepts have made their way to a variety of other locations including Christianfield in Denmark, Wiltshire and Suffolk in the UK, and West Palm Beach and Cambridge in the US. In each case, improvements in safety have been recorded.

Shared space along a BRT corridor is closely related to the transit mall concept introduced in Chapter 5 (*Corridor selection*). The BRT vehicle intermingles in an undefined space with pedestrians and other non-motorised users. The sharing of space will likely affect public transport vehicle speeds. However, this concept is successfully utilised along the corridors such as "Alameda Jimenez" in Bogotá (Figure 13.32). Shared space is also found along the central bus routes of Biel (Switzerland) (Figure 13.33).

Shared space is also relevant to BRT in the context of safe routes to accessing stations. Pedestrian corridors connecting to the station can benefit from an application of shared space, which will reduce speeds of private motorised vehicles and thus encourage more persons to utilise the public transport system (Figure 13.34).

13.2.5.4 Reducing exposure risk

Expanding protected pedestrian space to reduce exposed walking time

Minimising the amount of time a pedestrian is exposed to traffic greatly reduces the risk of accidents. There are a few fundamental ways to reduce exposure risk when crossing the street.

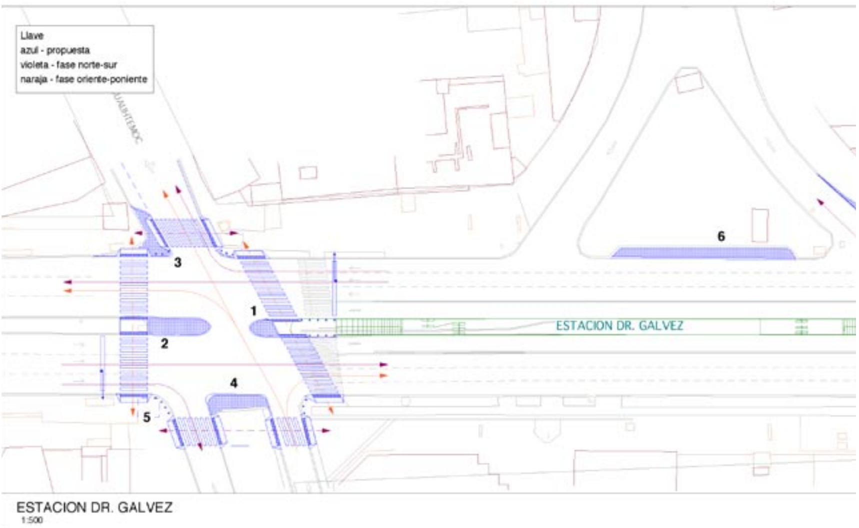
The time it takes a pedestrian to cross a street is a function of the width of the road and the

Fig. 13.34
As this image from Copenhagen illustrates, a shared space environment can make for a safe corridor for accessing public transport.
Photo courtesy of Cara Seiderman

Fig. 13.35
Authors successfully testing an abandoned toll plaza on a high speed road in Guangzhou as a possible safe pedestrian crossing for a very wide high speed road.
Photo courtesy of ITDP

distance between pedestrian refuge points. The greater the distance between pedestrian refuge islands, the longer the pedestrian is exposed to risk from oncoming vehicles. The more lanes a pedestrian must cross, and the wider the lanes, the greater the time of exposure. Many measures to increase pedestrian safety focus on expanding the amount of road space that can be used as pedestrian refuge islands in order to reduce pedestrian exposure time.

In an extreme example to illustrate the point, if a one-metre wide pedestrian refuge island is built between every lane, and at that point the lanes are narrowed from say 3.5 to 3 metres, pedestrians can cross even extremely wide extremely high speed roads in reasonable safety.



Most intersections and road links have a lot of space that is not actually used by through traffic. This lack of use is generally visible from dust collecting on the road, or by the occupation of the space by vendors, illegally parked vehicles, refuse, etc. Building pedestrian refuge islands in all locations where space is available within an intersection that is not absolutely needed for traffic throughput will not only regulate vehicle behaviour to make it more predictable but also significantly expand the amount of space where pedestrians can take refuge.

The roadway can be narrowed, either entirely or at specific points via curb extensions. Pedestrian refuge islands can be added or extended, permitting pedestrians to wait in the middle of the street (Figure 13.36).

While removing free right (or left) turns and slip lanes all together is ideal for pedestrians, sometimes traffic volumes do not permit this. As an alternative, building a pedestrian island and tightening the turning radius can slow turning vehicles at slip lanes and access ramps while reducing the distance pedestrians must cross to reach the other side of the road safely. In such cases, a “pork chop” slip lane design will force vehicles to slow down where they enter the oncoming traffic, just at the point where pedestrians need to cross (Figure 13.37). Coupled with an elevated crosswalk, this slip lane can significantly improve an intersection’s pedestrian safety.

Figure 13.38 shows an intersection on the TransJakarta BRT Corridor I before the busway was built. Existing crossing facilities for pedestrians were of poor quality. A pedestrian overpass some 50 metres from the intersection was available, but it was steep, narrow, poorly maintained, and virtually unused. Field observations showed that much of the roadway was not actually utilised for through traffic but rather for idling paratransit, illegally parked vehicles, and street vendors. Project consultants recommended at-grade

Fig. 13.36
A redesigned intersection in Mexico City for safe BRT access. The medians have been extended into the intersection to reduce turning speeds and provide more pedestrian refuge, and crosswalks brought into line with actual observed pedestrian movement.
Image courtesy of ITDP

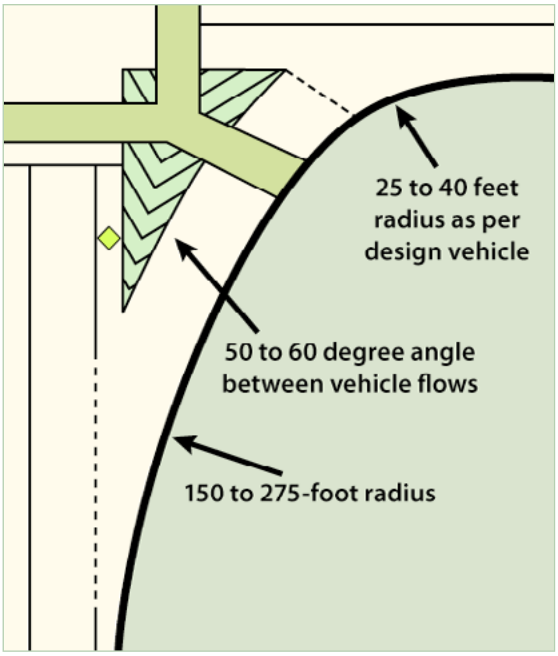


Fig. 13.37

A pedestrian island in conjunction with a tightened turning radius can do much to benefit pedestrian safety.

Image courtesy of ITDP

access to the TransJakarta station with a significantly redesigned intersection that dramatically increased the amount of space dedicated to pedestrian refuge islands (Figure 13.39) without impeding traffic throughput.

On arterials with great distances between intersections, it is common for pedestrians to cross at random points along the corridor. The median used to separate the BRT bus lanes from the mixed traffic lanes can also be used as an additional pedestrian refuge island. In the new BRT system being designed for Dar es Salaam, the entire corridor will use the separator median as a pedestrian refuge (Figure 13.40). As a result, pedestrians along the BRT corridor will only have to cross a maximum of two lanes at any given point.

Separating pedestrians and motorists through turning restrictions and signal timing

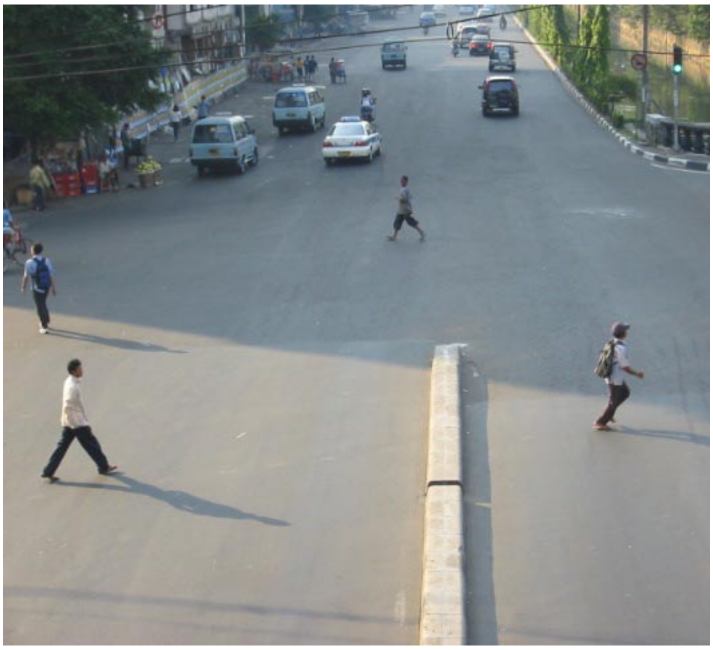
Pedestrian exposure can also be reduced by separating the use of the road in time through turning restrictions and signal phasing. Free right and left turns improve vehicular travel times but they are very dangerous for pedestrians, and induce additional delay for pedestrians. To optimise the intersection, the vehicular turning volumes should be weighted against the pedestrian volumes and the level of accidents at the intersection. If turning volumes are relatively low and pedestrian volumes and accidents are high, free right and left turns should be restricted. Simplifying the intersection from three or four phases to two phases will also help simplify turning movements and allow pedestrians to face fewer turning conflicts during the green phase of a traffic light.

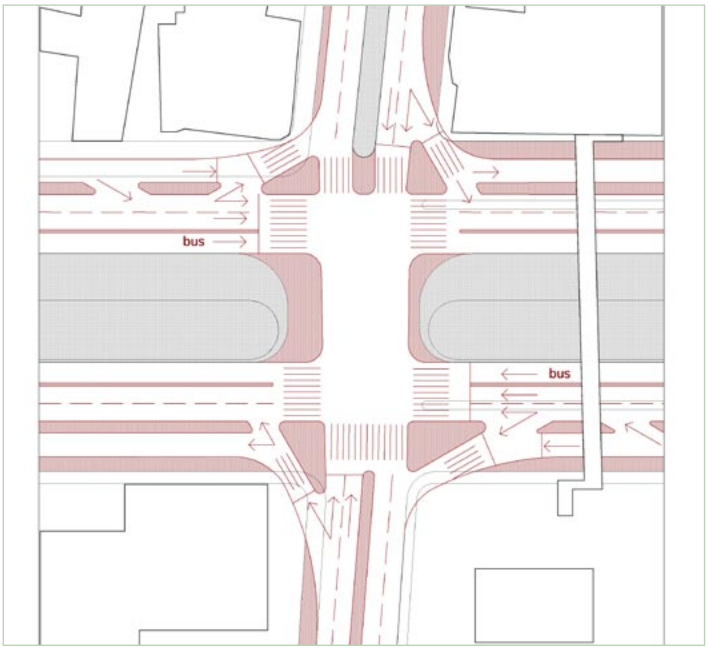
A novel technique to reduce pedestrian exposure at intersections is the leading pedestrian interval (LPI). An LPI re-times the signal phasing so that a pedestrian-only phase begins

Fig. 13.38 and 13.39

A poor-quality intersection prior to the development of the TransJakarta BRT system (left photo). A potential solution to this intersection includes the introduction of pedestrian islands (right image).

Photo and image courtesy of ITDP





a few seconds before the vehicular phase. Typically, this permits a pedestrian to get halfway across the street and establish presence in the crosswalk before vehicles start turning, thus increasing the chance that drivers will yield as required. Figure 13.41 shows the pedestrian phase of an LPI. Figure 13.42 shows the pedestrian plus vehicle phase, at which time all of the pedestrians have cleared the intersection.

An analysis of 10 years of crash data from New York City shows that intersections with LPIs have 26 percent fewer pedestrian injuries and those injuries are 36 percent less severe (King, 1998). Data from San Francisco (USA) show that 89 to 98 percent more drivers yielded to pedestrians after LPIs were installed (Fleck, 2000). Data from St. Petersburg (USA) show that 95 percent more drivers yielded to pedestrians after LPIs were installed (Van Houten, 2000). LPIs are relevant to BRT in situations where customers are accessing the median public transport station from an at-grade crosswalk located at an intersection.

Separating pedestrians and motorists through grade-separation

One of the most controversial aspects of BRT planning is how to get pedestrians to a BRT station in the middle of the road safely without significantly compromising mixed traffic flow. Though accessing a BRT station in the road median can be a challenge, it is no more challenging than getting pedestrians across the street safely. The most significant BRT access decision is typically whether to utilise at-grade crossings (street level crosswalks) or grade-separated infrastructure (overpasses or tunnels). Crossing at-grade over multiple traffic lanes with no pedestrian refuge islands is often unsafe and may be a psychological disincentive to using the BRT facility. By contrast, with grade separation, the exposure risk to pedestrians is effectively minimised. Grade-separated crossings also incur fewer delays to the BRT system itself due to customer entry. Grade separation can be done by forcing pedestrians to use overpasses or underpasses, or it

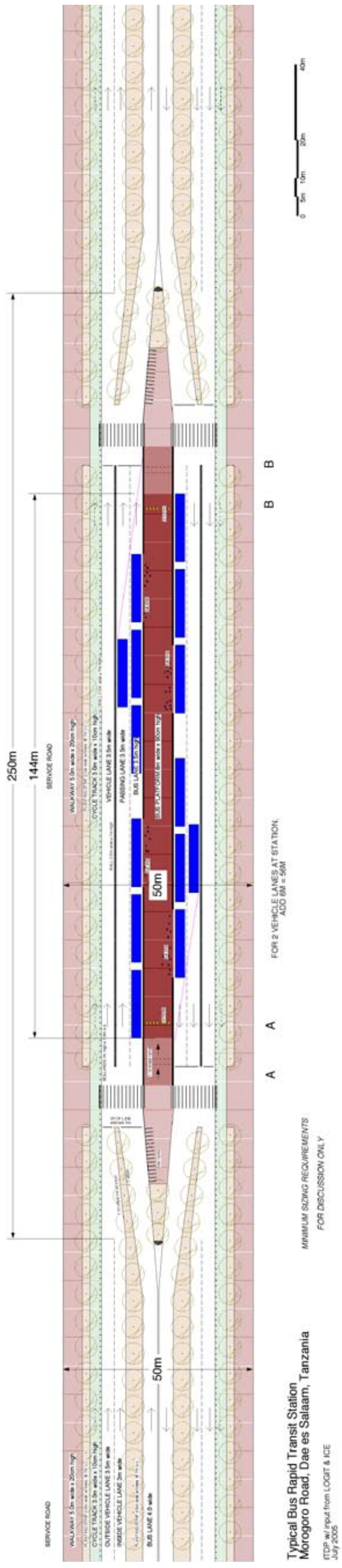


Fig. 13.40
The Dar es Salaam BRT system will include a median strip that will double as a pedestrian island, facilitating safer crossings for all pedestrians.
Image courtesy of the Dar es Salaam City Council

Fig. 13.41 and 13.42
Pedestrian and vehicle phases of a leading pedestrian interval (LPI) in New York City.
Photos by Michael King

can be done by forcing the road to pass under or over an at-grade pedestrian crossing.

In general, pedestrians prefer at-grade crossings due to the directness of the access and the inconvenience of climbing up stares or ramps (Figure 13.43). Elevators, escalators, and ramps with a low gradient partially mitigate the problems with grade separation. Further, there can be safety and security issues related to overpasses and tunnels. Pedestrians, and especially women, often feel vulnerable walking along overpasses and tunnels. The narrow confines of these spaces and infrequent usage mean that criminals have greater opportunities for theft and assault. Overpass and underpass walkways which are more heavily utilised are also frequently infringed upon by informal vendors, which further narrows the space and slows walking speeds (Figure 13.44). Poorly maintained infrastructure with graffiti and litter will discourage potential customers from utilising the public transport system. If the overpass or underpass requires walking up and down stairs, then many individuals will simply not be able to make use of the infrastructure (Figure 13.45). The physically disabled, elderly, and parents with strollers will essentially lose access to the public transport system.

Fig. 13.43
Due to their ease of use and directness, at-grade crossings are almost always the preference of customers.
Photo by Lloyd Wright

Fig. 13.44
A pedestrian bridge in Dhaka (Bangladesh) is crowded with vendors, and thus limits and discourages passenger use.
Photo by Lloyd Wright

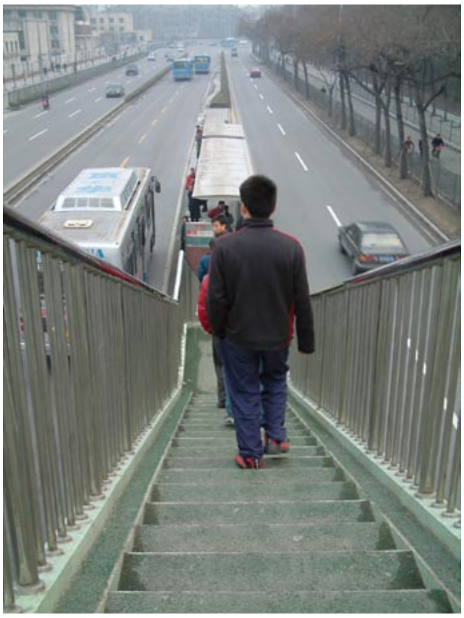


Fig. 13.45
A steep, narrow stairway in Beijing makes for poor accessibility to the busway.
Photo by Lloyd Wright

Pedestrian overpasses in the absence of a BRT system are frequently underutilised because it is frequently much faster to cross at grade and because users feel vulnerable to criminal activity. Studies indicate that as the additional time required by an overpass approaches 50 percent longer, almost no one will utilise it. Usage of underpasses (tunnels) was even less (Moore and Older, 1965). While grade-separated infrastructure is often built under the pretence of pedestrian "safety", in reality, roadway engineers

Fig. 13.46
This overpass in Mexico City is virtually ignored as most pedestrians choose to cross directly.
Photo by Michael King

Fig. 13.47
With traffic stopped at a signal crossing in Jakarta, pedestrians find it easy to cross without use of the overpass.
Photo by Walter Hook

may simply want to give priority to motorised vehicles over persons (Figure 13.46 and 13.47).

However, there are conditions where vehicle topography, vehicle speeds and traffic levels make grade separation a reasonable option. If a closed BRT system can only be accessed from a pedestrian overpass, at least the BRT passengers will use the overpass. This usage alone will guarantee a certain minimum amount of traffic, which will reduce the feeling of insecurity to criminal activity. If the median station is flanked by high-volume, high speed multiple lane expressways far from any intersections, then the constant flow of high speed vehicles will be almost impossible to cross. Adding a signalised pedestrian crossing phase mid-block on such a facility may not be respected by motorists, creating unsafe conditions. In such circumstances, an overpass or underpass can be a reasonable option. Further, with high quality design standards and reasonable gradients, many of the problems of grade separation can be overcome. The conditions that may imply the need for grade-separated access to a median BRT station include:

- Three lanes or more of traffic to cross per direction without pedestrian refuge islands along a high-volume and high-speed arterial or expressway (Figure 13.48) ;
- Connecting an underground subway station to a median BRT station (a tunnel will be most effective in this situation);
- Overpass or underpass leads directly to a high-demand destination such as a sports facility, school, or shopping complex (Figure 13.49);
- Distance to nearest major intersection is far, so traffic flow is nearly constant;
- A culture of driving behaviour which does not respect traffic signals;
- If the street network funnels people to a bridge or tunnel, then they will be more inclined to use it.

While even in some of these situations there are frequently design solutions that could make at-grade crossing reasonably safe and feasible, pedestrian overpasses in these conditions are a reasonable option, and may even be preferred by pedestrians since it may reduce overall crossing time and improve the walking environment.

By contrast, the type of conditions that will favour an at-grade solution include:

- If the street has two lanes of less per direction, then an at-grade solution is almost always preferred;
- If traffic volumes are light and speeds are relatively slow (less than 40 kph);
- If there is a traffic signal within 200 metres of the crossing location, then gaps will be

Fig. 13.48
In conditions where the BRT station is in the median of a multi-lane expressway, Bogotá utilises a pedestrian overpass.
Photo by Lloyd Wright

Fig. 13.49
This elevated pedestrian passage directly links the Nagoya BRT system to the Nagoya Dome sports stadium.
Photo by Lloyd Wright

Fig. 13.50, 13.51, and 13.52
Bogotá utilises a variety of pedestrian access techniques, depending on the local circumstances. Clockwise from top left:
1. At-grade crossing
Photo by Carlos F. Pardo
2. Pedestrian overpass
Photo courtesy of TransMilenio SA
3. Underground tunnel
Photo by Carlos F. Pardo

created in the traffic flow, and pedestrians will subsequently tend to eschew an overpass;

- If the network is more of a grid system with multiple paths, then people will want to cross the street as soon as they get to it.

A BRT system may use both at-grade and grade-separated solutions, depending on the local design and street features. Bogotá, in fact, uses multiple mechanisms to facilitate pedestrian access (Figures 13.50, 13.51, and 13.52).

Designing effective grade-separated infrastructure

The design of Bogotá's overpasses demonstrates how an effective grade-separated solution can be achieved. To enter the overpass, Bogotá provides a ramped entry with a sufficiently gradual slope to ease the climb. Passengers typically also have the option of a stairway if they wish to access the overpass more quickly. Utilising a 2.5 metre-wide pedestrian space and an open design, Bogotá's pedestrian bridges alleviate many of the security concerns normally associated with overpasses. The design is also quite aesthetically pleasing, which further enhances the overall image of the system. When designing grade-separated pedestrian access, the following design considerations should be considered:

- ***Illumination*** – overpasses and tunnels should be well lit; otherwise, evening usage will fall dramatically;
- ***Visibility*** – There should be clear lines of sight between the bridge or tunnel, station and street; without clear sight lines, pedestrians will fear that criminals are lurking in hidden spaces;
- ***Width*** – Overpasses and tunnels should be wide enough to accommodate the peak hour number of people;
- ***Ramps, escalators, or elevators*** – The overpass or tunnel should be accessible to a person in a wheelchair, a parent pushing a baby carriage, someone with a bicycle or packages, or one who has trouble climbing stairs; if elevators are used, stairs must also be provided for circumstances when the lifts are not functioning;
- ***Flood protection*** – Tunnels must be supported by an effective drainage plan;
- ***Vendors, graffiti, homeless, etc.*** – If the bridge or tunnel is perceived as unsafe or unclean it will not be used, regardless of the design.

The aesthetic design of the pedestrian infrastructure will affect a system's overall image and therefore part of the system's ability to attract customers. If the access infrastructure looks pleasant and inviting, then more people will place confidence in the system. Figures 13.53 and 13.54 illustrate visually-appealing examples of overpass design.

Designing effective at-grade BRT access

Pedestrians need time to cross a road safely that is directly proportional to the width of the road.

Fig. 13.53
A park-like environment makes this pedestrian overpass in Guangzhou (China) more inviting.
Photo by Michael King

Fig. 13.54
The modernistic design of this pedestrian overpass in Seoul makes for a captivating sight.
Photo by Lloyd Wright

When the BRT station is at or near an intersection, pedestrians can cross with the rest of the traffic during the green signal phase. Measures suggested above for safe intersection design are generally applicable: elevating crosswalks across slip lanes to slow speeds, providing additional pedestrian refuge space, tightening vehicular turning ratios through "pork chop" slip lanes, extending medians, reducing the distance between curbs, etc.

Frequently, however, there are advantages of locating the station away from the intersection. This arrangement is generally done to avoid interference between public transport vehicles queuing to cross the intersection and public transport vehicles queuing to pick up and discharge passengers. Pedestrian facility designs for a mid-block BRT station have a few particular characteristics.

When the BRT station is mid-block, a few additional points need to be made. Pedestrian crossings mid-block are somewhat unexpected, so features which signal to the driver that they are approaching a pedestrian crossing are more important. A slow bump before the crosswalk will force motorists to slow down before they reach the crosswalk, rather than once they are already about to collide with the pedestrian. An elevated crosswalk will also help to slow the traffic down. Additional pedestrian refuge islands between lanes will further slow traffic by narrowing lane widths while also reducing the pedestrian exposure time. Using different surface colours and textures will draw further attention to the motorists. Lighting at the crosswalk is important at night.

Several different types of signalling options may be employed at mid-block crossings. In some countries, where pedestrians only have to cross two lanes, and where speeds and vehicle volumes are not that high, no signals at all are necessary. With higher volumes and higher speeds, and more lanes, a simple flashing yellow signal is sometimes used to indicate that pedestrians have priority at all times (Figure 13.55). In this case, if a pedestrian appears on the sidewalk near a crossing, then motorists have the obligation of stopping, even if the pedestrian has not yet entered the crossing area. This approach has the benefit of not impeding traffic except when pedestrians need to cross. If pedestrian volumes are very high, this could have adverse affects on mixed traffic. The effectiveness of this approach will also depend on the local culture and the level of enforcement.

The signal can also be controlled by a request button on the sidewalk. In these instances, the cycle for vehicles will be shortened when a pedestrian activates the button. In developing countries, such signals have a high frequency of failure and sometimes are not respected by motorists.

As traffic speeds, volumes, and lanes increase, the need for standard red-yellow-green signals mid-block also tends to increase. Pedestrian

Fig. 13.55
In London, a pedestrian crossing with a flashing yellow light means that pedestrians have complete right of way.
Photo by Lloyd Wright

minimum green times for crossing roads are nearly proportional to the total width to be crossed. Traffic delay is roughly proportional to the amount of red signal time given to the mixed traffic. For mid-block signals, it is generally possible to only signalise the crossing for the mixed traffic lanes, allowing public transport vehicles to continue without a light. Pedestrians then cross the busway whenever a gap appears. At higher bus volumes, though, the public transport vehicles should also be controlled by a traffic signal.

The mixed traffic signal will be a two phase signal and it should be timed to correspond to the red and green time at the nearest intersection. In this way, most motorists will only have to stop once at either the pedestrian crossing or the intersection, but not twice.

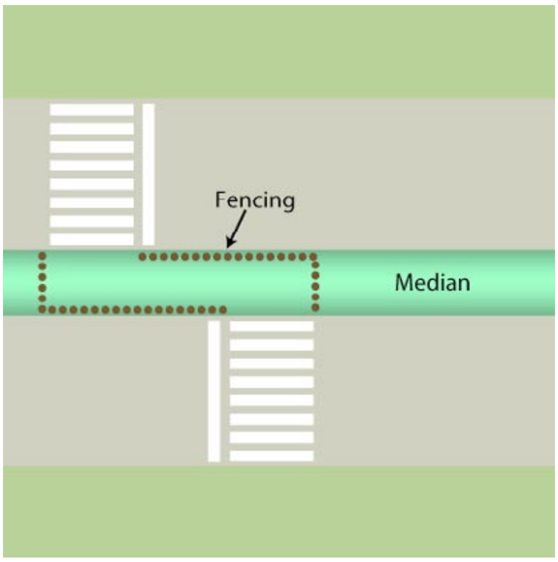


Fig. 13.56
Separating the pedestrian crossing into two separate phases may improve intersection efficiency for mixed traffic, but it may delay and frustrate pedestrians.

Some cities have split the signal phasing for the pedestrian movements into two separate movements, one for each half of the road. In other words, instead of mixed traffic in both directions facing a red time of 40 seconds (green for pedestrians) to allow a full pedestrian crossing, two separate signals with 20 seconds of red time are utilised. Splitting the pedestrian crossing into two separate independent signals allows the lights to be adjusted to maintain a green wave on each direction, lessening the impact for general traffic. Figure 13.56 provides an illustration of this configuration.

However, by splitting the crossing, the planner is effectively giving priority to mixed traffic vehicles at the expense of pedestrian convenience. Forcing the pedestrian to wait through two separate signal phases can lead to higher levels of non-compliance and accidents amongst pedestrians, especially for pedestrians not entering the BRT system and simply wanting to cross the full intersection. The fences that attempt to force pedestrian behaviour are frequently disparaged as “cattle pens” due to the implicit priority the design gives motorists

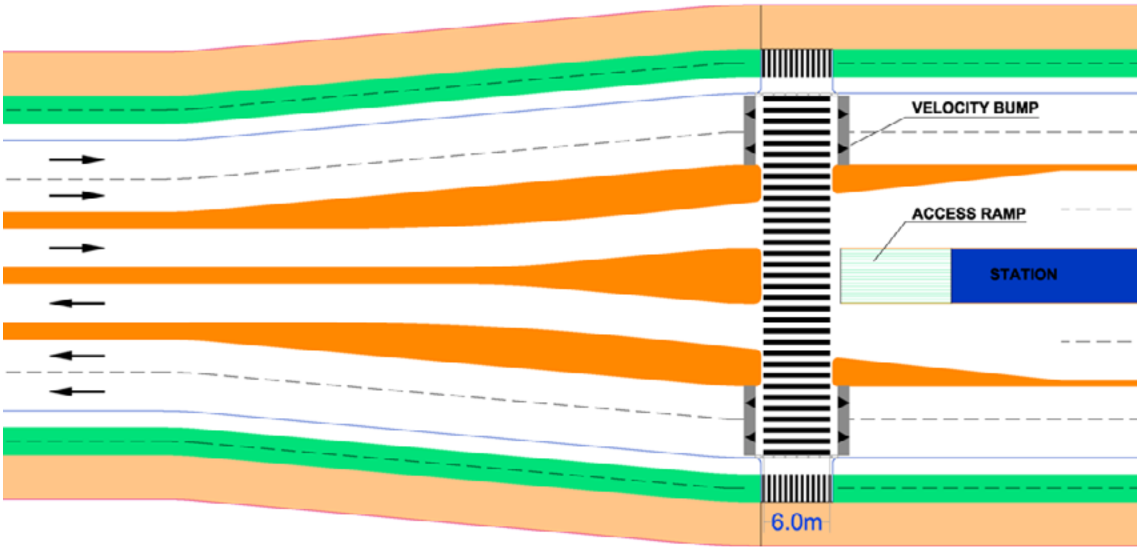


Fig. 13.57
When passing lanes are required at stations, it is recommended to include pedestrian islands between the busway and mixed traffic lanes.
Image courtesy of ITDP

over the pedestrian. In many cultures and situations, pedestrians will attempt to run across the intersection rather than be forced to wait through two signal phases.

On BRT systems with very high demand (over 10,000 pphpd), an overtaking lane is required at each station in order to allow multiple stopping bays. The BRT system therefore will occupy more right-of-way throughout the length of the station, which may be as long as 200 metres. By simply extending this additional right of way by a few additional metres, (shown in orange in Figure 13.57) an additional pedestrian refuge island can be created between the BRT lanes and the general traffic. This refuge allows pedestrians to cross only two lanes at any given time, instead of three. This island can be dimensioned to a convenient size for the projected passenger demand.

Finally, at-grade crossings should be placed as close to the station entrance as possible. Otherwise, customers may simply cross at an uncontrolled point closer to their intended destination. Figures 13.58 illustrates poorly placed crossings, in which the crossing is 100 metres away from the station. Passengers must walk 100 metres down the roadway and then 100 metres back to access a point that is actually less than 12 metres from their starting point. Figure 13.59 indicates the likely result of expecting the pedestrian to make a substantial detour. Quito's "Blue Heart" (Corazones Azules) programme places a blue heart in the street wherever a pedestrian has been killed. In the case of Figure

Fig. 13.58
This pedestrian crossing in León (Mexico) is 100 metres away from the BRT station, and thus will tend to encourage some persons to cross nearer to the station without a crossing.
Photo by Michael King

Fig. 13.59
These two "Blue Hearts" in Quito mark the spot where two pedestrians lost their lives while taking the most direct route to the BRT station.
Photo by Lloyd Wright

13.59, two different pedestrians were struck down while taking the most direct route to the Quito BRT station. Planners should strive to fully account for likely human behaviour whenever designing a pedestrian crossing.

13.2.5.5 Driver and pedestrian predictability

Promoting predictable pedestrian and motorist behaviour at stations

Station areas are prone to unpredictable pedestrian behaviour as customers have a tendency to run to catch an approaching bus or train without paying close attention to signals (Figure 13.60). Motorists may not be expecting this type of pedestrian movement, particularly in mid-block locations. Motorists may also not be expecting traffic lights at mid-block. At intersections, complex and badly timed turning movements sometimes give pedestrians the false security of a crossing light precisely when left turning vehicles are dashing across the crosswalk with their attention focused on the oncoming traffic. Counter-flow bus lanes may also confuse pedestrians and motorists. Thus, unpredictable movements often carry with them lethal consequences.

Pedestrian violations of crossing at red signals can best be avoided by timing the traffic signal to provide more frequent, shorter cycles. The likelihood of compliance with pedestrian signalisation falls greatly if wait times exceed 30 seconds (Table 13.3). In a similar fashion, elevators are generally designed so that people do not have to wait more than 30 seconds. The concept of pedestrian delay applies primarily to traffic signals, but also to gaps in traffic and to crosswalk location. Where there are no signals, pedestrians generally must wait for a "gap" in traffic to cross the street. If the flow of traffic is so great that sufficient gaps are not available, then the person afoot will attempt to cross the street dangerously.

Fig. 13.60

In Quito, customers rushing to catch a bus are at risk from passing motorists.

Photo by Lloyd Wright

Table 13.3: Pedestrians Patterns per Delay (TRB, 2000)

Pedestrian Delay (seconds)	Likelihood of Non-compliance
<10	Low
10–20	
21–30	Moderate
31–40	High
41–60	
>60	Very High

Some physical barriers to inhibit this movement can also be used. Driver unawareness of mid-block pedestrian crossings can best be avoided by combining the mid-block crossing with clear signals, traffic calming measures like speed bumps, as well as vivid visual clues. Pedestrian conflicts at intersections can best be mitigated

Fig. 13.61

This BRT identification post in Quito is placed in a pedestrian island, and acts to block the pedestrian's view of both oncoming mixed traffic as well as oncoming BRT vehicles.

Photo by Lloyd Wright

Fig. 13.62 and 13.63
Pedestrian refuge island, with and without lighting, Guangzhou.
Photos by Michael King

by simplifying the turning movements to two or three phases, restricting free right or left turns where possible, including slip lanes where possible, and using the physical measures described above.

Sight lines and visibility

The areas to the side of the roadway should allow for clear visibility, so that the sight lines of both pedestrians and vehicle users are unimpeded by signage or vegetation. Often, street landscaping is the focus of landscape architects who pay little attention to the median or the side of the road as a place for pedestrians, and place plants along the roadway that fully obstruct pedestrian sight lines. Likewise, signage from the BRT system should be carefully placed to avoid obstructing pedestrian sight lines (Figure 13.61).

The crossing's painted surface should be highly visible and well maintained. Luminescent paints or reflectors can provide additional visibility for evening hours. Additionally, high illumination street lighting should be placed over the crossing area. In contrast, signage and advertisements can create an area of visual clutter that will distract motorists from seeing traffic signals and pedestrians properly, and should be avoided to the extent possible.

Figures 13.62 and 13.63 illustrate the value of good illumination. In the case without illumination, drivers cannot tell if there are people waiting on the pedestrian island, which makes it nearly impossible to predict what is going to happen.

13.2.6 Pedestrian level of service

"All walking is discovery. On foot we take the time to see things whole."

—Hal Borland, author, 1900–1978

Walking in the right environment can be more than a means of going from one place to another; it can also be a desirable activity for its own sake. Much can be done to improve the quality of the walking environment that will simultaneously encourage people to use public transportation.

13.2.6.1 Effective width of footpath

Starting with the basic pedestrian facilities audit described previously, a more detailed audit will note each obstruction found along the footpath as well as record the remaining width. Figure 13.64 shows an audit sketch of a footpath in Bangkok. While the footpath itself is 5 metres in width, many obstructions line the route. These obstructions include signage, utility boxes, bus stands, telephone booths, stairways, and poles. Due to the presence of these obstructions, the "effective width" of the footpath is just 1.4 metres.

The notion of effective width is central to footpath usability. The effective width affects issues

Fig. 13.64
An audit of this footpath in Siam Square, Bangkok, indicates that obstructions have reduced the effective width from 5 metres to less than 1.5 metres.
Image courtesy of the Bangkok Metropolitan Administration

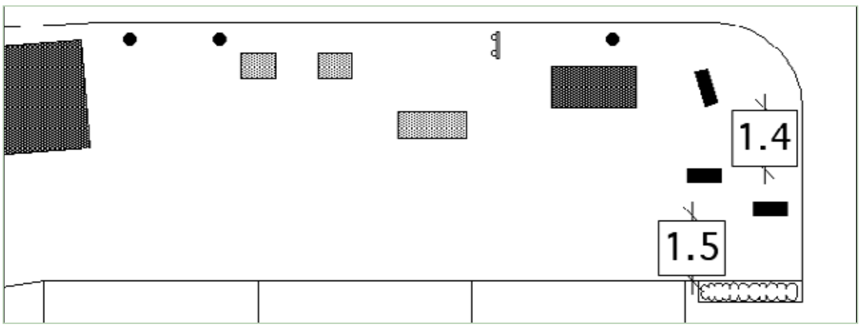


Fig. 13.65
This footpath in Rio de Janeiro provides ample space for high pedestrian volumes.
Photo by Michael King

Fig. 13.66
These steps in Brasilia (Brazil) reduce the effective width of the footpath to less than 0.5 metres.
Photo by Michael King

such as footpath capacity, pedestrian comfort, and personal security. Figures 13.65 and 13.66 give two different examples of effective width.

13.2.6.2 Walkway level of service

Just as a public transport corridor is designed to handle a particular passenger volume, a pedestrian corridor also possesses an inherent capacity. During peak periods, pedestrian path volumes can easily be reached. If pedestrian conditions become too closely packed, then the desirability of walking is compromised. Such conditions will delay overall travel times as well as create the opportunity for crime such as pick-pocketing.

Walkway level of service (LOS) is a scaled measurement which quantifies the flow of pedestrians in a given walkway width. It is most applicable to footpaths, corridors and bridges with high pedestrian volumes where the essential concern is the provision of sufficient space. Calculating LOS requires two inputs: effective width and number of pedestrians per hour. A pedestrian facility provides a high LOS if few pedestrians are present.

Figure 13.67 visually shows the range of area needed per person under average and platoon conditions. Platoons are created when a group of pedestrians is released en masse by crosswalk signals, public transport doorways, or other temporal displacements. A platoon of walkers requires more space than if the same number of people were spaced evenly throughout a footpath. When two platoons meet each other, as in a crosswalk, the spatial requirements are even greater.

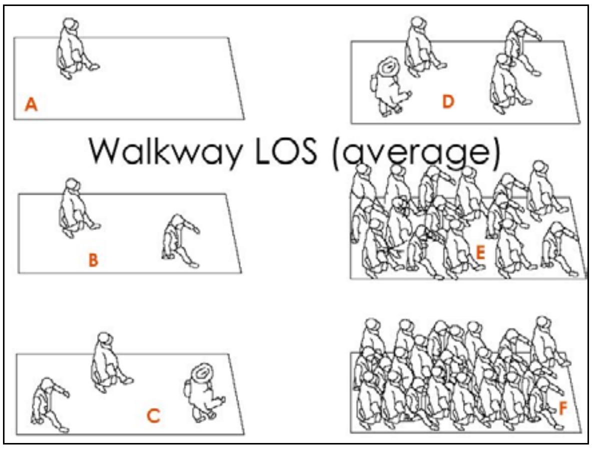
Box 13.3 outlines a methodology for determining a broader "pedestrian level of service". These types of methodologies can be useful as checklists for ensuring all relevant design factors are considered.

Fig. 13.67
Walkway area as a function of pedestrian volume.
Source: TRB (2000)

Walkway LOS

	Average	Platoon
A	> 5.6	> 49.2
B	> 3.7 - 5.6	> 8.4 - 49.2
C	> 2.2 - 3.7	> 3.7 - 8.4
D	> 1.4 - 2.2	> 2.1 - 3.7
E	> 0.7 - 1.4	> 1.0 - 2.1
F	<= 0.7	<= 1.0

square meters per person



Box 13.3: Pedestrian level-of-service model

The city of Kansas City (USA) has developed a pedestrian LOS model based on five specific measures: Directness, continuity, street crossings, visual interest and amenity, and security. The five measures essentially ask five questions:

1. Does the pedestrian network provide the shortest possible route to the transit facility?
2. Is the pedestrian network free from gaps and barriers?
3. Can the pedestrian safely cross streets?
4. Is the environment attractive and comfortable, offering protection from harsh conditions?
5. Is the environment secure, well lit with good line of sight to see the pedestrian, and far away enough from vehicular traffic to provide a feeling of safety?

While Kansas City developed these measures for citywide use, the points below are tailored for use in station access planning.

- Directness: The measure of directness is simply how well key destinations (*e.g.,* schools, parks, commercial centers, or activity areas) are connected to the transit facility via the pedestrian network. The directness LOS is based on a ratio of the actual distance and minimum distance between two points. To determine the Directness Ratio, measure the actual distance between a representative key destination and the transit facility and divide it by the minimum distance between those two points.
- Continuity: Continuity is the measurement of the completeness of the pedestrian network with avoidance of gaps and barriers. The measure considers not only accessibility for the physically disabled, but also the condition of the pedestrian pathways and whether there are barriers in the pathway (*i.e.,* light poles in sidewalk, newspaper vending machines, etc.). This measure requires a field survey of the most logical routes to the transit facility from key destinations.
- Street crossings: This is the measurement that predicts how easy and safe it will be for a pedestrian to cross various types of streets with various street crossing and intersection designs to reach a transit facility based on Pedestrian Level of Service (LOS). The Pedestrian LOS is dependent on the type of crossing, the number of lanes to cross, lane widths, parking lanes, travel speed and the presence or lack of attributes listed above. As design elements and features are reduced, parking lanes exists, higher speeds are estimated, and/or additional lanes to cross are increased, the LOS is reduced. Some of the key measures of a crossing's effectiveness include:
  - How many lanes must the pedestrian cross to reach the transit facility?
  - Are the signals easily visible to the pedestrian and the motorist?
  - Is the intersection and crosswalk well lit so that the pedestrian is visible (to motorists) at night?
  - What are the walk-times (if any) for each phase?
  - Are median refuge areas available?
  - Are there any amenities, including signing and design features, that strongly suggest the presence of a pedestrian crossing?
  - What are the intersection's sight distances? Sight distance measures the unobstructed view between the motorist and the pedestrian.

13.2.7 Designing for ease of access

"The sum of the whole is this: walk and be happy; walk and be healthy. The best way to lengthen out our days is to walk steadily and with a purpose."

—Charles Dickens, novelist, 1812–1870

A well-designed network for public transport access will encompass both a routing strategy and attention to design detail. As stressed in this chapter, the public transport corridors should extend from the stations well into the communities themselves. A few metres of quality infrastructure around the public transport station do little to attract customers from their homes and offices.

Simple design features such as vegetation, water, pavement tiles, and covered pedestrian walkways can add much amenity value to the customer. Addressing these details is a relatively small investment in comparison to the total investment for the BRT system. However, providing a safe, attractive, and convenient pedestrian environment can deliver significant benefits in terms of customer satisfaction and total ridership.

13.2.7.1 Pedestrianised zones

Pedestrianising pathways leading to the public transport system can be part of a mutually beneficial strategy for both public transport and public space. A pedestrian zone, especially in city centre locations, can do much to concentrate large numbers of customers towards the BRT system. In Curitiba, the central pedestrianised areas lead directly to BRT stations (Figure 13.68).

The public transport system likewise supports the feasibility of pedestrian areas by reducing the demand for city centre parking. Without a high-quality public transport system, it is much more difficult to cater the both space for full pedestrianisation and car access to parking facilities.

13.2.7.2 Covered pedestrian walkways

Some cities now are providing low-cost, covered pedestrian walkways in order to eliminate the disincentive that the weather can bring to walking and cycling. In cities with extreme heat, covered walkways can reduce temperatures by 5 to 8 degrees Celsius, and thus make the difference to the viability of comfortably reaching a BRT station.

13.2.7.3 Urban context

Beyond the technical assessments described above, planning a BRT station requires an understanding of how it fits within the urban context. Key factors which influence the viability of a station include flow, conflicting movements, and detours. An additional element of context is the pattern of land uses surrounding a BRT station, to which the traveller may want to access (the goal of the trip). Historically, segregated land uses were favoured in order to minimise conflicts. Such land-use patterns reduce the opportunities for access, forcing residents to drive to many individual destinations to run errands, attend school or find work. Instead, more mixed land use provides more concentrated origins and destinations, which can be served by a BRT station within walking distance.

Context should also include acknowledgment that many of these factors may be perceived and not actual. Even if a factor is only perceived, the resulting impact will limit the effectiveness of the BRT station.

The documentation of context will be necessarily qualitative. For example, if system users can see the BRT station across a plaza or large street, they will want to find the shortest route there. However, if the paths are organised such that the station is not visible until it is directly accessible, then they will be less likely to take a detour. However, placing the station in a prominent, more visible location will increase its presence, security and use. Ultimately one needs to have a good understanding of human travel characteristics when discussing pedestrian routes to a BRT station (Gehl, 1971).

Fig. 13.68
The pedestrian mall in Curitiba leads directly to the BRT stations.
Photo by Lloyd Wright

Fig. 13.69
As this example from Panama City illustrates, covered pedestrian walkways help to dramatically reduce pavement temperatures and thus make walking more comfortable.
Photo by Lloyd Wright.

13.2.8 Accessibility

"Some do not walk at all; others walk in the highways; a few walk across lots." (from "Walking")

—Henry David Thoreau, author and naturalist, 1817–1862

Accessibility refers to the user friendliness of the system from the perspective of the most physically challenged customers. Designing from the perspective of a parent with a stroller, a child, a senior, or a physically-disabled person can result in good design for everyone. The dominant considerations in accessibility design are overcoming physical barriers, avoiding excessive volumes which may impede timely access, providing a safe route, and minimising conflicts and detours. Accessible design does not end at the station door. There is little value in making station platforms and public transport vehicles friendly to the physically disabled if it is impossible for those individuals to reach the stations in the first place.

Universal design especially helps those with physical, sensory, and cognitive disabilities. Tourists, visitors, and first-time users in effect have cognitive disabilities as have difficulty understanding signs, layout, etc.

13.2.8.1 Customers with limited mobility

The key to providing accessibility to physically challenged customers revolves around providing a level, consistent, and reliable access way. Designing appropriate infrastructure is increasingly being inscribed into law, even for developing-nation cities. While the field of accessibility is still growing, there are some key documents that can help cities with correct design (Rickert, 2006; Venter *et al.,* 2004; Rickert, 2003; Alvarez and Camisão, 2005). This section summarises some of the best practice recommendations developed to date.

For customers using a wheelchair, the Americans with Disabilites Act (ADA) prescribes an effective Paved Accessible Route (PAR). The PAR refers not just to a footpath or an individual walkway, but the entire system providing accessibility to all destinations. Table 13.4 summarises PAR recommendations for walkways and street crossings (Access Board, 2005). The recommendations can also be applied to interior space design issues, such as the width of turnstiles and other access points.

Figure 13.70 shows a good, accessible route to transit. Systems designed to these standards are not only useful to the physically disabled but also to the elderly and parents with strollers (Figure 13.71).

Curb ramps are a basic and yet essential infrastructure component for making public space and public transport more accessible to the physically disabled. The ramps should provide a reasonably gentle gradient to ease usage. Table

Table 13.4: Recommendations to accommodate customers with limited mobility

Factor	Recommendation
Walkways	
Access width	Minimum of 1.2 metre, although it is best to double this width to provide enough clearance for two wheelchairs to pass each other.
Surface	Surface should be stable and firm, and consist of slip resistant material.
Surface transitions	Transitions from ramps to planes should be flush; "Lippage", or changes in elevation that are vertical, may not exceed 6.5 mm.
Vibrations	Materials should be smooth to minimise vibration
Grades	At existing planes with grades of more than 11 percent, a level strip should be provided to serve as a site-specific leveller.
Cross slopes	Cross slopes should be consistent (*i.e.,* planar) and should not exceed 2 percent.
Obstacles	Obstacles, including grates, access covers, poles, parking metres, and bike racks, should be kept out.
Cracks	Maximum width of cracks: • 6.5 mm if vertical, 13 mm if bevelled; • Openings may not exceed 13 mm horizontally; • Must be at least 0.75 m between two horizontal planes; • Over 13 mm must be 1:12, like a ramp.
Crossings	
Curbs	Curbs along the pedestrian route to the transit station should all be ramped.
Corners	Corners should include small curb radii, to maximise visibility of pedestrians to turning drivers.
Ramp slope	The maximum slope of a ramp should be 1:12 and ramp runs should be straight.
Ramp direction	Ramps should be located directly adjacent to crosswalks to avoid the need for turns once a wheelchair is in the street.
Ramp location	Curb ramps should be located within crosswalks, *i.e.,* within the marked pedestrian crossing.
Ramp foot	Include a level area at the foot of the ramp to avoid water from pooling.

Fig. 13.70
Level surfaces can greatly increase the accessibility of transit stations for those with physical disabilities.
Photo courtesy of Queensland Transport (Brisbane, Australia)

Fig. 13.71
Designing for the physically disabled also helps families with strollers and others carrying bicycles or large packages.
Photo by Carlos F. Pardo

13.5 summarises recommended ramp gradients and their associated appropriate uses. In general, a curb ramp should be the same width as the given pedestrian crossing (Rickert, 2006). A narrow ramp could force a disabled user to be unable to complete the crossing. A steep ramp can effectively make it unusable to a person in a wheelchair. Curb ramps should also include protective warning strips that advises users of the ramp's presence and the transition to the roadway.

All physical infrastructure should be designed with the physically disabled in mind. Station and vehicle entry points are critical as well as use of any fare collection equipment. Fare purchasing counters, fare vending machines, fare readers, and turnstiles should consider the usability for persons in a wheelchair. Rickert (2006) recommends the following structural dimensions for counters in order to be wheelchair friendly:

- 800 mm in height;
- 500 mm deep;
- 900 mm wide;
- 1,200 mm of clear space in front.

This Guidebook has stressed the preference for simple platform transfers rather than requiring customers cross intersections, overpasses, or tunnels in order to go from one route to another. This preference carries obvious advantages for the physically disabled who would otherwise require special infrastructure to make any grade-separated transfer happen (Figure 13.72). If grade separated transfers are required, then appropriate mechanisms must be put in place to make such transfers feasible and comfortable for the physically disabled. Elevators are perhaps the most convenient option, although breakdowns and initial costs do not make elevators the perfect solution (Figure 13.73). Often it is best to have another alternative. Ramps with gentle gradients are a solid secondary option in such instances. In some systems a movable platform can facilitate the movement of the disabled up a conventional set of stairs (Figure 13.74). Ideally, such a device can be operated independently by the customer since otherwise long waits for assistance from station personnel can be frustrating for users.

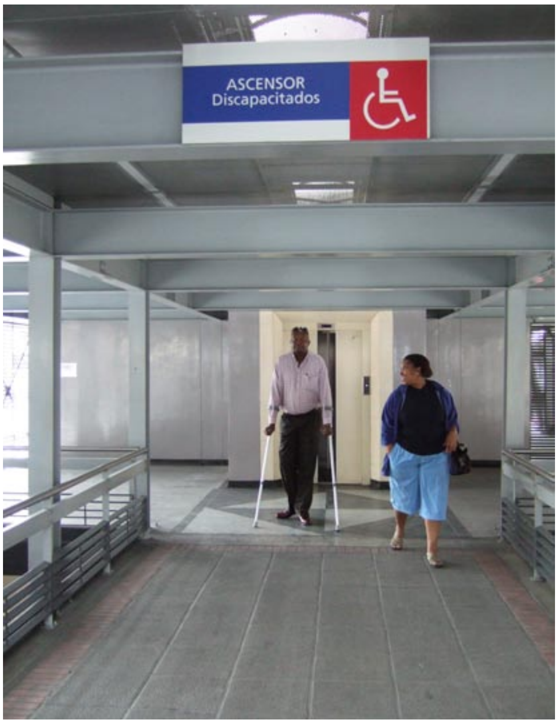
Table 13.5: Ramp gradients and recommended uses

Ramp gradient	Recommended use	Maximum horizontal length
10% (1 in 10)	Very short distances only	1 metre
8% (1 in 12)	Most curb ramps	2 metres
5% (1 in 20)	Ideal gradient	10 metres

Adapted from Venter *et al.,* (2004) in Rickert (2006)

Fig. 13.72
The level station floors and platform transfers in Bogotá make it easy for anyone to move from one route to another.
Photo by Carlos F. Pardo

Fig. 13.73 and 13.74
If grade separated transfers across an intersection are necessary, then infrastructure must be available to make such transfers possible Elevators as in Bogotá (left photo) and movable platforms as in Seoul (right photo) are two of the options.
Photos by Lloyd Wright



However, such devices are susceptible to mechanical breakdown and must be carefully monitored and tested.

Vehicle design is also an area that requires special focus on accessibility issues. The vehicle's entry points and interior design are particularly crucial in user-friendliness for the disabled. As noted earlier, gaps between the vehicle and station platform can dissuade usage for those with wheelchairs and others. A boarding bridge as utilised in cities such as Guayaquil and Quito can be quite beneficial in ensuring easy and safe entry for all.

Most high-quality BRT systems utilise at-level boarding for their trunk corridors (Figure 13.75). Other systems, such as the Kunming system, ply standard stepped vehicles on their principal busways (Figure 13.76). The result is

Fig. 13.75
In cities, such as Bogotá, platform level boarding on trunk corridors makes boarding and alighting easy for those in wheel chairs.
Photo courtesy of TransMilenio SA

Fig. 13.76
Stepped entry into the Kunming BRT system limits who can make use of public transport.
Photo by Lloyd Wright

Fig. 13.77
A manually operated ramp extended from the bus provides access for wheelchair users.
Photo courtesy of City of Seoul

Fig. 13.78
In Nagoya, a feeder vehicle equipped with a flip-out boarding bridge does make boarding easier for many customers.
Photo by Lloyd Wright

that the system is largely unusable to sectors of the community who cannot rapidly manage the series of steps for boarding and alighting.

While BRT trunk corridors typically ensure easy vehicle entry with platform level boarding, feeder vehicles almost always utilise standard stepped-entry vehicles. Thus, despite the good design for accessibility in principal corridors, many parts of BRT systems remain off-limits to those who cannot easily access a standard bus. However, there are some solutions that can make feeder vehicles more amenable to the physically disabled. One option is to utilise low-floor vehicles for feeder services. Low-floor vehicles ease entry for a great number of persons as well as can be combined with a manual ramp to even permit wheelchair entry (Figure 13.77). Special suspension systems, known as “kneeling” vehicles, lower the vehicle close to the curb to further reduce the size of the step.

Another alternative is a higher-floor vehicle with a flip-out boarding bridge (Figure 13.78). While this device does not facilitate wheelchair entry, it does make boarding somewhat easier for the elderly and others who find steps difficult.

However, whenever external interventions are required, such as the driver manually pulling out a ramp, the disabled individual is dependent upon others. Likewise hydraulic lifts are a solution for feeder vehicles that do not have low-floor access, but the operation of the device requires a disruption of the entire service (Figure 13.79). The action of the driver walking to the doorway and manually operating the ramp will create delays for all passengers. This situation can make physically disabled persons feel quite different from others as well as creates feelings of being a burden to the other waiting passengers. For these reasons, entry systems, such as platform level boarding, that give the physically disabled complete independence are much preferred. Creating an environment in which the physically disabled can access the system in the same manner as anyone else is the best solution for everyone.

Fig. 13.79
A special lift allows access for a wheelchair patron to a high-floor feeder vehicle in Bogotá.
Photo courtesy of TransMilenio SA

Fig. 13.80
The blue seats within the Bogota TransMilenio vehicles are set aside for the elderly, children, and pregnant women.
Photo by Lloyd Wright

Low-floor vehicles, especially on the secondary feeder routes of developing-nation cities, also have other limitations. The surface road conditions may make low-floor operations quite difficult and prone to expensive maintenance.

The interior design and space available will also be determinant in the vehicle's usability for the physically disabled. An open area near the doorway ensures there is sufficient space and manoeuvrability for a wheelchair patron. The wheelchair area may also include a tie-down device that will reduce jarring movements during the journey. A tie-down device can be particularly important on hills and curves where the wheelchair may be susceptible to dangerous movement. The space provided to wheelchair patrons also serves a double purpose when not being used by a physically disabled patron. These open areas are quite useful during peak periods for handling large numbers of standing passengers.

Interior seating may also be reserved for special customers through the colour-coding of the seats. For example, blue seats within in the Bogotá TransMilenio system are reserved for certain patrons, such as the elderly, children, and pregnant women (Figure 13.80). Other customers may use the blue seats if there is no one from the designated groups using them. However, passengers are requested to surrender their seats in the event a needier person requires it. The effectiveness of such schemes clearly depends on local customs and culture.

Finally, creating an environment that is access-friendly to all must be based in the management philosophies of the public transport company and must extend to all staff levels. Thus, driver and staff training regarding sensitivity towards

Fig. 13.81
The peak period on Bogotá's TransMilenio is not entirely favourable to customers with special needs.
Photo by Carlos F. Pardo

Fig. 13.82
Raised pavement markings can be a cost-effective way of providing safe access to the sight impaired.
Photo by Lloyd Wright

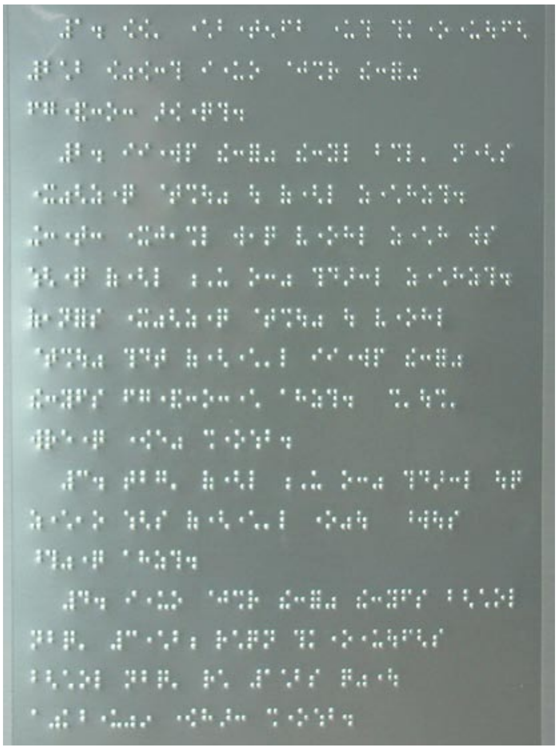


Fig. 13.83
Travel information in Braille helps the sight impaired to plan and undertake their journeys (Nagoya, Japan).
Photo by Lloyd Wright

the needs of the physically disabled must be a fundamental part of employee development. Drivers should be highly aware of the boarding and alighting requirements of the disabled and should conduct themselves accordingly, especially in terms of possibly extending stationary time until a wheelchair customer is securely on-board and other passengers have reach hand grasps.

Catering to the needs of these special customers also provides another reason to avoid overcrowding in the system. A wheelchair user or a parent with a stroller needs additional space within the station and the vehicle. If a system is operating at maximum capacities, these individuals may be stranded at the station platform for a considerable wait (Figure 13.81). Persons should not have to avoid peak periods simply because they have a disability.

13.2.8.2 Customers with limited vision

Like those with limited mobility, customers with limited vision can easily be catered for within a BRT system. Simple design features and new technology can do much to improve accessibility for these individuals. The critical areas for design attention are intersections and the borders between pedestrian accessways and vehicular roadways. Further, design features, such as tactile guideways (*i.e.,* raise pavement markings) can be instrumental in leading those with limited vision to the public transport system (Figure 13.82). Likewise, the ability to access basic travel information through well-placed Braille readers can make a substantial difference in terms of the viability of the system for a sight-impaired person (Figure 13.83).

At intersection crossings with a pushbutton crossing request, several technologies are available to allow a person with limited vision to activate the walk phase. Additionally, these systems also permit the person to sense when the walk phase is active. These options include:

- Accessible Pedestrian Signals (APS);
- Pushbutton locator tones to alert the pedestrian to the audible WALK indication Figure 13.84);
- Vibro-tactile WALK indication (Figure 13.85);
- Tactile arrow;
- Tactile map or pushbutton information message;
- Automatic sound adjustment.

Fig. 13.84
Audible signal at a crossing leading to a BRT station in León (Mexico).
Photo by Michael King

Fig. 13.85
A vibro-tactile pushbutton for requesting a crossing phase.
Photo courtesy of Janet Barlow

Detectable warnings are raised bulges at key locations which alert the pedestrian to a changing condition. These warnings are appropriate to denote station edges and curbs. Geometry and landscape modifications at intersections can also improve accessibility. Design recommendations include providing two ramps per corner, so that each ramp is alighted with the curb ramp on the opposite curb at the intersection. This usually means curb ramps should cross perpendicular to the curb and gutter. However, there are times when the curb ramp should not be perpendicular to the curb and gutter if that tends to send a blind person across the roadway on a path which will not lead to the curb ramp on the other side.

13.2.9 Legibility

Legibility refers to how visually understandable a system is against the backdrop of the urban area. The selective use of appropriate signage and maps contributes to a system's legibility. Likewise, design options such as infrastructure colouring determine how quickly customers understand system information.

With regard to pedestrian access, good legibility can play a role in directing customers to the system. Local route signs along the pedestrian path serves both help the customer find the BRT station as well as direct customers to their destination (Figure 13.86). Thus, the development of a BRT system can be an effective mechanism to upgrade the street legibility along the main corridors of the city.

Fig. 13.86
In Kobe (Japan), distances to public transport stations and other key destinations are provided at the human scale.
Photo by Lloyd Wright

13.3 Bicycles

"When man invented the bicycle he reached the peak of his attainments. Here was a machine of precision and balance for the convenience of man. And (unlike subsequent inventions for man's convenience) the more he used it, the fitter his body became. Here, for once, was a product of man's brain that was entirely beneficial to those who used it, and of no harm or irritation to others. Progress should have stopped when man invented the bicycle." (From "Hovel in the Hills")

—Elizabeth West, author

In a growing number of cities, BRT projects are being used to simultaneously improve the cycling environment. Integrating the design of cycling facilities into the BRT system is as important as integrating the design of facilities for motorised modes of travel. Since cycling generally improves human health through exercise, generates no pollution, reduces a nation's dependence on imported oil, and uses road space extremely efficiently, most cities these days are actively promoting cycling as a viable, sustainable, and low-cost commuting mode.

Feeder bus access to the BRT system is one of the most costly elements of the system, and if a large share of feeder trips can be made by bicycle it will significantly reduce system costs. Most customers will consider the public transport system a viable option if it is within a certain time budget of their home. For instance, individuals may consider a time travel budget of 20 minutes acceptable in reaching a BRT station. Bicycles are capable of covering a distance around five times greater than walking in the same time period. Thus, bicycles present the opportunity to increase one's effective customer catchment area by about 25 times (since area is the related to the square of the distance travelled). Unfortunately, the lack of safe cycling streets and bicycle parking at stations sometimes means that many systems forgo this profitable opportunity.

13.3.1 Bicycle parking facilities

"Every time I see an adult on a bicycle, I no longer despair for the future of the human race."

—H.G. Wells, novelist, 1866–1946

From the cyclist's viewpoint, the best option is to allow bicycles on-board the BRT vehicles, so that the person may use the bicycle to access his or her destination on the other end of the trip (Figures 13.88 and 13.89). The viability of permitting bicycles to be brought on board the transit vehicle depends on the level of crowding on the system and is discussed in more detail in Chapter 12 (*Technology*). Some systems, especially during non-peak hours, permit bicycles to be brought on board the BRT vehicles. This section will review options for bicycle parking at the station area.

Fig. 13.87
A cycle way integrated with a BRT corridor in Eindhoven (Netherlands) helps to maximise the mobility options for residents.
Image courtesy of Advanced Public Transport Systems

Fig. 13.88
The Copenhagen metro system permits cyclists to enter the system with their bicycles. The use of one's bicycle on both sides of the journey is a significant benefit to the customer.
Photo by Lloyd Wright

Fig. 13.89
The Las Vegas MAX BRT system offers special entry points for customers with bicycles.
Photo courtesy of NBRTI

Fig. 13.90
An attractive and visible bicycle parking facility can do much to promote the use of bicycles.
Photo courtesy of TransMilenio SA

The provision of secure bicycle parking infrastructure is essential for cyclists to feel comfortable in leaving their bicycles prior to boarding the system. The challenge with bicycle parking facilities for BRT systems usually relates to the space available. To an extent, the location of the bicycle parking facility can act as a marketing tool to encourage bicycle use. The more visible and attractive the cycling the facility, the more likely it is to gain the attention of potential users (Figure 13.90).

Fig. 13.91
Bicycle parking in front of the Oyumino rail station (Chiba, Japan).
Photo by Lloyd Wright

Fig. 13.93
The upright bicycle parking used in TransMilenio, does save space, but it can be difficult for many to use.
Photo by Carlos F. Pardo

Fig. 13.92
Upon entering the TransMilenio terminal, the customer is provided with a secure bicycle parking areas.
Photo by Carlos F. Pardo

Fig. 13.94
Bicycle lockers provide a highly secure environment for the bicycle, but the lockers can be somewhat costly relative to other options.
Photo courtesy of Cycle-Safe

Fig. 13.95
A self-locking U shaped post is a low-cost and relatively secure option.
Photo by Lloyd Wright

Fig. 13.96
Provision of bicycle parking with only the front wheel locked can be less secure.
Photo by Lloyd Wright

While rail stations in Denmark, the Netherlands, and Japan are often are able to devote considerable space to bicycle parking (Figure 13.91), BRT facilities are typically more spatially constrained. For BRT stations located in the median of the roadway, space may be available in front of or behind the station structure in the median. Underneath the entry ramp of a pedestrian bridge may also be a possibility. Alternatively, bicycle parking could be provided on the curb side of the street. In all cases, the security of the bicycle becomes an over-riding consideration. At terminal sites in particular, BRT systems typically have sufficient space to provide a higher-quality parking area for bicycles.

An area being in view of security staff or public transport staff is preferred since a watchful presence can be a significant deterrent to theft. Security camera coverage of the bicycle parking area is also quite helpful. At the TransMilenio Americas Terminal, bicycle parking is provided inside the terminal, at a point after a person has paid to enter the system and in clear view of the fare collection agent (Figure 13.92).

The type of bicycle parking can also affect security and usability. The upright storage facility shown in Figure 13.93 provides secure parking, but it is quite difficult for children, women, and the elderly to lift their bicycle into position. TransMilenio selected this design to minimise the space required per bicycle, but the end result clearly has disadvantages in terms of usability for some individuals. Another option is known as the bicycle locker (Figure 13.94). The locker is easy to use and provides a highly secure space which controls entry by a key. However, the disadvantage of the locker is its relatively high cost (approximately US$300). Likewise, covered bicycle sheds provide both protection from rain and from theft, but can be costly to construct.

One of the best options for a simple, self-locking device is a "U" shaped tube cemented to the base layer (Figure 13.95). The "U" shape permits secure locking of both the front and rear wheels. Other self-locking devices that only permit the locking of a single wheel are less secure (Figure 13.96). If only one of the wheels can be locked, then the risk of theft will increase.

If a sufficient number of cyclists are utilising the station, it may be economically viable to offer a formal cycling storage area with a permanent attendant. The attendant ensures a secure environment through personal surveillance. Also, a system can be established in which the bicycle can only be taken by providing the appropriate "claim ticket". Financing the operating costs of the storage area (principally the salary of the attendant) can be accomplished in several ways. Preferably the cost is seen as part of the overall service provided to customers and thus included as part of the system's overall operating cost. Alternatively, it would also be possible for the attendant to charge a standard fee to each cyclist to cover the labour cost.

Fig. 13.97
Due to the lack of formal cycleways in Quito, cyclists frequently make use of the busway infrastructure. However, this practice can lead to serious accidents.
Photo by Lloyd Wright

13.3.2 Cycleway infrastructure

"The bicycle is the most civilized conveyance known to man. Other forms of transport grow daily more nightmarish. Only the bicycle remains pure in heart."

—Iris Murdoch, author and philosopher, 1919–1999

13.3.2.1 Basic principles of cycleway infrastructure

The best BRT systems reconstruct corridors not only to put in exclusive busways, but also to significantly increase amenities for cyclists, pedestrians, and mixed traffic. Reaching the station by bicycle can be a challenge if quality cycleways are not provided, and even for passengers wanting to transfer to the BRT system, cyclists are likely to use the BRT corridor for part of this trip (Figure 13.97). It is no coincidence that

Fig. 13.98 and 13.99
It is no coincidence that Bogotá possesses both a world-class BRT system and world-class bicycle infrastructure. The two systems are mutually complementary.
Photos by Lloyd Wright

cities with world-class BRT systems also possess exceptional bicycle networks. Bogotá is home to Latin America's largest bicycle network with some 320 kilometres of dedicated cycleways (Figures 13.98 and 13.99). The new Orange Line BRT system in Los Angeles, the BRT system in Eindhoven, and many other new BRT systems under development also have parallel bicycle facilities along the entire corridor.

Furthermore, just as separating the motorists and the buses can often increase the speed, capacity, and safety of both modes, so too separating facilities for cyclists and motorists can also increase the speed and safety of both in certain conditions. If no cycling facilities are provided, the likelihood of bicyclists using the busway as a bikeway is fairly high, and very difficult to control. Currently, the frequency of bicyclists in the Curitiba BRT system is higher than the frequency of buses, leading to some unfortunate accidents.

For all these reasons, a city planning to build segregated busways should also consider adding cycling facilities when the corridor is reconstructed. Cycling facilities on higher volume, higher speed access roads serving the corridor will also help bring cyclists to the BRT system, and should also be incorporated into the overall system design when possible. The combination of a BRT system with a cycleway network can do much to provide city-wide mobility on a sustainable basis.

The BRT system and the cycleway network should ideally be planned jointly. The planning process should aim to connect major cycleways with BRT stations at strategic locations. The idea is not to force cyclists to transfer to the BRT system but rather to offer the option of a combined public transport-bicycle commute.

Using concentric circles of two kilometres or more from the public transport station, important corridors should be analysed for the quality of the cycling environment. Most of the safety and traffic calming measures discussed in the previous section on pedestrians will not only slow down vehicle speeds but also simultaneously improve the cycling environment. A few simple rules should be considered when planning cycling facilities:

- Cyclists are even more sensitive to road surface than motorists, and prefer smooth surfaces. Cobblestones and rough brick may be aesthetically pleasing but such surfaces can discourage cycling.
- Cyclists want to go straight. Nicely meandering cycle paths often appeal to landscape architects but utilitarian cyclists want to get where they are going as fast as anybody else and do not want to have to meander around trees and park benches.
- Cyclists will not use sub-standard, poorly maintained, obstructed, narrow bikeways. Build high quality level of service A or B bike lanes, or else redesign the road for safe mixed bicycle and motorised vehicle traffic operation.

Fig. 13.100
Cyclists are often quite exposed to delays, safety risks, and high-levels of contamination when confined to using the curb lane.
Photo by Lloyd Wright

Developing an effective cycle way network involves an array of institutional, design, and infrastructure issues. The GTZ Training Course on "Non-Motorised Transport" provides a thorough overview of these issues (Hook, 2005) and should provide sufficient basic guidance for cycling facilities on non-BRT corridors. However, some specific issues with regard to the location of cycleways on a BRT corridor are presented in the next section.

13.3.2.2 Physical design

The physical design of bicycling facilities is an emerging art rather than a science, and much remains unknown about optimal facility design. Relocating buses into the central median already helps to resolve one of the most pressing conflicts faced daily by cyclists. On normal mixed traffic lanes, bicycles are typically required by law to use the curb lane. In the curb lane, cyclists frequently find themselves stopped behind boarding and alighting buses, taxis, parked vehicles, and loading and unloading freight and delivery vehicles. The curb location thus exposes the cyclists to safe risks and high levels of contamination. Further, having a large vehicle bearing down upon a cyclist can also be quite stressful (Figure 13.100). Relocating public transport vehicles out of the curb lane by itself helps increase cycling speeds in a BRT corridor and reduces dangerous conflicts with stations.

Collecting information about existing cycling activity and cyclist behaviour is a useful first step before designing cycling facilities. Methodologies for doing this are roughly equivalent to methodologies for designing pedestrian facilities, starting with a review of existing cycling facilities, the identification of locations dangerous or illegal for cyclists to operate, mapping of popular cyclist OD pairs, identifying major severance problems, reviewing data about locations of high levels of cycling accidents, and targeting interventions to these locations. The methodologies are similar to those described for pedestrians above, and a more complete account is available in Hook (2004). Nevertheless, some specific guidance for BRT corridors is provided here.

BRT corridors tend to be located on reasonably wide primary or secondary urban arterials. In developing countries, which frequently lack a strong secondary road network, these arterials tend to serve a great diversity of trip types, from intercity bus and truck trips to medium and long distance intercity transit trips, to short distance cycling and walking trips. This complex, multi-functionality of a BRT corridor makes road design reasonably difficult. As the right-of-way widens, vehicle speeds tend to increase, and hence the desirability of segregating modes of significantly different operating speeds increases.

Just like motorists on such an arterial, some cyclists are going longer distances and value uninterrupted higher speed travel, while others are only going a short distance and value access to adjacent properties. For motorists on such arterials, this conflict is frequently resolved by providing separate through lanes for long distance vehicular travel and service lanes for property access. Introducing BRT on such an arterial into the central road verge introduces no particular problems for motorists. Excluding cycle tracks, the standard cross section would have bus lanes in the median, then two mixed traffic lanes, and then a median, and then a service lane for local access trips, and then a sidewalk.

The question which has led to considerable debate among the experts is where to put the bicycle lane.

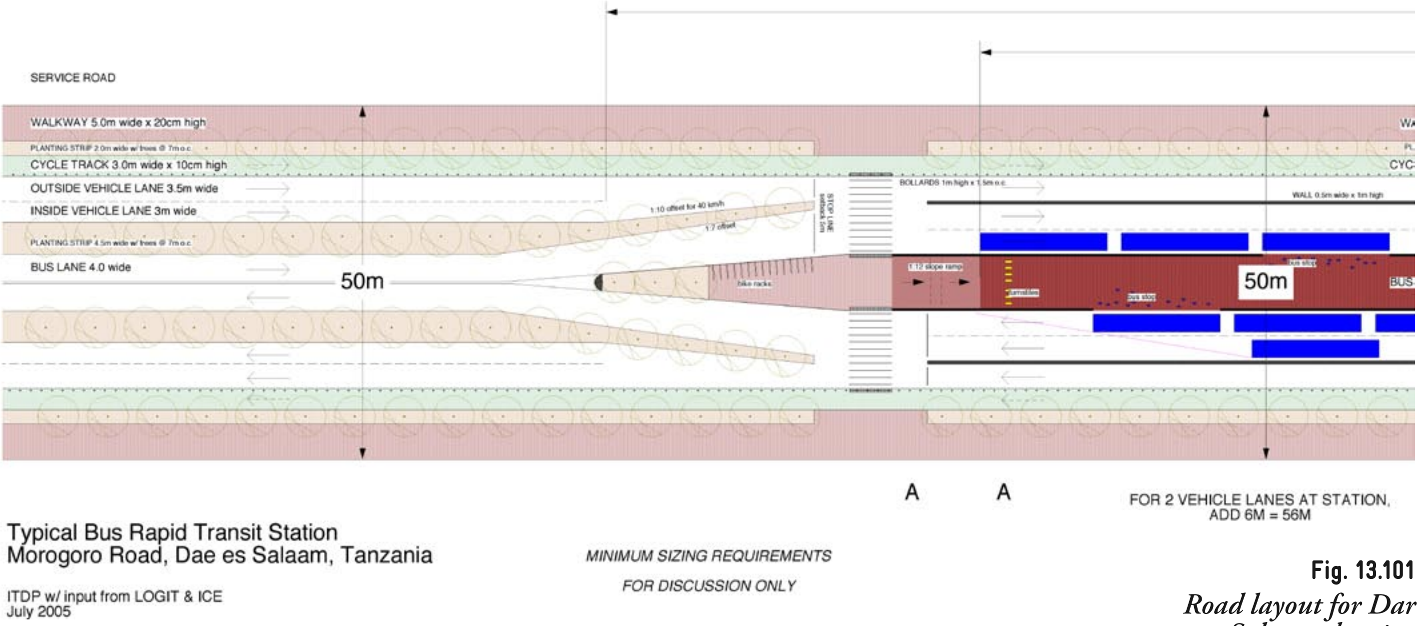


Fig. 13.101
Road layout for Dar es Salaam showing a median busway and a cycleway located between the walkway and the mixed traffic lanes.
Image courtesy of ITDP

Whether or not there is a service lane, the standard location of the bicycle lane has been between the mixed traffic lanes and the walkway. Figure 13.101 shows this configuration for one proposed cross section in Dar es Salaam. This location of the bicycle lane serves well those cyclists making short access trips along the corridor. Normally, curb-side bicycle lanes are built adjacent to the roadway, and sidewalks are built between the bikeway and the building wall. This arrangement occurs because bicycle speed and behaviour is closer to that of motor vehicles than pedestrians. If a cycle lane is obstructed, the cyclist needs to have easy opportunity to enter the roadway, and this access is more difficult if they must also pass through pedestrian flows. For this reason, frequently designers will design the bike lane adjacent to the roadway. The Hangzhou BRT system makes use of this configuration with wide cycleways

Fig. 13.102
The cycleway along the Hangzhou BRT system is sited between the BRT lane and the pedestrian footpath.
Photo by Karl Fjellstrom

Fig. 13.103
Wide cycleways and footpaths allow the two modes to be successfully integrated in Bogotá.
Photo courtesy of Oscar Diaz and Por el País que Queremos (PPQ)

located between the pedestrian footpath and the BRT lane (Figures 13.102).

Some designers advocate putting a line of shrubbery and trees between the bicycle lane and the roadway, and placing the bicycle lane on a high curb on the same level as the footpath. With proper curb cuts at intersections, this design will insulate cyclists from speeding traffic, improve the cycling environment, and prevent motorists and delivery trucks from parking their vehicles on the bike lane. However, this line of shrubbery and trees between the bikeway and the roadway, and the high curb, makes it difficult for cyclists to pass between the bikeway and the roadway in case of an obstruction. In the developing world, obstructions are sadly the rule rather than the exception. If this configuration is used, as in some parts of Bogotá, it should be accompanied by very high grade, wide bicycle ways at minimal risk of obstruction (Figure 13.103).

In Dar es Salaam, where the risk of encroachments by vendors, high pedestrian volumes, utility poles, and building materials from adjacent properties is high, it was decided to put the bike lane on a specially designated raised shoulder of the roadway, and to separate the bikeway from the pedestrian walkway with trees and shrubbery, but not the bikeway and the mixed traffic lanes. Putting the bikeway on a raised shoulder of the roadway makes motorists more aware of the cyclists' presence on the road, which becomes important at the intersections. It also allows the raised shoulder to be used by broken down vehicles if necessary. Placing trees and shrubbery between the bicycle lane and the walkway will help to inhibit encroachments onto the bikeway by pedestrians and street vendors, and allows the cyclists to more easily escape the bikeway in case of an obstruction. This configuration, however, still creates conflicts between cyclists and right turning vehicles, stopping taxis, illegally parked vehicles, and other curb-lane obstructions.

On wider arterials with existing service roads, it is being considered in the Ahmedabad BRT project and the Delhi BRT project to put the cycle tracks on the median between the service road and the mixed traffic lanes, as illustrated in Figure 13.104.

This configuration is generally accompanied by the termination of the service road before each intersection. In this way, the conflicts between many of the stopping and parking vehicles can be avoided as most of these activities will happen in the service lane. Access to the adjacent properties by bicycles can easily be accommodated in the slow moving service lanes. Such a configuration, however, requires a very wide right-of-way. It also fails to resolve the conflicts between cyclists going straight and right turning vehicles at intersections. These conflicts, though, can be resolved through standard intersection treatments.

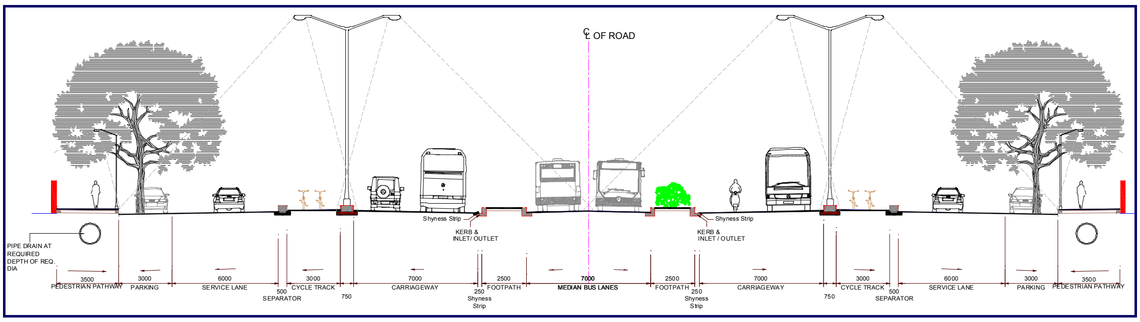
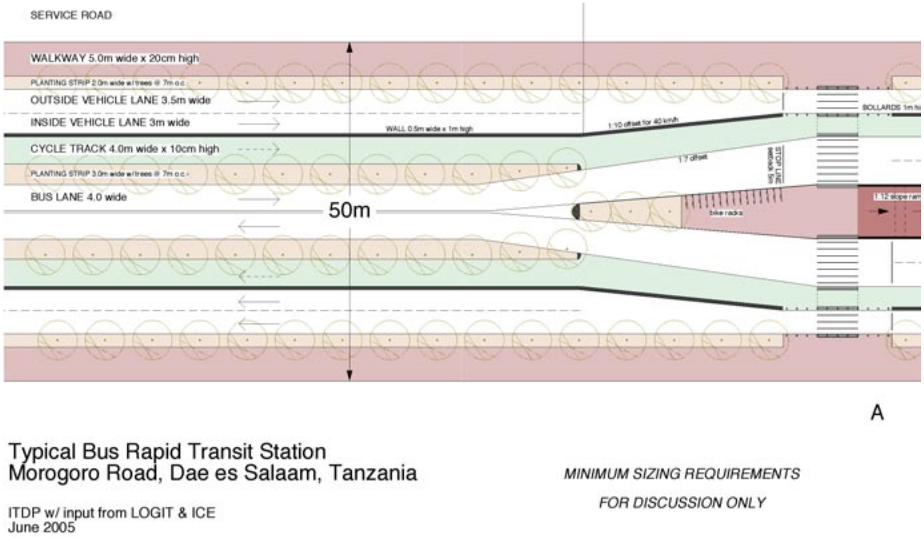


Fig. 13.104
For wide roadways with service lanes, the cycleway can be located between the service lanes and the mixed traffic lanes.
Image courtesy of ITDP



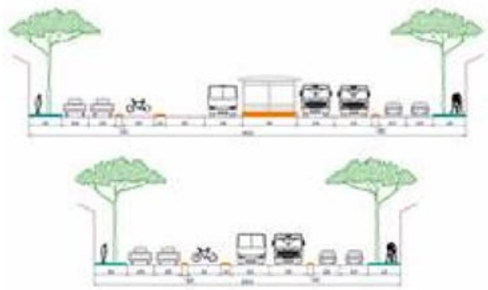


Fig. 13.105
A configuration placing the cycleway adjacent to the median busway potentially carries with it multiple benefits.
Image courtesy of ITDP

Another configuration that has been discussed is to give cyclists the same sort of advantages that buses enjoy from central lane operation: freedom for vehicles going straight at intersections from turning conflicts. Many cycleways in Bogotá are located in the street median, in a manner similar to BRT. Thus, another alternative would be to place the cycleways adjacent to the busway (Figure 13.105).

This configuration would remove many of the turning conflicts between bicycles going straight and turning and stopping vehicles. It would significantly reduce the risk of encroachments onto the bikeway by street vendors. It could provide a very high speed cycling corridor. Bicyclists wanting to make local access trips would simply exit the cycle way at the nearest intersection or pedestrian crosswalk to their destination, and use the service lane or sidewalk for the remaining distance.

13.3.3 Bicycle rental facilities

Increasing the availability of bicycles helps to fulfil the modes usefulness as an integrated component of a public transport trip. In developing-nation cities, bicycles may not be widely available or widely affordable. Further, casual users may not be willing to purchase a bicycle, but could consider short-term rentals. BRT system planners may thus wish to consider providing bicycle rental facilities within station areas. The Osaka Monorail system provides such a service at most of its stations (Figure 13.106). Rental bicycles can also be useful to even existing bicycle owners. If a person is travelling to a destination via the public transport and the ultimate destination is beyond walking distance from the station, the rental bicycle may be the perfect solution as a highly-flexible feeder service. As in the case of the Osaka bicycle model, the availability of a carrying basket helps patrons with briefcases, shopping bags, and other personal items.

On a broader scale, the city of Copenhagen provides “free” city bicycles throughout the urban area, including public transport stations (Figure 13.107). A person only needs to insert a 20 DKr coin (US$3.30) to gain access to a bicycle. Upon returning the bicycle at any station, the coin is fully returned to the user. If the bicycle is parked away from a bicycle station, then anyone can return it and collect the 20

Fig. 13.106
Bicycle rental facilities within stations of the Osaka Monorail provide a cost-effective option for casual users.
Photo by Lloyd Wright

Fig. 13.107
The City-Bike programme in Copenhagen makes bicycles available for "free" at public transport stations and elsewhere in the city.
Photo by Lloyd Wright

DKr coin. The brightly painted advertisements on the bicycles help to pay for maintenance. While bicycle theft had plagued many of the initial attempts at city-bike programmes, modern technology in combination with simple design changes has largely eliminated this concern. The Copenhagen bicycles are fitted with a chip to permit GPS-based tracking. Further, the shape and size of the bicycle components are unique to the City-Bike and thus rendering theft of components to be ineffective (Poulsen and Mozer, 2005). Many other European cities, such as Berlin and Zürich, have similar types of bicycle rental programmes.

In the developing-nation context, bicycle availability and affordability can be substantial barrier to usage. The Institute for Transportation & Development Policy (ITDP) has initiated a programme in conjunction with major bicycle manufacturers to improve bicycle distribution in developing nations. The basis of programme is a low-cost and high-quality bicycle, marketed as the "California Bike", which is designed to meet the requirements of developing city conditions. ITDP and its local partners help small retailers access the "California Bike" and then distribute on an affordable basis to low-income customers.

13.4 Other public transport systems

"I waited and waited on the platform, but the train never came and it seemed odd that no one else was waiting with me… Finally, I went and asked a porter and he indicated to me that I had to take a bus and, when pressed as to where I might find this bus, motioned vaguely with the back of his hand in the direction of the rest of the world." (From "African Diary")

—Bill Bryson, author, 1951–

BRT can also be complementary with other urban and long-distance public transport options. Cities with existing metros and urban rail services should ideally integrate these options with BRT. Cities with water transport systems should also seek to closely integrate these systems with the BRT network.

São Paulo, for instance, uses BRT to connect the end of its metro line with other communities. Some cities with existing metro systems are unable to finance the completion of the metro. In such instances, BRT has been an economical option that will help bring a public transport connection to the entire city.

The key to a successful integration lies in the physical connection between the two systems,

Fig. 13.108
The Brisbane Busway (top centre) is closely integrated with the city's commuter rail service (right).
Photo courtesy of Queensland Transport

Fig. 13.109
The Ozone Station of the Nagoya public transport system represents a nexus of the elevated BRT system, the suburban rail system, the subway system as well as ample provisions for bicycle parking.
Photo by Lloyd Wright

the complementary marketing and promotion of the two systems, and the unification of fare structures. In São Paulo, the physical connection is made simple by ramps departing the metro system leading directly to the BRT system. In Brisbane, the co-location of a BRT station facility with the city's commuter rail service makes for a good deal of customer convenience in moving from one system to another (Figure 13.108). Likewise, in Nagoya (Japan), the Yutorito BRT Line is closely integrated with both the subway system as well as the suburban rail system (Figure 13.109).

Clear signage also helps make this integration relatively seamless. Further, the two systems can be marketed jointing under one name and logo, so that the systems are clearly unified in the eyes of the customer. Finally, an integrated fare structure permits customers to leave one mass transit mode to another without the need of purchasing an additional fare.

BRT should also be integrated with long-distance public transport infrastructure such as long-distance bus stations and train stations. Again, the physical planning of the interface is key to making this option viable. Passengers from such modes often are carrying luggage or goods, and thus particularly need a convenient transfer mechanism.

13.5 Taxis

"Too bad all the people who know how to run the country are busy driving taxi cabs and cutting hair."

—George Burns, comedian, 1896–1996

13.5.1 Car taxis

Car taxis are too frequently seen as competitors to public transport rather than as complementary services that can effectively extend the coverage of a transit system's service area. By developing integrated car taxi facilities in conjunction with BRT stations and terminals, multiple benefits can be achieved.

In many cities of the world, and especially in developing-nation cities, taxis represent a large proportion of the vehicles on the road at any given time. However, taxis spend much of their time in search of passengers rather than providing actual passenger trips. Prior to the introduction of improved taxi ranks and dispatch systems, taxis in Shanghai were estimated to spend 80 percent of their travel time without passengers. Thus, these non-customer trips can add greatly to congestion levels without serving any real purpose.

Developing taxi ranks at public transport stations reduces the need for taxi drivers to operate without passengers. Instead, the passengers come to the taxis rather than the other way around. The strategic location of taxi stands in close integration with BRT stations can thus prove to be a win for system designers, taxi drivers, city officials, and the public (Figures

Fig. 13.110 and 13.111
In cities such as Quito (left photo) and Kuala Lumpur (right photo) the provision of formal taxi facilities integrated with the public transport system provides benefits to the customer, the transit system, and the taxi driver.
Photos by Lloyd Wright

13.110 and 13.111). System designers win by adding another important feeder service to their route structure. The taxi owners and drivers win by dramatically reducing their operating costs. The BRT stations provide a concentration of customers for the taxis without the need to circulate the city expending large quantities of petrol. City officials win by helping to reduce a major factor in urban traffic congestion. And finally, the public wins by having a more flexible and convenient public transport system that also reduces urban emissions and promotes greater overall efficiency.

Any policy affecting taxi operations will require planning and participation from the affected taxi owners. In developing-nation cities, taxi associations can be politically powerful and are often left relatively uncontrolled. Since taxi facilities at public transport stations will likely be perceived as quite favourable to the taxi owners, this infrastructure can be the basis for improved quality control with the industry.

13.5.2 Pedicabs (bicycle taxis)

Modern vehicle designs, escalating fuel prices, and growing environmental concerns have led to a resurgence in pedicabs in many parts of the world, especially in the Western European cities of Berlin, Copenhagen, and London. Pedicabs can make for an almost ideal feeder service to BRT stations, especially trips of 4 kilometres of less (Figures 13.112 and 13.113). Pedicabs are low-cost vehicles that provide high levels of employment while producing zero emissions.

In parts of the developing world, pedicabs have been actively banned in order to make room for more motorised vehicles. Pedicabs were banned in Bangkok beginning in the early 1960s. Subsequent bans have been employed in cities such as Jakarta and New Delhi. However, public attitudes are changing, and the Delhi BRT system has integrated designated pedicab parking into the corridor design. Through a collaboration between the Institute for Transportation & Development Policy (ITDP) and

Fig. 13.112 and 13.113
As evidenced by these images from Bogotá, the pedicab can help form part of a seamless package of integration options for BRT customers.
Photos courtesy of INSSA

several local partners a modernised "cycle rickshaw" (pedicab) was developed for the Indian market. Beginning in the Indian city of Agra in 1998, this initiative, sponsored by funding from the US Agency for International Development (US AID), has quickly spread to many other cities, including the capital of Delhi. The project produced a modern, light weight vehicle at a modest cost (Figure 13.114). Today, over 100,000 modernised pedicabs are plying the streets of Indian cities.

Manila has a long history of pedicab use in conjunction with other public transport options. Additionally, cities such as Yogyakarta in Indonesia are following the lead of the Indian cities and bringing back a modernised version of the cycle rickshaw (known as a "becak" in Indonesia).

A successful pedicab project will likely encompass a range of operational and design components. Some of the features of a modern pedicab initiative will include:

- Modernised, re-engineered or high-technology vehicles (Figure 13.115);
- Dedicated non-motorised vehicle lanes in some areas;
- Formal pedicab stations (Figure 13.116);
- Pedicab system maps;
- Posted fare information;
- Professionalised driver training;
- Driver uniforms.

Fig. 13.114
The modernised cycle rickshaw in India has revitalised the pedicab marketplace.
Photo courtesy of ITDP

Implementing a BRT system at the same time as introducing pedicab services can help both modes. Pedicabs can form a critical part of the feeder service, especially for communities with streets too narrow for buses. It may also be quite possible to integrate the fare of the BRT system with the pedicab fares.

13.6 Park-and-ride

Private vehicle owners can also be successfully integrated with the system through the development of "park-and-ride" or "kiss-and-ride" facilities. These facilities allow private vehicle

Fig. 13.115
Modern pedicab designs help attract both customers as well as advertising revenues.
Photo by Lloyd Wright

Fig. 13.116
Formal pedicab stations, posted fare information, and driver uniforms all help to boost the image of the system.
Photo by Lloyd Wright

users to access the transit system, and therefore complete their total commute by way of public transport. A park-and-ride facility provides a parking garage or parking lot for vehicles to be kept securely during the day. A kiss-and-ride facility does not provide parking but rather includes a passenger drop-off area for private vehicles. A park-and-ride facility should also include space for the kiss-and-ride option.

The benefits of park-and-ride facilities immediately adjacent to a popular public transport station must be weighted against the benefits of alternative uses for this land, such as for commercial development or public amenities. Commercial services and safe and comfortable access for feeder buses, cyclists, and pedestrians should have priority in public transport station design.

Park-and-ride and kiss-and-ride facilities are most appropriate in suburban locations where population densities may be insufficient to justify costly feeder services, and distances are too far to make direct walking and cycling access to the station viable for most people. In developing cities, these conditions will primarily be found in neighbourhoods dominated by affluent households that have sufficient disposable income to own a private vehicle. Attracting this income group to the public transport system can deliver several benefits. First, offsetting private vehicle use pays significant dividends in terms of emission reductions and congestion relief. Second, a public transport system that is of sufficient quality to attract even the highest income groups is a worthy objective. Third, a healthy mix of all a city's income groups in the system means that all political interests will have an incentive to ensure the system's future. Finally, systems which serve all income groups also serve an important social function since the public transport system may be the one location where all segments of society come together.

Fig. 13.117
The park-and-ride facility at the Mo Chit station of the Bangkok Skytrain helps to boost ridership, especially from customers who would normally drive in private vehicles.
Photo by Thirayoot Limanond

The park-and-ride and kiss-and-ride facilities are best situated in suburban locations where land is less at a premium, and where the target customers are encouraged to travel as much of their total trip by public transport as possible. Park-and-ride is less desirable in downtown locations where the parking facility is likely to be used to drive into the downtown. The park-and-ride provided at the Mo Chit station of the Bangkok SkyTrain is quite popular due to its proximity to major residential areas (Figure 13.117). Private vehicle owners are less likely to use a park-and-ride facility if they are driving a substantial distance into the city and then using the public transport only for a small final portion (Figure 13.118). The time and cost of switching to public transport only for the final few kilometres means that few customers will utilise the system under such circumstances. The principal incentive to these customers will be the time savings achieved by the exclusive busways over the main portion of the commute.

The location of the parking facility should be convenient to the station area (Figure 13.119). A long walk may discourage usage from discretionary customers. In cities with frequently unseasonable weather (wind, rain, strong sun), covered walkways in the parking area may be a worthwhile investment. In some areas, it will be necessary to include security measures at the parking facilities. Security measures such as an attendant or security cameras can be effective. If security is insufficient, motorists will choose to use their private vehicle for the entire commute.

Whether motorists should be charged for parking at a park-and-ride facility depends on the location of the facility and the set of incentives in place. Subsidising parking for higher income motorists far from the city centre can be justified because it will encourage motorists to make a long public transport trip, reducing significantly

Fig. 13.118
Proposed park-and-ride facility in Nantes (France).
Image courtesy of François Rambaud

the congestion and air pollution that would otherwise have resulted from the trip. The closer the park-and-ride facility is to the city centre, the less the social benefit, and hence the weaker the justification for a public subsidy.

Parking facilities can be quite costly to develop and construct. Each at-grade parking bay may cost US$3,000 to US$15,000 when land purchase costs are included. Each parking bay within a multi-level parking facility will likely cost in the range of US$20,000 to US$35,000. Costs can be even greater in areas with significant land costs. Thus, it can be quite appropriate to establish a fee for use of parking facilities at public transport stations. The challenge is to develop a fee structure that still provides a strong incentive for using the public transport system.

Fig. 13.119
The parking facility at the Eight Mile Plains station of the Brisbane BRT system provides convenient access for customers.
Photo courtesy of Queensland Transport

14. TDM and land-use integration

"I personally...do not understand why the Czech, European and global ideal is manufacturing an ever-increasing number of automobiles, which presumes the construction of more roads and motorways, and thereby again the irreversible destruction of our country. Are we perhaps happier, merrier, more satisfied? Not at all. We are restless, beaten, weary, incessantly hurrying from one place to another."

—Vaclav Havel, former president of the Czech Republic, 1936–

BRT systems are often implemented simultaneously with restriction measures on private vehicles, as bus speeds can be increased by simply reducing vehicular congestion. For example, Bogotá restricted private vehicle use during peak hours as well as eliminated on-street parking from parts of the city. London too has been a prominent leader in car restriction measures through its application of congestion charging. Transportation Demand Management (TDM) represents a collection of measures and techniques that encourage shifts from private vehicles to public transport options such as BRT. Likewise, land-use policies to encourage development and densification around public transport nodes can do much to incentivise shifts to public transport.

The contents of this chapter include:

14.1 Disincentives to automobile use

"The right to have access to every building in the city by private motorcar, in an age when everyone possesses such a vehicle, is actually the right to destroy the city."

—Lewis Mumford, historian, 1895–1990

BRT inherently changes the regulation of private vehicle use on certain roads. The implementation of a BRT system sometimes requires difficult-to-negotiate changes in how road space is designed and regulated on some streets, particularly on roads through the city centre. Often, traffic planners will advocate underground or elevated systems on the grounds that they do not "disrupt" the conditions on the road surface. However, conditions on the surface roads of most developing-nation cities are far from optimal. BRT, while more socially complex to implement as a result, also offers the opportunity to fundamentally change how surface street space is regulated and organised, with the potential of profoundly improving economic and social conditions in the city.

In order to deliver sustainable high speed bus service, BRT systems need to be protected from the problem of growing private motor vehicle-induced congestion. Because the best BRT systems provide improved services for the largest number of passengers, they tend to be built on urban arterials serving the city centre, where congestion and competition for scarce road space is the highest; precisely where dedicating a lane will be the most difficult.

In ideal circumstances, BRT will be built on roads that pass through the city centre where bus volumes are high and the right of way is wide enough to allow for at least two traffic lanes open to trucks, private cars, and other forms of mixed traffic. Under these conditions, implementing BRT can increase both bus and mixed traffic speeds and throughput. In this case, the use of cars has been regulated but not restricted.

Sometimes, however, this sort of solution is not possible, and in other cases it may not be desirable. Decision-makers may decide that the benefits to public transport passengers outweigh the disbenefits to motorists. Building a BRT system may make congestion worse for mixed traffic on certain sections, and certainly during the construction phase, this problem is likely to be acute. Some parts of the BRT network may need to pass through very narrow streets with multiple access needs. On such streets, building physically segregated busways while allowing truck and car access may not be feasible or desirable. Inevitably, some parts of the BRT network, as a minimum the feeder buses, will operate in congested mixed traffic conditions. One option to maintain bus speeds on those streets is to restrict car access by other means, through a variety of measures. Some of these measures will tend to decrease trips by private motorised vehicles, and are known as transportation demand management, or TDM. Other measures may not decrease car use, but regulate the time and location of private vehicles.

Restricting vehicle access and throughput on certain streets in order to improve bus system performance can generally be balanced by improvements for private vehicles on parallel streets, so that the net effect on mixed traffic is neutral or even positive.

However, a growing number of politicians are also deciding that BRT projects, by improving the quality of public transport service, create a unique opportunity to reduce car use in the city more generally, in order to reduce air pollution, increase public space, and to increase public transport ridership and profitability. This section discusses the mechanisms for implementing measures which increase the ability of the municipality to better regulate private motor vehicle access to different parts of a city according to specific local needs.

These measures include the following:

- Reduction in available parking units;
- Increased parking fees;
- Increased parking enforcement;
- Parking cash-out programmes;
- Day restrictions by license tag number;
- Congestion charging and road pricing;
- Travel Blending or TravelSmartTM;
- Green travel plans;
- Traffic calming measures.

A more complete description of TDM options can be found in the on-line TDM Encyclopaedia of the Victoria Transport Policy Institute (VTPI, 2006).

14.1.1 Parking regulation

"What if we fail to stop the erosion of cities by automobiles?... In that case, we Americans will hardly need to ponder a mystery that has troubled men for millennia: What is the purpose of life? For us, the answer will be clear, established and for all practical purposes indisputable: The purpose of life is to produce and consume automobiles."

—Jane Jacobs, writer and activist, 1916–2006

Few policies are as emotionally charged for citizens as parking policy. Threatening to remove even a few parking spaces to put in a BRT system may seem a daunting challenge to a politician, even if it improves hundreds of thousands of public transport passenger trips daily. First world mayors have the legal powers to regulate on-street parking, but most fear to use this power. In the developing world, political control over parking is generally not fully in the hands of mayors, but in the hands of the police, submunicipal governments, or even local mafias.

A lot of parking is in private hands. Often government employees and the police themselves

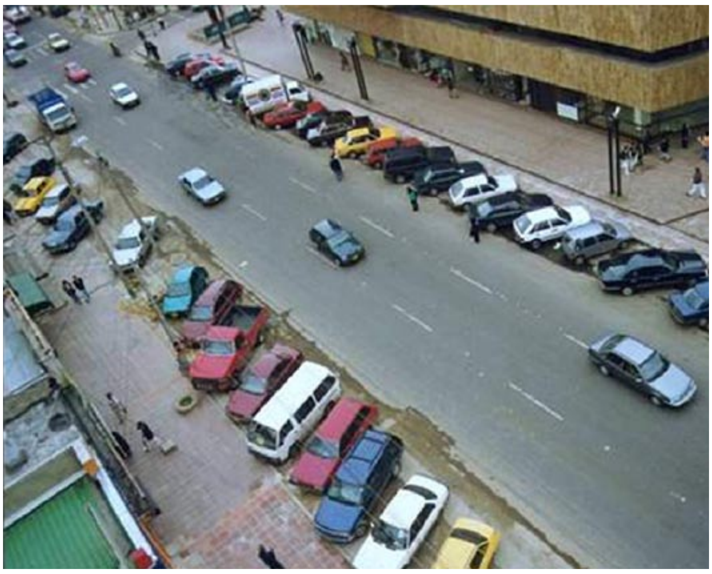


Fig. 14.1 and 14.2

Before and after images of Avenue 15 ("Carrera 15") in Bogotá. Mayor Enrique Peñalosa was nearly impeached for enforcing parking laws and upgrading public space. In the end, he became one of most Bogotá's most popular Mayors ever with his ambitious vision.

Photos courtesy of the Mayor's Office of Bogotá are recipients of privileged access to choice parking locations and parking revenues. Bogotá Mayor Peñalosa was nearly impeached when, in preparation for implementing TransMilenio, his admiinistration eliminated on-street parking from much of the central portion of the city (Figures 14.1 and 14.2). Curitiba Mayor Jaime Lerner faced similar upheaval from shopkeepers when removing parking and pedestrianising streets adjacent to the new BRT system. However, both mayors reaped large political rewards once citizens saw the benefits and shopkeepers saw their business increase rather than decrease.

Existing parking conditions in most developing countries are generally far from optimal from almost anyone's perspective. This situation creates the opportunity to use a BRT project to actually improve the overall parking situation for motorists, even if the project itself needs to remove thousands of units of on-street parking. While a mayor may choose to use the BRT project to actually reduce total city centre parking in order to encourage public transport use and discourage driving, there are technical tools available even for a mayor that does not want to reduce parking availability. In either case, a technically sound parking plan is critical, and the mayor's office should prepare a good public awareness and outreach campaign.

Table 14.1 summarises the various parking management strategies that better allow municipalities to control public space and the growth of private vehicle use.

14.1.1.1 Surveying parking conditions

Securing political support for any change in the existing parking regime is critical. The first step is to understand fully the existing parking situation and then publicise those elements of the status quo that are unfair and inequitable. The BRT system can then be presented as an opportunity to optimise parking regulation in the impacted area, and if time permits in the city more generally. To make this case to the public, policymakers should prepare themselves with as much information as possible. A good place to start is to conduct a parking occupancy study reviewing the existing parking situation.

The parking study usually first involves collecting data on the following:

- Total existing officially designated on-street parking units and their specific locations;
- Total locations where people regularly park, whether or not officially designated;
- Total off-street parking units available;
- Existing parking regulatory regime, including time period restrictions if any, and charging structure for each type of parking unit;
- Total actual occupancy of these parking units throughout the day.

The evaluation of the existing parking situation and its ramifications for parking availability in the area impacted by the BRT system should then be discussed at a public dialogue. In such a dialogue, it will generally become clear that some people benefit much more from the existing parking regime than others.

14.1.1.2 Parking fees

Even if the political will to reduce the existing number of parking spaces does not exist, there are measures that can be taken to improve parking efficiency. Increasing parking fees can do much to discourage vehicle usage even without removing any parking spaces.

Implementing progressive parking policies do frequently require certain legislative changes. In most cases, local council approval and even national legislative approval may be required to implement a fee of this type. Turning over the enforcement of parking infringements to a municipality or a private company from national or provincial level police can be a difficult process. As with many of these issues, political will is critical, and devising a successful political strategy is the key to success. As with any tax or fee, many interest groups will be vehemently opposed to it. Influential groups, such as motorists and business interests, could form a powerful opposition, but increasing parking fees can also increase the rotation of parking spaces which will help shopkeepers. Regaining political control from politically powerful mafias is always a challenge. Certainly, a direct link between increased parking fee revenues and a politically popular high profile public transport improvement like BRT can often be a successful political strategy.

Of course, not all vehicles that enter an urban area are destined to utilise a parking space.

Table 14.1: Parking management strategies

Management strategy	Description
Strategies that result in more efficient use of parking facilities	
Shared parking	Parking spaces are shared by more than one user, allowing facilities to be used more efficiently.
Regulate parking facility use	More convenient and visible parking spaces are managed and regulated to give priority to higher-value trips, increase efficiency and user convenience.
More accurate and flexible standards	Reduce or adjust standards to more accurately reflect demand at a particular location, taking into account geographic, demographic and economic factors.
Parking maximums	Establish maximum in addition or instead of minimum parking standards to avoid excessive parking supply.
Remote parking	Encouraging longer-term parkers to use off-site or fringe parking facilities, so more convenient spaces are available for priority users.
Improving user information and marketing	Provide convenient and accurate information on parking availability and price, using maps, signs, brochures and electronic communication.
Smart growth and location efficient development	Encourage more clustered, mixed, multi-modal, infill development, which allows more shared parking and use of alternative modes.
Improved walkability	Improve pedestrian conditions to allow parkers to conveniently access more parking facilities, increasing the functional supply in an area.
Transportation Management Associations	Transportation Management Associations are private, non-profit, member-controlled organizations that can provide variety of services that encourage more efficient use of transport and parking resources in an area.
Strategies that reduce parking demand	
Transportation Demand Management programmes	Various strategies and programmes can encourage more efficient travel patterns, which reduces automobile trips and parking demand.
Parking pricing	Charge motorists directly for using parking facilities, and set fees to encourage efficient use of parking facilities.
Improve parking pricing methods	Use of more convenient and effective parking pricing techniques to make parking pricing more acceptable and cost effective.
Commuter financial incentives	Parking cash out and transit benefits give commuters financial incentives to shift modes and reduce parking demand.
Unbundle parking	Rent or sell parking spaces separately from building space, so occupants pay for just the number of parking spaces that they use.
Tax parking facilities	Impose special taxes on parking facilities and commercial parking transactions.
Improve enforcement and control	Enforcement should be consistent, fair and friendly. Parking passes should have clear limitations regarding where, when and by whom they may be used, and these limitations should be enforced.
Bicycle facilities	Supply bicycle parking, storage and changing facilities instead of some automobile parking spaces.
Strategies that reduce negative impacts	
Develop overflow parking plans	Encourage use of remote parking facilities and promote use of alternative modes during peak periods, such as busy shopping times and major events.
Address spill-over problems	Address spill-over parking problems directly with management, pricing and enforcement strategies.
Parking facility design and management	Improved parking facility design to address safety, storm water management, user comfort, security and aesthetic objectives.

Source: Litman, 2004a

Traffic that is only passing through the city will not be affected by the parking fee. The imposition of a parking fee may also encourage additional chauffeured trips in which another family member, friend, or hired driver takes the person to their destination. In this case, the person is merely dropped-off at the destination and no parking is involved. These types of chauffeured trips actually double the number of trips taken and the distance covered since each journey involves a two-way trip (one trip into the city and another trip back to the home). Thus, in order for a parking fee programme to work, it will likely have to be combined with other TDM measures that will discourage such "gaming" of the system. For example, combining a parking fee with a license tag programme restricting travel to certain days based on one's number plate can work well to avoid such problems.

Variable parking fees

Most parking experts agree that parking policy should aim to ensure that available parking is occupied roughly 85 percent of the time. If parking units are occupied less than 85 percent of the time, the space is being underutilised. If parking units are occupied more than 85 percent of the time, potential parking customers will have to spend a lot of time driving around looking for a parking space and contributing to traffic congestion.

Fig. 14.3
A variable parking charge can be a simple yet effective means to control private vehicle usage, as seen here in Brasov (Romania).
Photo by Manfred Breithaupt

Achieving an 85 percent parking unit occupancy rate is generally done through two mechanisms: time limits on free parking or parking charges (Figure 14.3), or a combination of both (meters combined with a time limit). Variable parking charges are the preferred method, for reasons that will be described below.

When planning a BRT system, the level of parking occupancy in different parts of the impact area will tell you a lot about whether there is an absolute shortage of supply or a misallocation of the existing supply. Very rarely is the status quo anywhere remotely close to the optimal. Most of the time, the existing parking supply has been badly misallocated, and optimising existing parking supply at the same time that parking units are removed by a BRT project will mitigate the need for building additional parking units.

Typically, even if parking is in short supply in some locations, there is plenty of parking available in nearby locations which require somewhat longer walking trips. Allocating the most convenient parking spaces on a first come first serve basis at a very low parking cost does not lead to the optimal allocation of a scarce parking resource. A good parking policy will rationally allocate the scarce parking units to those who need it the most. The convenience of a parking space should be proportional to the number of people who need to make the trip in a given day. The consumers of parking can be divided into different market segments with different parking needs:

- Local residents, who tend to park at night and make only a few trips per day between their apartment and their car;
- Employees, who will tend to park all day and pass between their car and their office only once a day;
- Trucking and delivery services who need to be adjacent to the curb only for short pickups and deliveries, but at many different locations throughout the day;
- Shoppers, who need to park at a shop for only a short time, or at a shopping area for a somewhat longer time, but a shop needs many of them to survive;
- Leisure users including recreational users, people going out to dinner, to movies, etc.

A good parking regime will discourage commuters and employees from parking in front of shops, where the space should be available for customers and delivery vehicles. If a hundred people would like to visit a downtown shop or museum, but only one person is working in the shop or museum, it is obviously better to allow the shoppers to park directly in front of the shop, and to encourage the person working at the shop or museum, or living in an apartment nearby, to park farther away. This approach increases efficiency since the worker or the apartment dweller only make the walking trip once a day, whereas inconveniencing the customers inconveniences hundreds of customers a day. Free and undervalued parking in front of shops creates the likelihood that one resident or one shop employee will consume the scarce parking space for an entire day, forcing perhaps hundreds of shoppers to walk a long distance, to the detriment of the businesses in the area (Figure 14.4). Increasing hourly parking charges will increase the availability of parking in popular locations for parking customers with the greatest economic incentive to use the parking: Short term shoppers and delivery trucks.

A parking analysis conducted under the Dar es Salaam BRT project helped to identify the potential for an increase in parking efficiency through a new parking fee structure. Box 14.1 summarises the process that led to parking management improvements in Dar es Salaam.

The next step is to investigate the hot spots, and the turnover rate of parking at these locations. If average parking time per vehicle is very long, it generally indicates that parking charges are too low. A study in the commercial district of Westwood, California (US), indicated that the parking occupancy rate was 100 percent, meaning that it was virtually impossible for shoppers to find a parking place. At a 100 percent parking occupancy rate, the hourly number of people who could park in 829 units was 829 vehicles. When curbside parking charges were increased to the same levels as off-street parking in garages, the number of vehicles able to park increased to 1,410, due to an increase in the turnover rate. It also induced people to share vehicles, so the vehicle occupancy went up as well. The total number of people arriving at the shops therefore increased from 1,078 per hour to 2,397 per hour (Shoup, 2005, p. 366). As each one of these visitors is a potentially high-income customer, increasing prices was able to significantly increase the availability of parking downtown and the total number of shoppers. Therefore, increasing parking charges did not function as a traffic demand management measure; it in fact induced new demand. It did not reduce the supply of parking, it increased it. Therefore, if a BRT project has to cut parking units, this loss of parking availability can be mitigated by increasing the parking charges and hence the turnover rate of the available parking units.

Fig. 14.4
Uncontrolled parking in the historical centre of Quito means that pedestrians lose footpath access, the visual ambiance of the historical architecture is compromised, and motorists have no incentives to use alternative means of transport.
Photo by Lloyd Wright

Parking space levy

In developed countries, commercial parking taxes are perhaps the most common form of parking fee. This technique is a simple sales tax applied to private parking companies. The amount of the tax varies by city; examples include a 50 percent parking tax in Pittsburgh (US) and a 25 percent parking tax in San Francisco (US) (Litman, 2006a). While such taxes are quite popular, the commercial parking tax can create unwanted consequences. First, without a highly defined record-keeping and enforcement system, tax evasion can occur. Second, the tax burden will generally be fairly geographically restricted to commercial centres since commercial parking facilities are generally

Box 14.1: BRT and parking management in Dar es Salaam

Dar es Salaam represents one of the better regulated parking systems for a developing country. The Dar City Council currently charges a single hourly rate for all on-street parking in the CBD, and a slightly lower hourly rate for parking in a popular market area nearby. No other areas within the city charge for on-street parking.

The project team for the Dar es Salaam BRT (DART) system determined that 1,004 parking units will require removal from central Dar es Salaam in order to accommodate the exclusive lanes of the BRT system. To assess whether these parking units needed to be replaced with new units somewhere else, or simply removed, a parking occupancy survey of the area was conducted.

The study found that there were 13,803 on- and off-street parking units available on average during peak business periods, and that only 10,594 of these were generally occupied. Some of the on-street parking supply had been sold in blocks to small businesses at a very low price, and other blocks of on-street parking were controlled by government and international agencies. These findings showed an occupancy rate of some 77 percent. As normally, 85 percent is generally considered the optimum balance between efficiency and ease of finding a space, the study determined that there was no overall shortage of parking availability in the city centre, and that the removal of the parking units for the DART system could proceed without the need for constructing or designating new units.

It did find, however, that the occupancy rate was far from uniform. In the southern part of the CBD, the occupancy rate was 104 percent, due to a large number of illegally parked cars, whereas in other areas, the occupancy rate was as low as 62 percent. It also found that some 20 percent of the vacant parking spaces were in parking units reserved for specific businesses. From this it was concluded that parking in the Southern part of the CBD was underpriced, in other locations the prices were okay, and that the sale of blocks of parking to specific businesses was significantly limiting the overall supply of parking. These two changes would more than compensate for the loss of units resulting from the BRT project (Millard-Ball 2006).

These findings were presented in a public meeting and were successful in mitigating the concerns of most shopkeepers and property owners. The exercise demonstrated to the public that the issue of parking availability is not absolute but relative to location and price. Flat parking rates undercharge for parking in certain locations, and overcharge in others; it is not inherently more equitable and by no means economically optimal.

only found in such areas. Third, while the tax may provide an incentive for operators to reduce commercial parking spaces, it can at the same time encourage an increased number of free parking spaces.

By contrast, a "parking space levy" works by charging a set fee to all non-residential parking spaces, regardless of whether the space is used or not (Figure 14.5). A parking space levy can be collected on a periodic basis in a similar manner to common forms of land taxes. A parking space levy provides multiple benefits that can not only encourage public transport usage but also lead to improved usage of public space. Several cities in Australia, including Sydney and Perth, have pioneered the parking space levy concept.

Based on these experiences, a parking fee can be quite effective at multiple complementary objectives: 1.) Reducing private vehicle usage; 2.) Encouraging journeys by public transport; and, 3.) Raising revenues for public transport infrastructure. Parking fees may also be a particularly relevant option for developing-nation cities, especially as a short- to medium-term revenue raising mechanism.

Since the parking space levy is assessed whether or not a space is being utilised regularly, property owners have an incentive to scrutinise the usefulness of maintaining each parking space. Without a parking space levy, an urban parking lot may be financially viable even if only a fraction of the spaces are actually used (Figure 14.6). With a parking space levy, property owners will tend to convert the space to more productive uses.

Fig. 14.5
With a parking space levy, shops have an inherent incentive to only provide the number of parking spaces that are truly required.
Photo by Lloyd Wright

Fig. 14.6
A parking levy can also lead to the re-development of parking lots that may be currently viable with a few parked vehicles.
Photo by Lloyd Wright

14.1.1.3 Parking enforcement

"A thousand policemen directing traffic cannot tell you why you come or where you go."
—T.S. Elliott, poet and dramatist, 1888–1965

The site of a vehicle parked on the pedestrian pavement is not uncommon in many developing cities (Figure 14.7). Police are often unable or unwilling to deter such practices. The result is a culture that permits private vehicles to consume public space, which further weakens the social position of walking and other sustainable forms of mobility. However, enforcement of traffic and parking laws can immediately produce the opposite effect. Applying fines and penalties to illegally parked vehicles will discourage the practice as well as curb the overall parking supply. Work has been done to suggest various mechanisms for improving parking enforcement (Cracknell, 2000). Improvements in parking enforcement hold many benefits beyond encouraging public transport usage. Parking enforcement also helps instil a citizen culture, improves pedestrian and traffic safety, and creates a more pleasant urban environment.

14.1.1.4 Reducing parking supply

Because BRT provides passengers with a new high quality mass transit service to a downtown area, a mayor may choose to reduce the total private motor vehicle parking supply in order to try and induce a modal shift between cars and the new BRT system, to reduce congestion, air pollution, and to free up city centre land formerly used for parking for other public purposes. Bogotá has been the most aggressive about cutting back on available parking, cutting approximately one-third of the total on-street parking units in central areas prior to the implementation of TransMilenio. Off-street, private parking facilities took up some of this demand. However, unlike on-street parking, the private parking facilities charged a fee for the service. The end result was the termination of free city parking and the reclamation of public space. In many instances, the previous parking spaces have been converted to an attractive new environment for pedestrians (Figure 14.8).

Removing on-street parking, for all its political complexity, is extremely simple from a technical point of view. The designated parking area can simply be removed. It can be replaced either with a mixed traffic lane, a bicycle lane, a foot-

Fig. 14.7
Illegal parking on pedestrian sidewalks discourages walking and sends a message that private vehicles are more important than persons.
Photo by Lloyd Wright

Fig. 14.8
Bogotá has eliminated much of its previous on-street parking in order to deter private vehicle use. The former parking spaces are being converted into more attractive public space.
Photo by Lloyd Wright

path, or landscaping. In many cases, planners may decide to replace the parking space with additional footpath space. Since enforcement is an issue in developing countries, the use of physical structures like very high curbs and bollards can be necessary to keep motorists off the footpaths. In general, though, use of trees of other landscaping are a more aesthetically-pleasing form of protective barrier. Some countries use bicycle parking as a bollard which provides a useful additional service (Figure 14.9).

Fig. 14.9
Bicycle parking facilities can double as bollards and useful infrastructure for cyclists.
Photo by Lloyd Wright

Off-street parking can also be regulated through taxation, the removal of subsidies, and changing building codes. In some countries building owners are given a property tax break if they provide off-street parking. Such tax breaks tend to encourage the use of private motor vehicle use. To discourage driving, these tax breaks should be removed or subsidies of equal value should be given to employees willing to bicycle or use public transport. Parking garages can also be taxed.

Building codes also often frequently create sub-optimal parking supply incentives, and should be reviewed and, if necessary, changed. A BRT project might be a good opportunity to review these standards. Table 14.2 notes the minimum parking standards required in Dar es Salaam.

Figure 14.2: Dar es Salaam minimum parking requirements

Use	Parking requirement
CBD	
Offices	1 space per 100 m^2
Commercial	1 space per 200 m^2
Hotel	1 space per 10 beds
Hospital	1 space per 10 beds
Flats	1 space per unit
Kariakoo district	
Low-rise buildings	One space per floor
High-rise buildings	Minimum of four spaces

These standards are roughly 25 percent to 50 percent of the same standards in the US, which are high by international standards. Dar es Salaam, however, has a modal split for private cars entering the city centre of under 5 percent, compared to a typical modal split for private cars in the US of greater than 70 percent. The Dar es Salaam figures are fairly typical for a developing nation. Developers would frequently be happy to build fewer parking units but are forced to overbuild parking facilities by government regulation. In Dar es Salaam, the result is that many of the parking facilities are actually used for storage and other purposes. A BRT project should be used to revise downward minimum parking requirements for buildings in the impact area.

14.1.2 Day restrictions by license plate number or vehicle occupancy

"If the automobile had followed the same development cycle as the computer, a Rolls-Royce would today cost $100, get a million miles per gallon, and explode once a year, killing everyone inside."

—Robert X. Cringely, InfoWorld

14.1.2.1 License plate-based restrictions

Deteriorating bus speeds, severe traffic congestion and air contamination in some developing cities has prompted officials to enforce vehicle bans based on license plate numbers. The last digit in a vehicle's license plate number determines the day(s) during which the vehicle is permitted to operate in a particular zone of the city. Travelling with a license plate that is not valid for a particular day will result in a penalty or fine. Such measures could be implemented simultaneously with a BRT project in order to increase bus speeds in situations where the buses are still operating in mixed traffic.

License plate restrictions, to be effective, must be enforceable. This generally requires designating the area within which the restriction is to be enforced, such as within a ring road or some other natural perimeter like a river, where the number of access points that need to be monitored can be minimised. Smaller zones relating specifically to BRT impact areas could also be tested.

The success of licenses plate restriction programmes has been mixed. The benefit of the license plate restriction dissipates as the number of vehicles increases. In cities such as Mexico City and São Paulo, the programmes had initial success that faded over time, and the crudeness of the approach had some unintended consequences. Many residents in these cities avoided the restrictions by simply purchasing a second vehicle with a licence plate that ends with a different number. Thus, by possessing two vehicles with different numbers, the person is still able to travel each day by private vehicle. Further, since the second car was typically a lower-quality used vehicle, the end result meant that even more emissions were put into the air.

A well-designed programme, though, can avoid the problems experienced in Mexico City and São Paulo (Figure 14.10). Some of the techniques used to prevent the gaming of tag numbers with multiple vehicles include:

- Restrict four or more numbers per day;
- Change the days corresponding to a particular day on a regular basis (*i.e.,* every 6 or 12 months);
- Only apply the restriction during peak hours
- Require the re-registration of any used vehicle changing ownership and give the same final number to any additional vehicle being registered at the same address;
- Apply vehicle ownership fees as a restraint to motor vehicle growth.

Fig. 14.10
A well-designed license plate scheme can easily avoid the problem of second-car purchases.
Photo courtesy of Fundación Ciudad Humana (Human City Foundation)

Bogotá has developed a license plate restriction programme that has succeeded in removing 40 percent of the city's private vehicles from the streets each workday during peak periods. The Bogotá approach has succeeded by carefully designing a system to discourage the purchase of second (or third) vehicles. First, Bogotá has chosen to prohibit four license plate numbers each day from use instead of just two or three. Table 14.3 lists by the day of the week the licence plate numbers that are restricted. The restriction of four license plate numbers each day implies that a person would have to purchase three vehicles instead of two in order to cover every day of the week. Second, Bogotá's vehicle prohibition only applies during peak hours. These hours are from 06:00 to 09:00 in the morning and from 16:30 to 17:30 in the afternoon. Thus, vehicles with the prohibited numbers for a given day may still travel at non-peak hours.

The net effect is to encourage a shift either to using public transport or to use a private vehicle at a non-peak time. This flexibility in conjunction with the restriction applying to four plate numbers has meant that Bogotá has not experienced a problem with persons purchasing multiple vehicles to overcome the restriction.

The measure has contributed to an estimated 10 percent of former car users to shift to public transport as their daily commuting mode.

Table 14.3: License plate restrictions in Bogotá

Day of week	License plates ending with these numbers are restricted from use
Monday	1, 2, 3, 4
Tuesday	5, 6, 7, 8
Wednesday	9, 0, 1, 2
Thursday	3, 4, 5, 6
Friday	7, 8, 9, 0

14.1.2.2 Restrictions based on vehicle occupancy

Cities can also restrict access to specific lanes, streets, or zones based on vehicle occupancy, and some have done so in a manner related to BRT. High occupancy vehicle lanes are popular in US cities. On highways where there are few stops, and in conditions like in the US and parts of Africa where bus volumes are very low but bus speeds are also low, combining a bus priority lane with other high occupancy vehicles may make bus priority lanes more acceptable to the public without significantly compromising their effect on bus speeds. A bus, HOV, and taxi lane exists in New York City on the Staten Island Expressway, the Brooklyn Queens Expressway, and over the Verazanno Bridge. Proposals for combined bus-HOV lanes are moving forward in Cape Town and several US cities. To be effective, vehicle occupancy restrictions require a fair amount of enforcement effort. The lack of enforcement in many developing-nation cities can mean that such schemes are blatantly ignored by most motorists.

Fig. 14.11
Charging motorists for access to road space provides a financial incentive to consider alternative modes such as BRT.
Photo by Lloyd Wright

Jakarta has a three-in-one restriction during the morning peak on the same north-south corridor where the TransJakarta BRT system was constructed. This vehicle restriction system has some effect on traffic but also some perverse effects. It has led to an industry of people who will ride with the driver for a small fee to increase the vehicle occupancy. In some cases, children are abandoning their studies in order to become three-in-one jockeys for car owners. It has also led to a peculiar dual peak, one at the normal morning peak and one just after the three-in-one restriction. As a result of the BRT system, there are active discussions to extend the three-in-one system to the entire day, and to eventually replace it with a congestion charging scheme.

14.1.3 Congestion charging and road pricing

14.1.3.1 Defining congestion charging

A city's road infrastructure has a finite ability to accommodate ever increasing amounts of private vehicles. The resulting congestion places innumerable costs upon a city in the form of air contaminants, noise, personal stress, unreliable delivery services, and the inability of persons to travel efficiently.

Most economists agree that traffic congestion is the result of a failure to properly charge for the value of road access, and see congestion charging as the optimal solution. The last motorist to enter a road slows down his or her own trip only marginally, but he or she also slows down everyone else on the road. As a result, the social cost of the motorist's decision to use that road during a congested period is much higher than the cost to the individual who has to make the decision. A congestion charge, by making the motorist pay the full social cost of the decision to use a congested road, can do much to reduce congestion (Figure 14.11).

In practice, implementation of a perfect pricing regime for road access has proven elusive, but a growing number of cities are getting much closer. By providing much improved public transport service, a BRT project also creates a possible political opportunity to begin to introduce congestion charging. New electronic road

Fig. 14.12
Singapore's Electronic Road Pricing (ERP) system has been effective in curbing vehicle use, especially during peak periods.
Photo by Manfred Breithaupt

charging methods are creating new possibilities for regulating vehicle access in more location-specific ways which can increasingly be coupled with BRT projects to optimise road use and bus speeds in specific locations.

Different approaches to better internalise the full social costs of driving are known by different names, including congestion charging, road pricing, and cordon pricing.

Congestion charging places a monetary value on using the road space during peak travel times. Motorists who wish to enter a congestion zone must pay a fee to gain legal access to the use of the road. By charging for the use of the road resource, only those who value road access more than the congestion charge will travel during the peak times.

London, Singapore, Stockholm, and three cities in Norway have implemented pricing schemes. The results have shown a marked reduction in congestion as well as the generation of revenues for supporting sustainable transport options.

14.1.3.2 Electronic road pricing in Singapore

From 1975 until 1998, Singapore operated a manually-controlled road pricing scheme. The scheme requires motorists to pay for entry into a central Restricted Zone. Technological advances enabled the city to implement an Electronic Road Pricing (ERP) scheme in 1998. The system utilises short-range radio signals between in-vehicle electronic units and overhead gantries (Figures 14.12). The gantries are both on major avenues entering the CBD and along certain highways. As such, charges are applied not only to the CBD but also to congested highways. A smart card is inserted into the in-vehicle unit to validate entrance into the Restricted Zone. Topping up the value on the smart card can be done at petrol stations or automatic teller machines (ATMs).

There are actually three functions to the gantries. First, one set of technology on the gantry sends a signal to the in-vehicle unit and deducts a charge. A second set of technology is an enforcement system. If the communication between the in-vehicle unit and the gantry radio antennae indicates that the road charge is not being paid, a camera on the gantry will photograph violating vehicles and identify their license plate. Third, the gantries collect traffic information and send it to a control centre to manage and coordinate the system.

The system software allows a different fee to apply during different half-hour periods. The highest peak rate is currently US$1.71 per half-hour spent in the Restricted Zone. The infrastructure cost of the Singapore ERP system was approximately US$114 million. Each year the system generates US$46 million in revenues with operating costs of US$9 million. The ERP scheme is credited with reducing traffic levels by 50 percent and increasing average traffic speeds from around 18 kph to 30 kph.

The Singapore system gives traffic managers great power to adjust the congestion charge to very specific points where congestion is at its worst. As such, it has the potential to come much closer to optimising the charging structure to locations where congestion is at its worst.

The Singapore system, however, requires anyone entering the CBD to have an electronic unit in their car. Because Singapore is a city-state, there is not a high volume of traffic entering Singapore from other jurisdictions, and that level of traffic can easily be handled by roadside facilities where the transponder can be rented or purchased. While the price of the in-vehicle electronic units is falling, for other systems to use the same scheme, a mechanism for facilitating access to the in-vehicle units for motorists from other jurisdictions must be developed. Enforcement is also easier when virtually all traffic is from the same municipal jurisdiction.

14.1.3.3 Congestion pricing in London

The introduction of the congestion charging scheme in London has now helped to broaden the appeal of congestion charging to transport planners worldwide. Over the past decades, London's traffic congestion had worsened to the point that average traffic speeds were similar to speeds of the horse carts utilised in London during the nineteenth century. In response, London's Mayor Ken Livingstone decided to implement a congestion charging scheme in the centre core of the city.

Currently, a £8 (US$14) fee is imposed upon vehicles entering the central zone from 07:00 to 18:30 (Monday through Friday). Motorists can pay through a variety of mechanisms including the internet, telephone, mobile text messages, self-service machines, post, and retail outlets (Figure 14.13). Motorists have until midnight on the day of entry to pay the charge, although payments after 22:00 increase to £10 (US$18). Subsequently, an £80 (US$144) fine is applied to motorists who fail to pay by midnight.

The London system differs from the Singapore system in several ways. First, the London system does not require an in-vehicle electronic unit, and requires no system of cash cards. It is an enforcement only system. London does not utilise gantries but instead relies upon camera technology to identify the license plates of all vehicles passing the point, and sends this information to a central computer (Figure 14.14). At the end of each day, the list of vehicles identified entering the zone is compared to the list of vehicles that have made payments to the scheme operators. Any unpaid owners are referred for enforcement actions.

Fig. 14.13
Motorists have a range of options for paying the London congestion charge, including local shops.
Photo by Lloyd Wright

Fig. 14.14
Camera technology is utilised in London to enforce the congestion charge.
Photo by Lloyd Wright

London adopted a camera-based system rather than an electronic gantry system for several reasons. First, it was hoped that the elimination of the in-vehicle electronic system and the cash card would reduce administration costs. Second, London also had aesthetic concerns over the large overhead gantries employed in Singapore. Third, officials were concerned over the limitations of GPS-based systems to operate without interference in narrow urban roads lined by tall buildings.

London's system has some disadvantages. Unlike the Singapore system, London's system has to charge a flat fee for a carefully defined area. To win political support, residents with motor vehicles inside the charging zone were given a 90 percent discount. This exemption has made expanding the zone difficult, as expanding the zone also expanded the number of people eligible for the discount. Congestion is also not uniform around a zone, particularly a larger zone. For a larger zone, it may be that there is minimal congestion on access roads serving lower-income areas and higher congestion on access roads serving higher-income populations. A point-specific charging system like Singapore has much greater potential to optimise charges to specific points of congestion.

The license plate detection is not required to ensure payment, but rather it is only required to enforce non-payment. For this reason, the system does not have to be 100 percent accurate; the system is only accurate enough to induce people to pay the fee voluntarily. The London system also has some trouble charging motorcycles, which are therefore exempt. The cameras incurred a failure rate of between 20 percent and 30 percent in reading motorcycle license plates due to the smaller size of the plates and the fact that motorcycles do not always operate in the centre of the lane. Some license plates can be difficult to read due to glare or obstructions from trucks, or other sight restrictions, and motorcycles are more prone to these problems. In London they decided to exempt motorcycles to ensure a high level of consumer confidence in the system, but in other cities with a large number of motorcycles they would need to be included.

In addition to exempting motorcycles, the London congestion charge is also not applied to taxis, public transport, police and military vehicles, physically disabled persons, certain alternative-fuel vehicles, certain health care workers, and tow trucks. The exempted vehicles represent 23 percent (25,000 vehicles) of the total traffic in the zone.

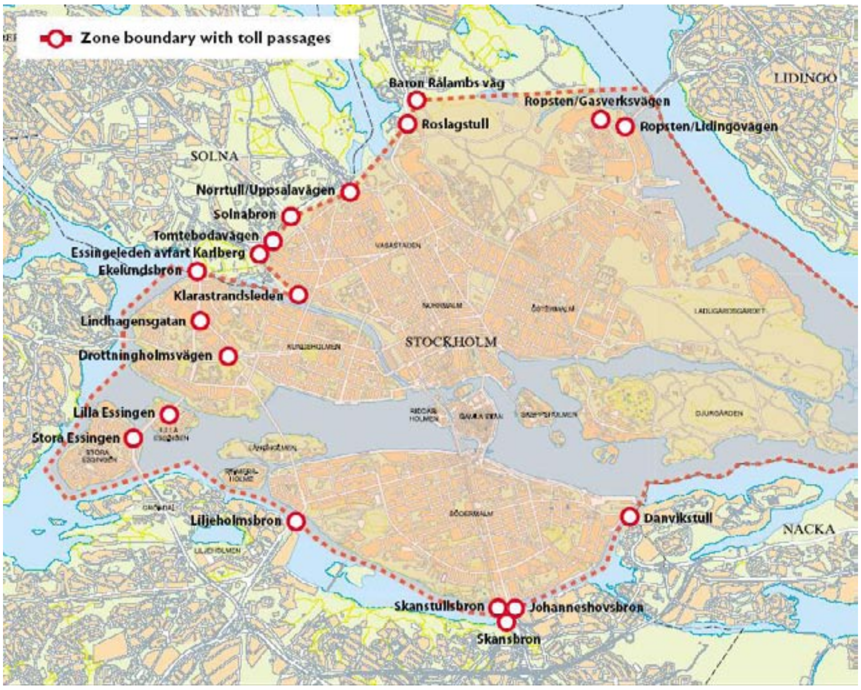


Fig. 14.15
The Stockholm charge zone and the 19 points of entry.
Image courtesy of the City of Stockholm

After one year of operation, London's congestion charge has produced some impressive results. Congestion levels have been reduced by 30 percent, and the total number of vehicles entering the zone has dropped by 18 percent. Average speeds have increased from 13 kph to 18 kph. Perhaps the most unexpected benefit was the impact on the London bus system. With less congestion bus journey speeds increased by 7 percent, prompting a dramatic 37 percent increase in bus patronage. The revenues from London's programme are applied to supporting bus priority schemes and cycleway projects. London is currently planning an extension of the congestion charging zone.

14.1.3.4 Congestion charging in Stockholm

On 3 January 2006, Stockholm joined London and Singapore as large cities employing a congestion charge. Stockholm has borrowed concepts from its two predecessors while also invoking several more recent technological innovations. The Stockholm charge was been implemented as a trial mechanism for a period of six months, after which time the public would voted on whether to keep it. In fact, in September 2006, a majority of the citizens of Stockholm did vote to keep the congestion charge.

Stockholm's charge zone includes the entire central area of the city with a total of 19 different gantry points permitting entry into the zone (Figure 14.15). Like Singapore, Stockholm has a fortuitous location with bodies of water restricting the number of actual access points to the city centre. Such naturally-restricted entry eases the technical tasks of controlling a large number of entry points.

The amount of the Stockholm charge depends on both the number of times a vehicle enters the central zone as well as the time of day (Table 14.4). For vehicles entering and exiting the charge zone multiple times per day, the maximum amount to be paid is 60 SEK (US$7.80). Like London and Singapore, several types of exemptions are permitted, including emergency vehicles, public transport vehicles and school buses, taxis, vehicles with disability permits, environmentally-friendly vehicles (*e.g.,* electric, ethanol, and biogas), and motorcycles. The capital cost for the six-month trial period of the charge was SEK 3.8 billion (US$494 million) (Pollard, 2006).

Table 14.4: Fee schedule for the Stockholm congestion charge

Time of crossing zone boundary	Cost (SEK)	Cost (US$)[1]
06:30 – 07:00	10	US$1.30
07:00 – 07:30	15	US$1.95
07:30 – 08:00	20	US$2.60
08:30 – 09:00	15	US$1.95
09:00 – 15:30	10	US$1.30
15:30 – 16:00	15	US$1.95
16:00 – 17:30	20	US$2.60
17:30 – 18:00	15	US$1.95
18:00 – 18:30	10	US$1.30
18:30 – 06:30	0	US$0

Source: City of Stockholm (2004)

Stockholm uses two different types of vehicle detection technologies, which are similar to both the technologies used in London and Singapore.

[1] Exchange rate of US$1 to SEK 7.7 (Swedish Kronor)

For regular travellers to the central area, motorists can obtain an electronic tag that automatically reads the vehicle's entry into the area. With this electronic tag, the appropriate fee is automatically deducted from the person's bank account. Approximately 60 percent of the people entering the zone utilise the electronic tag.

Alternatively, for vehicles not employing the electronic tag, a camera technology similar to that of London is utilised. The camera detects the plate number on the vehicle, and the motorist has five days to pay the charge by post or at a shop. If the charge is not paid within five days, then a fine of SEK 70 (US$9) is assessed. After four weeks, the unpaid charge results in a fine of SEK 525 (US$68) (Webster, 2006).

In the first month of operation, Stockholm's congestion charge reduced congestion levels by 25 percent, which is equivalent to reducing private vehicle travel by approximately 100,000 cars each day. The percentage reduction is relatively similar to that of London, but it was achieved with a significantly lower charge. The congestion charge has both influenced the time that people travel as well as their mode of choice. Approximately 2,000 drivers now travel to work earlier in order to enter the zone prior to the 06:30 start of the charge. Another 40,000 private motorists have now switched to public transport (Public CIO, 2006).

Perhaps the most instructive lesson from Stockholm has been the manner of implementation. The congestion charge has been applied as a six-month trial ending in July 2006. In September 2006, the public voted on whether to continue with the charge. At the outset of the congestion charge experiment, approximately two-thirds (67 percent) of the public was opposed to it. On 17 September 2006, 52 percent of the public approved the referendum to make the congestion charge permanent.

The referendum approach can thus be an effective mechanism to gain public support permitting an initial trial. Otherwise, protests at the outset may prevent a project from happening at all. This approach, though, is not without its risks. As people experience the benefits of reduced congestion, support for the measure may dramatically increase, as was the case in Stockholm. Nevertheless, any city employing a referendum approach to project approval and project continuance must be prepared for a negative vote. However, giving people a democratic voice in applying TDM measures can be an approach warranting serious consideration.

14.1.3.5 Developing city applications for congestion charging

The success of the London and Singapore pricing schemes has attracted interest for similar projects in developing cities. The high-tech nature of congestion charging amongst Mayors and other officials can increase its attractiveness to officials seeking modern technologies for their cities. However, the complexity of such schemes in conjunction with the relatively high initial costs may limit the extent to which congestion charging can be applied in the developing-nation context.

Several developing-nation cities, such as Jakarta and São Paulo, have given serious consideration of the congestion charging option. São Paulo under Mayor Martya Suplicy contracted a congestion charging feasibility study, but it was not implemented by the subsequent Mayor. The study nonetheless raised some issues of relevance to developing country applications.

The legal structures required for proper enforcement are one of the major concerns. It is important to determine legally whether it matters if the congestion charge is designated a "tax" or a "user fee". The law needs to give the municipality the right to directly enforce the collection of the charge. In São Paulo, approximately one-third of the motorists are operating their vehicles without a valid vehicle registration, making enforcement very difficult. An additional large number of vehicles are registered outside the State of São Paulo in states where there are no mutual enforcement rules between states for traffic violations.

The simplest thing would be to convert the existing rodizio license plate restriction scheme to congestion charging, since motorists already face a type of vehicle restriction that is sub-optimal. The zone for the rodizio scheme, however, includes roughly half of the city's population. Exemptions for residents inside the zone would render the charge meaningless in this situation, and the number of gantries or cameras needed is quite high.

Motorists in developed countries also value their time more than in developing countries. The technology used in the London and the new Singapore systems is quite expensive, and reaching full cost recovery for such high-tech systems would take much longer for lower-income motorists. Low-cost solutions such as the manually-operated Area Licensing Schemes (ALS) may be a more appropriate starting point for developing-nation cities. As was the case in Singapore, a manual ALS can eventually evolve into a more sophisticated Electronic Road Pricing (ERP).

Combining multiple, simpler TDM measures could be more appropriate for developing-nation cities. For example, the combination of day restrictions by license plate numbers and parking restrictions in Bogotá have been highly successful in reducing private vehicle use without the difficulty of implementing a road pricing scheme. Likewise, parking fee schemes can produce as many or more revenues (due to lower operating costs) than road pricing schemes. Thus, auto-restriction measures are not mutually exclusive. Road pricing schemes can be implemented in conjunction with parking reform and other TDM measures.

14.1.4 Reducing road supply

Priority public transport infrastructure on roadways serves an important purpose beyond providing a high-quality service to public transport customers. The simultaneous reduction in road space for cars creates a powerful incentive for motorists to shift to public transport use. While some may see the use of road space by public transport systems as a sacrifice, this consumption of car space may be one of the greatest overall benefits.

The notion of "induced traffic" is well supported in the mainstream of transport planning. Induced traffic implies a rather counter-intuitive conclusion: *Additional road construction results in* **more** *traffic congestion*. Induced traffic essentially says that a city cannot "build" its way out of the problem. While additional road construction may lead to a temporary reduction in traffic levels, this free road space eventually attracts additional traffic, especially when there is latent demand for private vehicle usage.

Fig. 14.16 and 14.17
Before and after images of the Cheonggyecheon corridor project in Seoul. Despite tearing down one of the principal expressways to the city, the resulting congestion impacts were minimal, especially since the new BRT corridors helped to gain ridership from former car users.
Images courtesy of the Seoul Development Institute

Interestingly, the research suggests the process works in reverse as well. Evidence from bridge and street closings in the UK and the US indicates that a reduction in road capacity actually reduces overall traffic levels, even accounting for potential traffic transfers to other areas (Goodwin *et al.,* 1998). This disappearance of traffic, known as "traffic degeneration" or "traffic evaporation", gives one of the strongest indications to the viability of developing BRT infrastructure. Further, the reduction in private vehicle lanes can have an overall beneficial impact on the city's urban environment.

Perhaps one of the most spectacular examples of this concept in practice is the Cheonggyecheon corridor project in Seoul. The Cheonggyecheon stream was historically a defining part of Seoul's environment, and in fact was the reason why Seoul was selected as the capital of the Joseon Dynasty in 1394. Unfortunately, in the face of modernisation, the waterway was covered in 1961 to provide better access for private cars. By 1968 an elevated expressway provided another layer of concrete erasing the memory of the waterway.

Upon his election in 2002, Seoul Mayor Myung Bak Lee decided it was time to bring back the Cheonggyecheon stream from its years of hiding under concrete. The Cheonggyecheon project has meant the restoration of 5.8 kilometres of waterway and historical pedestrian bridges,

Fig. 14.18
The new Seoul BRT system has helped make it possible to reduce road space dedicated exclusively to cars.
Photo courtesy of the City of Seoul

the creation of extensive green space, and the promotion public art installations (Figures 14.16 and 14.17). Based upon a study by the Seoul Development Institute (2003), the Cheonggyecheon restoration project will produce economic benefits of between 8 trillion and 23 trillion won (US$8 billion to US$23 billion) and create 113,000 new jobs. Over 40 million visitors experienced the Cheonggyecheon stream during the first year after restoration.

Further, despite the elevated expressway being the principal access way for cars into the city centre, there were no significant congestion impacts. In part, the new Seoul BRT system helped to defray some of the traffic impacts (Figure 14.18).

Other cities as well, such as Portland, San Francisco, and Milwaukee in the US, have demolished roadways to reduce automobile dependence and return a more human environment. The development of a new BRT system can be an opportune time to investigate opportunities for the reduction of road space.

14.1.5 Travel blending

Several cities in Australia and Europe have developed a new technique for achieving dramatic changes in mode shares at very low costs. The technique, known as "travel blending", is a form of social marketing. The idea is to simply give people more information on their commuting options through a completely personalised process, and then facilitating changes in travel behaviour. While the focus to date has been in developed countries, a recent success in Santiago (Chile) indicates that it may be applicable to developing cities as well.

More information on this technique is provided in Chapter 18 (*Marketing*).

Fig. 14.19
The high density of cities such as Bogotá makes public transport more financially viable and reduces overall trip distances.
Photo by Carlos Pardo

14.2 Integrating BRT with land-use policy

"The suburb is a place where a developer cuts down all the trees to build houses, and then names the streets after the trees."
—Bill Vaughn, columnist and author

A BRT project may be an opportune time to introduce long-sought land-use changes within the urban landscape. Land use refers to the manner in which urban form is shaped through policy actions and consumer preferences. Land use is often best characterised by what is known as the "3Ds": Density, diversity, and design. If developed through a mutually-supporting package of measures, the 3Ds can be the basis of creating an effective ridership base for public transport systems such as BRT.

Areas with medium- and high-density populations provide a critical mass of inhabitants

Fig. 14.20
Low-density communities, such as those in Houston, tend to make cost-effective public transport services impractical.
Photo by Lloyd Wright

to support shops and public services without requiring access by motorised vehicles (Figure 14.19). In low-density areas, customers must be drawn from a wider area in order for commercial centres to reach financial viability (Figure 14.20). The car becomes a necessity to cross such distances. Higher-density communities can provide a sufficient customer base within a walking distance. For this reason, a fortuitous circle of relationships exist between urban density, vehicle ownership, energy use, and vehicle emissions.

Diversity refers to creating a mix of uses within a local area. By combining residential and commercial uses into a single area, the number of trips and the length of travel are both reduced. People are able to meet most of their daily needs by walking, cycling, or public transport.

Design refers to the planning of housing, shops, and public transport in a manner that supports a reduced dependence on cars. Transit-oriented development (TOD) has emerged as one of the principal mechanisms to make this happen. This section reviews how land-use policy can be shaped to support a successful BRT system.

14.2.1 Introduction to transit-oriented development (TOD)

"In spite of its diverse and often conflicting meanings, all parties superficially endorse 'smart growth' because it is clearly superior to the alternative: 'dumb growth'."

—Anthony Downs, writer andpublic administration scholar

Local land-use patterns significantly affect the usage of public transport systems. Travellers will generally only use public transport if it requires walking less than a kilometre. Increasing the portion of destinations (homes, worksites, shops, schools, public services, etc.) located near public transport stations, and improving walking conditions in areas served by public transport, makes the system more effective to users and profitable for operators. This type of land use is called *transit-oriented development (TOD) or smart growth.*

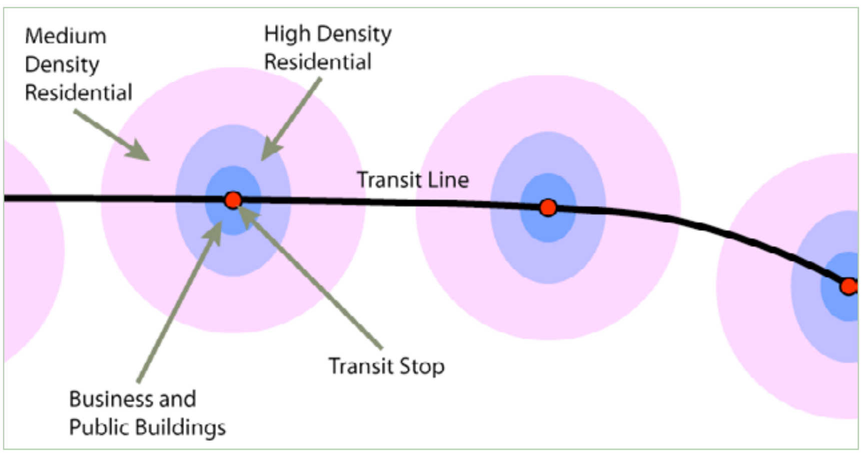


Fig. 14.21
Transit-oriented development (TOD) creates urban villages along transit lines, with a transit stop with major commercial and public facilities in the centre, surrounded by high- and medium-density residential development.

BRT projects can provide a catalyst for transit-oriented development. A public transport station can be the nucleus of a transit centre, also called an urban village (Figure 14.21). A typical village contains an appropriate mix of housing, schools, shops and public offices, employment centres, and religious (church, mosque, synagogue), recreation and entertainment facilities. As much as possible major destinations should be located within view of the public transport station so they are easy for visitors to find. Each urban village should have its own name and identity, which can be encouraged with appropriate signs and public art, and special events, such as a neighbourhood festival.

Higher density housing, such as multi-story apartment buildings and condominiums, should be located near public transport stations. Medium-density housing, such as low-rise apartments, townhouses, and small-lot single-family homes, can be located further away, but still within convenient walking distance of the transit centre.

A typical urban village has a diameter of 1 to 1.5 kilometres, a size that allows most destinations to be located within half a kilometre walking distance of the public transport station. This diameter contains an area of 80 to 160 hectares, enough to house 2,000 to 4,000 residents with medium-density housing (25 residents per hectare), or more with higher-density housing. Of course, not every urban village will follow this exact design, some may be primarily commercial, industrial or recreational centres, and others are limited in size due to geographic features such as parks and waterways. Some may be smaller or larger, depending on demographic and land use factors. Each urban village should be carefully planned to take advantage of its unique features.

Transit-oriented development provides many benefits compared with more dispersed land-use patterns. TOD increases the number of destinations within walking range of public transport stations. This, in turn, increases public transport system ridership and revenues, and reduces local traffic problems. More compact development with well-planned urban villages tends to reduce the cost of providing public services such as utilities, roads, policing, and schools. Improved walking conditions, reduced motor vehicle traffic, and better public services tends to increase neighbourhood liveability. It also provides economic efficiency benefits, including increased lower business costs for parking and goods distribution, and an expanded labour pool. These efficiencies tend to increase overall economic productivity, business activity and tax revenues. Even people who do not use public transport, benefit from having BRT service and transit-oriented development in their communities (Table 14.5).

Because of these benefits, property values tend to increase in areas with high-quality public transport services (Smith and Gihring, 2004). A recent study of residential property values along BRT lines in Bogotá, found that, after controlling for other building and neighbourhood attributes, residential rental costs increased between 6.8 percent and 9.3 percent for each 5 minutes reduction in walking time to a BRT station. This indicates that residents significantly value public transport access (Rodríguez and Targa, 2004). The upsurge in commercial and residential development along TransMilenio corridors clearly indicates the link between a quality public transport system and land-value appreciation (Figure 14.22). Likewise, Curitiba's BRT stations and corridors have become renowned for the large influx of accompanying development.

Fig. 14.22
Bogotá's TransMilenio system has led to significant commercial and residential development at stations and along the corridors.
Photo by Carlos Pardo

14.2.2 Transit-oriented development design features

"Let's have a moment of silence for every American stuck in traffic on their way to a health club to ride a stationary bicycle."

—Representative Earl Blumenauer, US Congress, 1948–

Transit-oriented development reflects several specific land use features. Density refers to the number of people or jobs in a given area. Increased density tends to reduce per capita automobile travel and increase public transport ridership. This result occurs because density increases the number of people and destinations served by public transport, which leads to improved public transport service (more frequent service with greater coverage) and better pedestrian conditions. As a general rule, densities of at least 25 employees or residents per hectare are needed within walking distance of a public transport line (*i.e.,* within 0.5 kilometres of each station) to create the demand needed for quality service. The exact density

Table 14.5: Benefits of transit-oriented development (TOD)

Transit Users Benefits	Transit Operators Benefits	Benefits to Society
■ More destinations near transit stations ■ Better walking conditions ■ Increased security near transit stations	■ Increased ridership ■ Lower costs per rider ■ Better image	■ Reduced traffic problems ■ Reduced public infrastructure and service costs ■ Community liveability ■ Increased property values, business activity and tax revenues

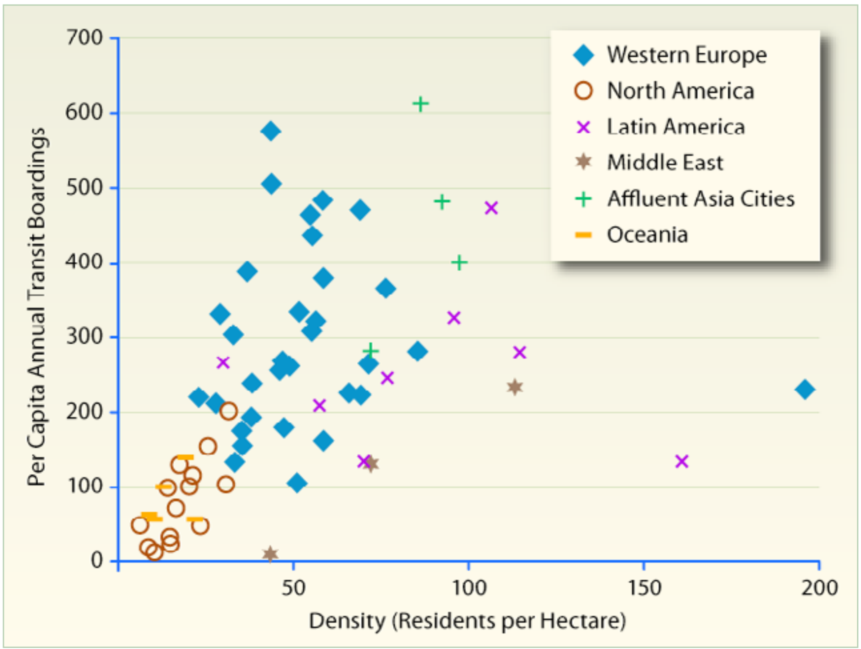


Fig. 14.23
City density vs. number of public transport trips.
Source: (Kenworthy and Laube, 2000)

requirements are affected by various factors, including the portion of residents who commute by public transport, and the distance that residents are accustomed to walk, and so may vary from one area to another.

Figures 14.23 and 14.24 illustrate the effects of density on public transport and automobile travel. As density increases, per capita public transport travel tends to increase and per capita automobile travel declines.

Clustering means that commonly-used businesses and public services are located together in an urban village, mall or district, as opposed to these services being dispersed throughout a community or scattered along a roadway. Clustering makes these businesses and services more convenient for pedestrians and public transport access. Clustering allows several errands to be accomplished during a single trip, helps create the critical mass of public transport riders needed for quality service, and encourages public transport commuting by locating more services (cafes, banks, and stores) near worksites for employees to use during breaks.

Curitiba has sought to exploit the advantages of clustering in conjunction with its BRT stations by developing "Citizenship Streets". These streets are a mix of shops as well as key public services such as health care, counselling, employment services, gymnasiums, and libraries (Figure 14.25). The Citizenship Streets are fully pedestrianised with one side typically bordering a BRT station. A person can often meet most of their daily journey requirements through visiting a single Citizenship Street. Likewise, Bogotá has located its "SUPERCADE" service centres at BRT terminals; these centres allow citizens

Fig. 14.25
Curitiba's "Citizenship Streets" are located near BRT stations and permit residents to fulfill multiple tasks within a single journey.
Photo by Vera deVera

Fig. 14.24
City density versus private vehicle usage.
Source: (Kenworthy and Laube, 2000)

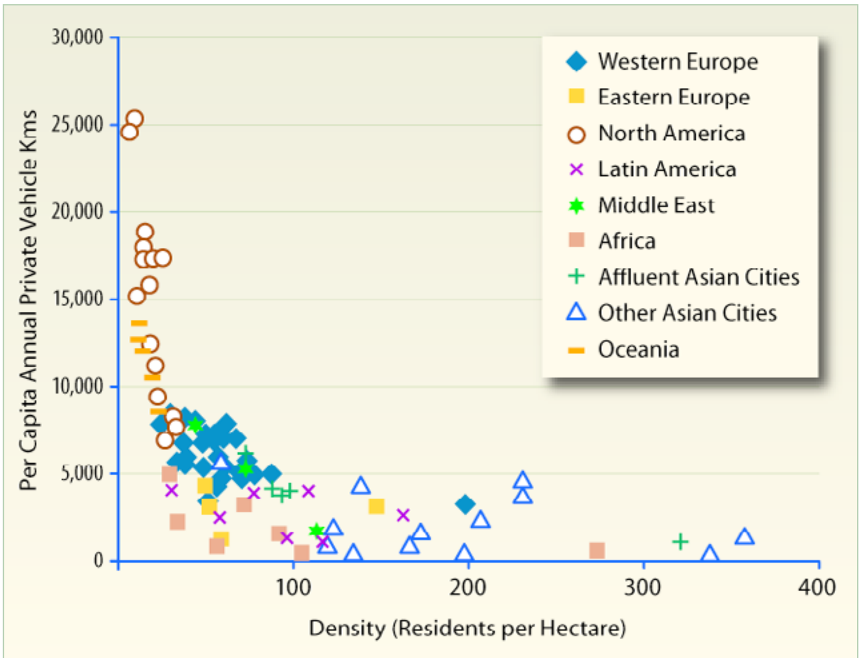


Fig. 14.26
Bogotá locates public service centres at its BRT terminals in order to more efficiently bring such services to the population.
Photo by Lloyd Wright

to pay bills and access public services in a single location (Figure 14.26).

Land-use mix refers to locating different but related activities close together, such as homes, schools and stores. Land-use mix reduces the need for automobile travel by allowing residents and businesses to walk rather than drive to more activities.

Connectivity refers to the degree that road and path networks allow direct travel from one location to another. Smaller city blocks, connected streets and shortcuts for non-motorised travel tend to minimise travel distances and support walking and cycling, and therefore public transport travel. Large blocks, dead-end streets and inadequate walking facilities reduce connectivity, increasing the distance that people must travel to reach their destinations. Figure 14.27 illustrates the difference between low and high connectivity street patterns.

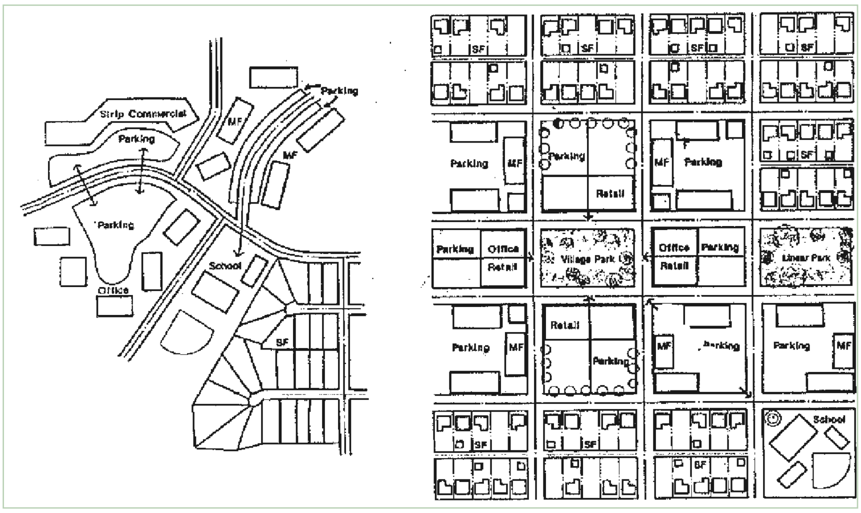
Walkability refers to the quality of the walking environment, including the condition of footpaths, road crossings, cleanliness and security. At a minimum, transit villages need wide, well-maintained footpaths, crosswalks that allow pedestrians to safely cross busy streets, and adequate cleanliness and security. In addition, it is desirable to have public parks, shade trees and other landscaping, attractive buildings, pedestrian refuges (so pedestrians need only cross half the street at a time) and traffic calming (to control vehicle traffic speeds), bicycle lanes, washrooms, drinking fountains, and other amenities to enhance pedestrian convenience, comfort and delight.

Site design refers to how buildings are designed and positioned with respect to roads, footpaths, and parking facilities. Buildings with entrances that connect directly to the footpath, rather than being set back behind a large parking lot, tend to encourage walking.

Parking management refers to how parking is supplied, regulated and priced. Generous parking supply creates more dispersed land-use patterns that are less suitable for walking and public transit access. Free parking represents a subsidy of driving which increases vehicle ownership and use. Ineffective enforcement of parking regulations can lead to motorists parking on footpaths, creating barriers to pedestrian travel.

Together these land-use factors can have a major effect on travel behaviour. Research in both developed and developing countries indicates that a combination of increased density, land-use mix, street connectivity and walkability increase public transport and non-motorised travel, and reduce per capita automobile travel (Kenworthy and Laube, 1999; Ewing, Pendall and Chen, 2002; Mindali, Raveh and Salomon, 2004; and Litman, 2004b). Figure 14.28 shows results from one study indicating that residents of the most urbanised neighbourhoods in Portland (US) use public transport about eight times as much, walk six times as much, and drive about half as much as residents of the least urban areas.

Fig. 14.27
The conventional hierarchical road system, illustrated on the left, has many dead-end streets and requires travel on arterials for most trips. A connected road system, illustrated on the right, allows more direct travel between destinations and offers more routes to choose from, making non-motorised travel more feasible (Kulash, Anglin and Marks, 1990).



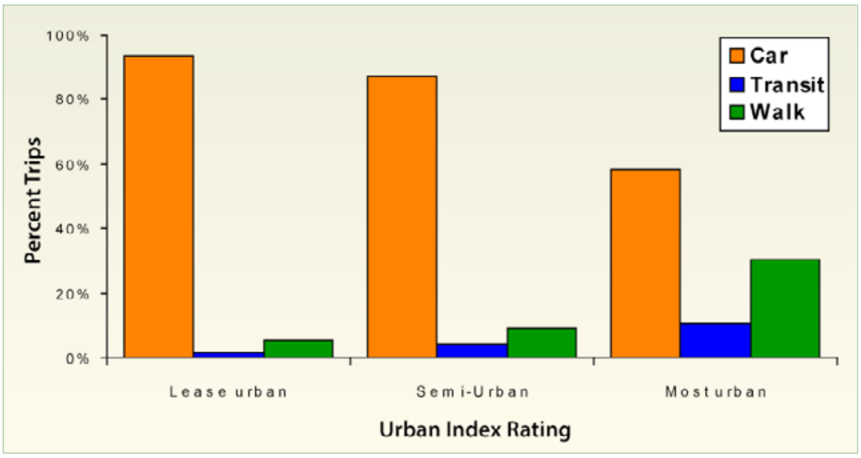


Fig. 14.28
The impact of urbanisation on mode choice.
Source: Lawton, 2001

14.2.3 Transit-oriented development policies

"Development has become something to be opposed instead of welcomed; people move out to the suburbs to make their lives, only to find they are playing leapfrog with bulldozers. They long for amenities that are not eyesores, just as they long to give their kids the experience of a meadow, that child's paradise, left standing at the end of a street. Many communities have no sidewalks, and nowhere to walk to, which is bad for public safety as well as for our nation's physical health. It has become impossible in such settings for neighbors to greet one another on the street, or for kids to walk to their own nearby schools. A gallon of gas can be used up just driving to get a gallon of milk. All of these add up to more stress for already overstressed family lives."

—Al Gore, former US Vice President, 1948–

In developing countries, where land use is frequently difficult to regulate, transport sector interventions like BRT are one of the best ways to affect changes in land use that are largely dominated by private market based decisions. However, there are some public policies that have been successfully used to encourage higher-density development in the area served by a new BRT system. This section describes specific public policies that can help implement transit-oriented development.

14.2.3.1 Public facility location and infrastructure investments

One of the easiest ways for a government to ensure transit-oriented development is to locate public facilities, such as government offices, schools and colleges, sports and recreation centres, and cultural facilities along public transport corridors. Bogotá built several new schools along the TransMilenio BRT corridor.

Transit centres and urban villages can be given priority when public investments are made to improve footpaths, roads, parks, public utilities and services such as water and sewage, garbage collection, and electricity. For example, the Rhode Island Transportation Improvement Plan (TIP) gives priority to projects that encourage compact development. As a result, the majority of transportation funds are spent on system management and preservation projects, and less is devoted to expanding roadway capacity in areas with unplanned, dispersed development.

14.2.3.2 Zoning codes

In cities where zoning codes exist and are enforced, up-zoning along a BRT corridor and down-zoning areas off the BRT corridors can be one of the most powerful ways of maintaining and increasing BRT system ridership over the long term. Perhaps the most well-known application of zoning codes in conjunction with public transport is the Curitiba BRT system. High-rise development in Curitiba is restricted only to those areas along the BRT corridors (Figures 14.29 and 14.30). The effect is quite striking in terms of city efficiency and public transport ridership. Areas with rows of skyscrapers in Curitiba make identification of the busways quite easy.

Density bonuses (higher density than would otherwise be allowed) can also be used to encourage major developments in areas well served by public transport, and to incorporate transit-oriented development design features. Many cities have Alternative Development Standards (ADS) that apply in transit-oriented centres, allowing higher densities, mixed land use and lower parking requirements. For example, the city of Portland, Oregon (US) reduces its minimum parking requirements by 10 percent for locations near bus lines, and by 20 percent if located near a rail transit station. Parking is reduced further for developments that are located in walkable neighbourhoods or near bikeways.

To discourage dispersed, automobile-oriented development at the urban fringe, some

Fig. 14.29 and 14.30
Restricting high-rise development to only the mass transit corridors produces multiple benefits for Curitiba.
Photos courtesy of the Municipality of Curitiba

jurisdictions limit the amount of development that may occur outside urban areas with urban growth boundaries and agricultural land reserves. Others limit the extension of water and sewage lines to prevent higher-density development in undeveloped areas.

14.2.3.3 Housing and BRT

In the developing world, where zoning codes are often difficult to enforce, housing policies can be one of the more powerful tools to affect land-use changes. The degree and form of government intervention into the housing sector varies greatly from country to country.

Though rarely done, the ideal would be to co-ordinate low-income housing programmes and BRT project development so that the beneficiaries of the housing programme could also benefit from the improvement of basic mobility. If such programmes were co-ordinated at the outset, low-income families could also be insulated from the risk of rent increases resulting from the new BRT system.

Governments have varying degrees of influence over the housing sector. At one extreme are countries with very powerful states with a lot of municipally-controlled land, like China. In China, all levels of government build some housing, publicly-owned enterprises own housing, and various branches of the government including the military are directly involved in real estate development. In such countries, the Mayor has enormous discretionary power to influence what land is developed and at what density. Densification of mass transit corridors in China happens almost automatically, however. At the other extreme, many very poor African countries can afford to do little to intervene in the housing sector short of providing some basic infrastructure.

Bogotá's Metrovivienda programme provides a good example of how low-income housing programmes can be linked to a BRT system. Metrovivienda is a municipal authority that bought land not immediately adjacent to the TransMilenio BRT trunk corridor, but in areas to be served by TransMilenio feeder services, where land was cheap but likely to increase due to the TransMilenio project (Figure 14.31). The municipality subsidised the land procurement, but then contracted private developers to develop affordable but profitable housing

Fig. 14.31
Bogotá's Metrovivienda programme has provided low-cost housing within close proximity to TransMilenio feeder services.
Photo courtesy of Por el País que Queremos (PPQ)

on the land. The developers were chosen by competitive bid. They were able to sell the houses at a profit because the developers did not have to pay for the land. This process was able to provide home ownership at prices roughly 25 percent less than could have been supplied by the private market. Furthermore, after TransMilenio was built, land prices in the area increased by more than 6 percent above the increase of land prices generally. By having the government procure the land but having private developers develop the land, Metrovivienda was able to provide low-income housing in an area served by TransMilenio while insulating the residents from land price increases.

Curitiba did not incorporate low-income housing programmes into its BRT system, and the densification along the BRT corridor led to very high density middle and upper income real estate development that did dislocate lower-income families to less desirable locations. Likewise, Quito did not intervene directly to encourage housing projects along its BRT corridors. Instead, the private sector has recognised the opportunity and has constructed several new developments near the corridors and stations (Figure 14.32). However, Quito has altered zoning regulations to help facilitate this process.

An innovating example from the US, a co-operative effort by US local and federal agencies, and private banks, is known as the Location

Fig. 14.32
Quito's Ecovía has boosted the development of high-rise apartment buildings and shops along the corridor.
Photo by Lloyd Wright

Efficient Mortgage Initiative. This initiative allows homebuyers to qualify for larger homes loans if the proposed housing is located within a quarter mile (400 metres) of a bus line or half a mile (800 metres) from a train or light rail system. The initiative also offers discounted annual bus passes for one member of the household.

14.2.3.4 Tax and fees

Taxes and utility fees can be structured to favour development of urban villages, reflecting the greater efficiencies and lower unit costs of providing public services in such areas. For example, taxes can be deferred or discounted for buildings that reflect transit-oriented development features. Households that do not own an automobile can be offered a property tax discount, reflecting the lower costs they impose on city road networks and traffic services.

For example, the city of Austin (US) imposes a special "Transportation User Fee" (TUF) to finance roadways, which averages US$30 to US$40 annually for a typical household. This charge is based on the average number of daily motor vehicle trips made per property, reflecting its size and use. For example, single-family development is estimated to generate 40 motor vehicle trips per acre per day, condominiums and townhouses are estimated to generate 60 motor vehicle trips per acre per day, and offices generate approximately 180 motor vehicle trips per acre per day. The city provides exemptions to residential properties with occupants that do not own an automobile, and for businesses that encourage employees to use alternative modes, such as public transport.

14.2.3.5 Street design and management

Streets in transit villages should be designed and managed to favour public transport and non-motorised modes, including special lanes for buses and bicycles where warranted, adequate space for footpaths, particularly around public transport stations; amenities such as benches, shade trees, garbage cans and public washrooms along footpaths and parks; traffic calming and enforcement to control traffic speeds; and effective enforcement of traffic and parking laws, and personal security protection of pedestrians. Some cities have implemented "road diets," which involves reducing the number of vehicle traffic lanes t allow more space for turning lanes, bike lanes, and footpaths.

For example, the city of Seattle (US) has implemented more than 1,000 traffic circles on residential streets and will be adding dozens more each year. The city has a standard process for residents to request the implementation of traffic calming on their streets, and various funding sources. The response has been positive: there are hundreds of requests each year for more traffic circles, and although devices can be removed if residents are unhappy with the final result, this has only happened once.

Fig. 14.33
In central district of Curitiba, the design of the BRT system is carefully blended with the surrounding urban environment.
Photo by Lloyd Wright