2. KEY ROAD DESIGN PRINCIPLES IN THE CONTEXT OF SAFE PLANNING

2.1. General Road Design Principles

Road infrastructure design plays a significant role in road safety outcomes, but typically safety is just one consideration among many during the road design process and is often not prioritized. This section outlines some of the broad design considerations. Further details on these issues can be found in several national design guides, such as The Austroads Guide to Road Design,\(^\text{11}\) which provides designers with a framework that promotes efficiency in design and construction, economy, and both consistency and safety for road users. Other similar documents include the AASHTO Green Book\(^\text{12}\) and PIARC Road Safety Manual, along with many others.

Road design and construction involves the geometric and structural design of a roadway. A key objective of this is to optimize operational safety and transport efficiency within constraints (including budgets, environmental concerns, and other social outcomes). Design needs to consider both the traffic volume and type that would be expected to use the road. This covers all user groups—motorized and nonmotorized.

Highway engineers design road geometry to ensure stability of all vehicles when negotiating curves and grades and to provide adequate sight distances for undertaking passing and stopping maneuvers. The design choices related to geometric road design will depend upon the environment through which the road passes - principally habitation and topography - and the interactions between these design features and the environment have a fundamental impact on safety. Each design situation is unique and there are no ‘off the shelf’ solutions that will fully address all situations encountered. As discussed in Section 1.3, the rigid and unthinking application of charts, tables and figures is unlikely to lead to a successful and safe design outcome. Good design requires creative input based on experience, knowledge about the local environment (including road user considerations), and a sound understanding of design, allowing evidence-based principles and solutions to be effectively applied with refinements to the exact local circumstances. Processes and tools to ensure safety is embedded in a proactive way in design are also required (see chapter 7).

Any design MUST:

- Address the needs of all road users.
- Be undertaken by a qualified road designer under the supervision of a professional engineer/senior design engineer, both with appropriate road design experience in line with the scope of the project.
- Be safe, ensuring that any recommended safety provisions are not reduced in favor of saving costs during the design and construction process.
- Be context sensitive, including being suitable for the land use.
- Demonstrate cost-effectiveness through value engineering processes, cost benefit analyses, and consideration of whole-of-life costs (which include safety benefits).
- Be fit-for-purpose, i.e., the function it is supposed to serve, while trying to achieve the highest possible


\(^{12}\) A Policy of Development of Highways and Streets 7th ed. 2018. AASHTO.
standard of design, safety, and operational efficiency within the context of the site, the project scope, and budget.

- Be subjected to an audit process by independent and qualified road safety auditors.

It SHOULD also:

- Be considerate of environmental, cultural heritage, and social requirements.
- Recognize the increasing impact of climate change on the resilience of road infrastructure.
- Maintain or improve the performance of an existing road.
- Fully document the rationale behind design decisions.
- Meet the objectives of the project while being mindful of the objectives for the road link and network.
- Be able to demonstrate it appropriately balances all of the above principles within the limits of the project scope and constraints and is complementary to the network.
- Consider and cater for the interaction between all road users and the roadway.
- Meet current needs while also providing for future needs.
- Be developed in accordance with sound design guidance. Innovative designs may be developed using the foundations provided in accepted design guidance; however, all other road design principles should be maintained.

In the context of designing and providing a safer road environment, the Safe System approach aims to ensure that potential collisions are avoided and, if they occur, that the crash impact forces do not exceed human tolerance. Findings from Sweden identified that, while there was a strong interaction between the three system components of vehicles, road infrastructure, and road user, road-based factors, including speed, were most strongly linked to fatal crash outcomes. Roads should therefore be designed to reduce the likelihood of crashes occurring and minimize injury to the road users even when a crash occurs, and there is very clear evidence that suggests that the severity of outcomes when crashes do occur is most heavily influenced by the road design. In particular, this includes the features that indicate to drivers the speed at which the corridor is designed to operate and the features which force lower speeds. The elements that are typically thought to impact on efficiency and safety include intersections, horizontal and vertical curves, camber (super-elevation), gradients, cross sections (lane and shoulder width, medians and roadside provision), and merge and diverge areas. All these elements (and more) are covered in detail in national/local design manuals and guidelines.

Roads should be designed to cater for a defined function and use (see section 2.2). By adopting a consistent and clearly differentiated design for each function group, the road can create a better appreciation of risk in (most) drivers. This in turn encourages road user behavior consistent with the safety standard of the road. The same general functional management principles should be applied in both urban and rural networks.

Appropriate design choices are needed for roads serving different functions to minimize the number of crashes likely to occur and to mitigate injury severity, particularly on higher-speed roads. Further, it is also important to state that a consistent selection of minimum design criteria is not a good practice and that such choices often lead to unsafe and inconsistent design.

While highway engineers concentrate on the geometric parameters, road users are more concerned with the context of the road and rely on visual cues and roadside details to determine safe and appropriate speed and risk. These elements need to be provided in such a way as to give all road users sufficient time to

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make appropriate decisions to avoid conflict and injury collisions. A balance is needed between too much and too little information, but whatever is provided needs to enable road users to assess an appropriate and safe behavior. (See section 2.2 for more information on self-explaining roads.)

Road infrastructure should be designed to proactively take account of the same injury tolerance criteria as those developed for vehicle occupant protection and pedestrian impacts, so that roads and vehicles together provide an effective safety system. Below are some associated risk levels for different road users.

Risk to cyclists varies substantially between countries, mainly reflecting the infrastructure provided for them and the motorized traffic levels they interact with.

- Risk for motorized two wheelers is particularly high, and solutions are needed to minimize the severity of injuries resulting from their impact with roadside furniture.
- Among pedestrians, the young and the elderly are most at risk.
- Elderly road users have diminished physical and cognitive capabilities.

Safety is fundamental to the design and operational life cycle of a road. Safety should not be left to reliance on road users behaving safely—the millions of crashes and injuries globally each year show that this does not work. The process should start with a safety impact assessment of a proposal even before a decision is made where to site a new road.

A proactive approach is required to improve road safety. Safety audits are then undertaken at specific points during the design, construction, and post-opening stages to ensure all aspects of detailed design that might affect safety are addressed. A safety audit during the construction phase also helps to ensure that workers and road users are not at risk during developing and changing road conditions.

Once the road is built and accepted by the highway authorities, they have a responsibility to ensure its safe operation. This is best done through a combination of a crash investigation and on-road inspection to enable cost-effective remedial programs to be developed; many tools exist to support these activities. These aspects of proactive assessments and tools are discussed in more detail in chapter 7: Design Tools for Safe Outcomes.

### 2.2. Road Function and Land Use

Historically, functional classifications have been used to group roads into classes, or systems, according to the character of service they are intended to provide. Functional classification outlines how travel can be channelized within the network in a logical and efficient manner by defining the part that any particular road or street should play in serving the flow of trips through a highway network. Major routes in the road network are most commonly classified by the two functions: Access and Mobility (or movement and place, see Figure and are often known as:

- Principal/Arterial Roads,
- Distributor/Collector Roads, and
- Local Roads.

These standard classifications remain constant for the whole route and this has often been used to inform the design and management criteria that are applied to different parts of the network.

Different road classifications offer different levels of mobility and accessibility depending on their overall usage which require different traffic speeds, segregation of users and other driving actions.

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e.g. readiness to deal with cyclists and pedestrians (including young children). Networks in most countries will therefore reflect the development of a hierarchy of motorized use, with motorways/freeways/expressways at the highest level of motorized use and local access roads at the lowest. In practice, a basic hierarchy will occur naturally through the more heavily trafficked routes being engineered to higher standards. But it is important that the hierarchy is established to clear guidelines linking design to actual function to provide the desired levels of mobility and accessibility. In many LMICs, however, this clear hierarchy becomes blurred, with roads serving a mixture of functions; for example, resources can be insufficient to finance a segregated road network, and trunk roads often serve as centers for commercial activity. Additionally, road networks interlace and connect residential, commercial, urban, and suburban areas of cities, towns, and villages. They fulfill many functions along their routes catering for many types of activity, not just journeys by different modes. Thus, roads need to be designed for their actual function, and it should be recognized this may differ along their length.

![Diagram](image)

Figure 2.1: Access and mobility functions for different classes of roads.

Source: FHWA.

It is not safe to assume that the intended function of a road will be its function along its whole length, or for its whole lifetime. By failing to take account of the changing context along the route this classification system limits understanding of how improvements, maintenance, or safety should reflect the wider functions that routes serve. This changing context is illustrated by some of the images in figures 2.2 through 2.4.

A clear distinction needs to be made between streets and other types of roads. Local roads within an urban area are often referred to as “streets” and are typically lined with buildings and non-travel activities including trade, play, and other forms of engagement. While movement is still an important requirement on streets, the ability to undertake other functions safely becomes increasingly dominant. In the context of LMICs, these hierarchies often face a major challenge due to the typical distribution of mode shares consisting of a significant portion of nonmotorized road users.

On streets in any given urban area, you might find people walking their dogs, having lunch in a sidewalk cafe, waiting for a friend, or simply watching people. For roads connecting Town A to Town B, you are less likely to find any of this, as mobility is the primary function. The term “street,” then, should be specifically applied to local urban roadways. Streets connect people for interaction, while other roads connect towns and cities for travel (although the function may differ for specific points on the road).

In 1997, the collective Dutch road management authorities reached an agreement on a major traffic safety program, called Duurzaam Veilig (“Sustainable Safety”). One of its principles is a clear-cut categorization of roads into a small number of visually distinct and clearly recognizable designs that must be applied consistently throughout the country. Four categories of road seem to be sufficient to cater for all needs; these are:

- Motorway,
• Major inter-city roads,
• Local roads or streets) to connect residential areas to shopping and services, and
• Woonerfs (or traffic-calmed residential zones).

Many countries now find that they need more categories to cover their full range of road types (e.g., rural access roads, urban collector roads), and the distinction between each category becomes more blurred depending on the various activities that need to be accommodated. The important point is that all roads and streets can be designed to create different expectations about how road users should act on them.

Figure 2.5 shows examples of movement and place matrix from the UK and Australia. The two axes represent the relative priorities of roads to facilitate the movement of people and goods, and to act as destinations for people. The position of the road on the movement axis is based on the strategic importance of the road, identified by its role in the broader network. The position of the road on the place axis is based on the strategic importance and community value of the road to act as a place.

The aim is that different classes of roads should be distinctive, and within each class, features such as

**Figure 2.2**: Sellers on the road in Senegal.

**Figure 2.3**: Shops taking over the footpath and roadway—Nepal.

**Figure 2.4**: The road is a meeting place in villages in Armenia.

**Figure 2.5**: Illustration on movement and place status of roads and streets.

Source: © Soames Job/GRSF/World Bank.
Source: © Soames Job/GRSF/World Bank.
Source: © Soames Job/GRSF/World Bank.

Wider Application of the Principles. Note that the term “high street” in this diagram relates to a busy commercial shopping street. This is sometimes termed a “main street” in other countries.; Government of South Australia, 2012 (right). Government of South Australia. 2012, Streets for people, Adelaide, Australia.
width of carriageway, road markings, signing, and use of street lighting would be consistent throughout the route and matched to their functional use. Drivers would thus perceive the type of road and “instinctively” know how to behave. The environment effectively provides a “label” for the particular type of road, and there would be less need for separate traffic control devices such as additional traffic signs to regulate traffic behavior. They become “self-explaining,” i.e., more intuitive, to all users.

However, simply spending precious resources to achieve consistency on an otherwise safe and efficient corridor might not be acceptable. Therefore, a less onerous philosophy to achieve an acceptable level of consistency of facility along a corridor may be applied.

That philosophy is one of predictability. That is for successive sections along a road within a consistent environment (rural vs. urban), there should be little or no variation in the level of cross section, horizontal or vertical geometric standard, or sight distance provided. A “no-surprises” approach has a consistency of context that provides the users with appropriate and relevant information in a timely fashion to facilitate their decision-making. Any rapid or isolated changes, e.g., sharp curves or shoulder narrowing, would be considered “out of context” and would ideally be eliminated, but if they are unavoidable, then more specific, local treatment should be considered to give advanced warning of their presence to drivers. Such approaches use simplicity and consistency of

Figure 2.6: A rural highway passing through a market—Chad.

Source: © Soames Job/GRSF/World Bank.

Figure 2.7: Stalls on the road with no separation of through high-speed traffic movements and mixed activity area—Nepal.

Source: © Soames Job/GRSF/World Bank.

Figure 2.8: Main urban arterial separated from the mixed activity area—Qatar.

Source: © John Barrell.

Figure 2.9: National road separated from the mixed activity area—Qatar.

Source: © Soames Job/GRSF/World Bank.

design to reduce driver stress and driver error and help guide driver behavior and their speed selection. It is already used for the highest road classes (motorways), but on low-class roads, consistency in design is often compromised by other objectives such as high access levels, variable alignment, mixed use, and variable roadside development, which result in a lack of consistency and a lack of differentiation between road classes.

The implications of self-explaining roads are especially profound for LMICs. Developments affecting parts of the road system that have customarily been used for social or commercial purposes should therefore be handled with particular care. If it is possible to retain the social or commercial function, then care should be taken to separate through traffic movements from the local traffic in mixed activity areas and ensure that a high-speed environment is not imposed on it. If it is not possible to retain the social and commercial functions, then a suitable alternative site for these activities should be found, and the new road facility which replaces the former mixed activity area should be clearly identifiable as primarily a traffic facility. In a situation where high-speed through traffic cannot be separated from the local traffic and activities, downgrading of the functional class is needed to maintain safe travel speeds through such areas with the help of suitable infrastructure design and speed enforcement. Figures 2.6 and 2.7 illustrate the lack of separation of through traffic from local traffic in mixed-activity areas while figures 2.8 and 2.9 illustrate the separation of high-speed traffic.

2.3. Vehicle and Road User Type in LMIC Context

The type, quality, and volume of vehicles and experience of road users are unique in the LMICs, often differing substantially to those in developed countries. This is primarily due to the socioeconomics, affordability of vehicles with modern technologies, and above all, country-level policies. As a result, there are several variants of vehicles under both light and heavy vehicle categories, with a broader range of acceleration-deceleration capability and the top speed that could be maintained. Furthermore, there is also a very high share of two- and three-wheelers, makeshift vehicles, overloaded vehicles, vehicles for agriculture and farming, and animals (e.g., horses) or animal-drawn vehicles. Such a mix of traffic is commonly known as a heterogeneous traffic mix, with a high variation in travel speed. While the vehicle dynamic characteristics vary widely in mixed traffic, there are generally no separate transport facilities in most LMICs; thereby, all vehicles use the same carriageways, often with poor or zero lane discipline. In addition to the motorized vehicles, the share of nonmotorized traffic and pedestrians is very high in any LMIC. However, most often there are no dedicated facilities for nonmotorized transport (NMT) road users, resulting in higher interaction with motorized and NMTs, and a high share of crashes and injuries involving these vulnerable road users, including people with disabilities (see chapter 4, Vulnerable Road User Infrastructure Design). Due to such issues, adopting design configurations and standards directly from high-income countries (HICs) may not be advisable to cater to all road users’ needs. This often means that the standard of design and infrastructure provision needs to be higher in developing countries for NMT (e.g., sidewalks are needed much more frequently in Bangladesh than Australia); yet the amount invested per kilometer on road projects is significantly lower. In addition, where significant numbers of animals and animal-drawn carts use a path, consideration for collision risks and slow-moving vehicles should be given to the design to accommodate them safely (e.g., additional width, special signage, fencing, road furniture such as noise barriers or guardrails, segregation at intersections and crossings) (see relevant separate sections for details of these measures, and FHWA [2020]. Improving Safety for Travelers and Wildlife for a comprehensive approach). There is a reality that budgets are limited and so affordability is important in developing countries, but more investment is needed to manage the challenging environment to achieve a safe road
environment. Figures 2.10 through 2.13 illustrate the different vehicle types in the context of LMICs.

For example, India has a heterogeneous mix of traffic, with a range of vehicle types in the vehicle mix, including passenger cars, motorcycles, light commercial vehicles (such as pickup trucks), motorized rickshaws, and heavy vehicles (such as trucks and buses). These vehicle types have very different acceleration and deceleration capabilities and ease of maneuverability in a traffic mix that does not follow any lane discipline.\(^{19}\)

As a result, traffic streams with a high percentage of these vehicles and lesser percentages of other vehicles are expected to have different traffic characteristics than traffic streams with different compositions, which will also have implications on safety. Additionally, the maneuverability of certain vehicles, especially motorcycles, may have different effects on safety. For example, it is prevalent for motorcyclists to maneuver side by side and weave between two larger vehicles, sharing virtually the same space across a lane, which

Figure 2.10: Different types of vehicles and high pedestrian volume.

Figure 2.11: Different types of vehicles—Vietnam.

Figure 2.12: Four different types of vehicles on highways—India.

Figure 2.13: Different types of vehicles.


is less common in largely homogeneous traffic. Slow-moving heavy vehicles are often seen occupying the outer lanes of dual carriageways, encouraging other drivers to overtake on the inside. In addition, the proportion of heavy vehicles has in some cases been found to have a negative effect on traffic safety, and there is evidence that a higher proportion of motorcycles in the traffic stream was positively and significantly associated with rear-end crashes. In contrast, the higher percentage of heavy vehicles in the traffic stream was found to be substantially related to head-on collisions. Various conflicts among road users in mixed-vehicle traffic are illustrated in figures 2.14 through 2.17.

While this identifies problems associated with specific vehicle types, the effects of overall vehicle composition on traffic streams are yet to be studied and investigated further across different regions of LMICs, to provide clear direction on the safety effects of these vehicles on the mix. As a result, it can be said that the safety effects of different compositions of vehicle types in heterogeneous traffic are still an underexplored domain.

Nonetheless, there is evidence that segregating a diverse traffic mix (especially where speed is involved),

such as high-speed through traffic and low-speed local traffic with the help of service roads, and separating vulnerable road users such as motorcyclists, cyclists, and pedestrians through the introduction of motorcycle lanes, cycle lanes, and sidewalks or footpaths, respectively, is likely to produce significant safety benefits. Section 4 describes the design of vulnerable road users in detail. Finally, integrating public transport facilities (e.g., bus rapid transit, BRT) with well-designed crossing facilities is found to be effective in enhancing the safety of public transport users who are mostly pedestrians before and after using public transport facilities.

**Further reading:**


• World Road Association (PIARC) (2016). Human Factors Guidelines for a Safer Man-Road Interface. Technical Committee C3.2, Design and Operation of Safer Road Infrastructure, World Road Association (PIARC), Paris, France

2.4. Context Sensitive Design

A road design cannot be considered safe, fit-for-purpose, or conforming if it simply adopts design minima, particularly in combination, for elements of the design. Most design criteria (range, desirable, absolute) have been researched or developed in isolation from each other (although there may be some implicit relationships) and when used in combination with other elements, while conforming to the published guidelines, may result in a solution that compromises safety or operational efficiency.

Any road also has to operate appropriately within the natural and built environment to meet a range of expectations of the users and the broader community. Consequently, the design cannot be carried out in isolation, but must be sensitive to the context in which the road will operate and, as a result, competing or conflicting criteria often need to be compromised to achieve a balanced, safe and cost-effective solution.

Context-sensitive design (CSD) is an approach that provides the flexibility to encourage independent designs tailored to particular situations while giving due consideration to all factors.

A “design domain” can be thought of as a range of values that a particular parameter might take. This applies to a range of design parameters that, when used in context, provide acceptable safe, efficient, and effective outcomes. They are justified in an engineering sense using a consistent set of principles, based on test data and sound reasoning, for example, and therefore can have a reasonable level of defense if challenged.

The design domain approach places emphasis on developing appropriate and cost-effective designs rather than providing a design that simply meets standards. It comprises a normal design domain (NDD), an extended design domain (EDD) (Figure 2.18) and also design exceptions (DE). These can also be referred to as design standard, relaxation, and a departure from standard. The concept requires a designer to select a value, appropriate to the context, for each design element from a range of values, taking into account the benefits and costs of each selection.

The lower regions of the design domain represent values that would generally be considered less safe or less efficient, but often less expensive than those in the upper regions of the domain. The decision on the values to adopt should be made using objective data on the changes in cost, safety, and levels of service caused by changes in the design, together with a benefit-cost analysis. The engineering principles and target values for each parameter in the design should be agreed at a very early stage in the project. Although these may be varied later in the design process as more information is obtained, early indications from the client to the designer are important to set the expectation of the roads purpose and function, and allow the design to progress with greater certainty of intended outcome.

CSD seeks to produce a design that combines good engineering practice in harmony with the natural

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26 Department of Transport and Main Roads. 2013. Road planning and design manual, 2nd ed., TMR, Brisbane, Qld.
and built environment, and meets the required constraints and parameters for the project. It refers to roadway standards and development practices that are flexible and sensitive to community values. It also makes allowance for the use of narrower lanes, lower design speeds, sharper turns, and special features not included in generic road design guidelines to help create a more balanced and efficient transportation system and meet community land use objectives.

However derived, a design should demonstrate value engineering and acceptable whole-of-life costs to cater for all road engineering disciplines including safety, geometric design, traffic, drainage, pavements, asset management, and stakeholders (e.g., road users, vulnerable road users, freight, public transport, emergency services, environmental), while taking into account current and future needs.

At the beginning of the project lifecycle, the project needs to determine what road users are present and how they will be catered for (see section Design for road user characteristics and compliance2.4.2). The suitability of a design should also consider the effects the design may have on adjoining road sections and the surrounding network.

Designs require decisions to be made on the value of improving the standard of a road and the impact this might have on the ability to fund improvements elsewhere on the road system. Depending on the controlling authority's funding priorities, for example, this may be focused on safety, environment or efficiency, which may drive different outcomes. The most appropriate compromise is usually a balance of all three categories, i.e., the highest value for a money safety solution may be the least attractive from an environmental aspect.

It is therefore important that design decisions are documented and based on sound engineering judgment and rationale to address the problem to be solved. These decisions are subject to appropriate review/governance and should show how they demonstrate value engineering and manage whole-of-life costs within the design constraints and context of the site.
Design Exceptions

Design exceptions are situations where the design does not conform to the minimum or limiting criteria set forth in the standards, policies, and standard specifications. They are most likely to occur due to challenging terrain; constrictions due to existing infrastructure, services, property boundaries, environmental conditions, cultural heritage and community expectations.

Design exceptions have the potential to negatively affect highway safety and traffic operations. For this reason, consideration of a design exception should be deliberative and thorough, and a clear understanding of the potential negative impacts should be developed through a risk assessment that is unbiased and supported by crash analysis. Sometimes the drivers for adopting design exceptions such as these may be for social, environmental, or economic reasons, however the risk assessment must show that the decisions associated with adopting such a low standard outweigh the potentially higher cost of fatal and serious injury crashes. If the decision is made to go forward with a design exception, it must be formally approved by the relevant road agency and supported by a well-documented justification. It is also especially important that measures to reduce or eliminate the potential negative impacts be evaluated and, where appropriate, implemented.

Documentation for design exceptions should describe all of the following:

- Specific design criteria that will not be met;
- Existing roadway characteristics;
- Alternatives considered;
- Comparison of the safety and operational performance of the roadway and other impacts such as right-of-way, community, environmental, cost, and access for all modes of transportation;
- Proposed mitigation measures; and
- Compatibility with adjacent sections of roadway.

Design exceptions should NOT be used where any one of the following applies:

- There is a crash history linked to the use of the Climate Resilient Roads

Road transport plays an important role in the overall socio-economic development of a country. However, road infrastructure is extremely environmentally challenging and highly vulnerable to the impacts of climate change such as flash floods and landslides caused by heavy rains. In addition, rapid growth in vehicle numbers and movement make road infrastructure vulnerable. The road networks of developing countries are generally more vulnerable to climate change impacts due to poor maintenance, a high proportion of unpaved roads and limited resources and technology to adapt.

A climate resilient road comprises a set of technological measures rather than a single technology. These can be either engineering or structural measures or bio-engineering measures. The structural measures include:

- Slope stabilization structures.
- Paving of roads with durable materials.
- Proper alignment of new roads to avoid vegetative loss.
- Improved drainage systems to avoid erosion of road materials.
- Improved planning of roads with proper cross section and standard dimensions.
design exception e.g. police crash reports indicate that limited visibility was a contributing factor to the crash(es). This is even more important in the following cases:

- if more than one such crash is reported
- mitigating devices are already in place.

- Use of the same, or similar, design exception has been known to cause safety problems elsewhere on the network.
- The value of the design exception is well outside the range of values of the design domain.
- The design exception is an isolated case, for example, if a roadway contains generous horizontal curvature except for one (or a few) very substandard horizontal curves. In this case, drivers become used to the general standard of horizontal curvature and are less likely to adequately perceive and negotiate the substandard element/s. This is different from a roadway comprising tighter, but more consistent horizontal alignment which would cause drivers to be more alert and have a greater expectancy of tight geometric elements.
- A design exception is combined with other geometric minima, especially other design exceptions. The greater the number of minima combined, the lower the likelihood that a design exception can be tolerated as one of these minima.
- On road restoration projects comprising higher function and/or higher traffic volume roads.
- The parameter being considered is intersection sight distance. In this case, the EDD values are the lowest that should be provided.
- Where little effort and expense is required to avoid using the design exception.
- On road restoration or low volume road projects where the pavement is being replaced, especially if minimal earthworks are required.

Reference to aviation industry. Sudeshna to share document

**Design for road user characteristics and compliance**

Conventional roadway design standards and guidance define features such as lane and shoulder widths, design speeds, and minimum parking supply. They often reflect the assumption that bigger and faster is better, leading to a design that effectively exceeds the standard required for its intended purpose. This can result in higher traffic speeds, increased project costs, and roadways that contradict other planning objectives. For example, wider and straighter roads tend to increase traffic speeds and disperse destinations, which can reduce accessibility, safety, and livability.

At the beginning of the project life cycle, the project needs to determine what road users are present and how they will be catered for. This requires that data are collected about who uses the road and how they use the road e.g., where do pedestrians walk, what percentage of vehicles are motorcyclists and what is the actual speed vehicles travel at. These data are important in understanding the true design environment, as opposed to a design for how people “should” behave. It is also important that at the start of each project phase the road-user and stakeholder requirements are clearly documented so that the designer can clearly understand how to develop a design that addresses the needs and requirements of all road users and balances these within the overall design solution.

**Complete streets**

The complete streets approach is a modern approach to urban design aiming to address the safety and amenity challenges of all road users and redressing the old school focus on motorized vehicles. Complete streets are streets designed and operated to enable safe use and support mobility for all users. This includes people of all ages and abilities, regardless of whether they are travelling as drivers, pedestrians,
cyclists, or public transportation riders. The concept of complete streets encompasses many approaches to planning, designing, and operating roadways and rights of way with all users in mind to make the transportation network safer and more efficient. Complete street policies are set at the state, regional, and local levels and are frequently supported by roadway design guidelines.

Complete streets approaches vary based on community context. A complete street in a rural area will look quite different from a complete street in a highly urban area, but both are designed to ensure safety and convenience for everyone using the road, including pedestrians with disabilities.

In the context of LMICs, community roads are generally used by all modes of transport, with a high share of nonmotorized users. However, with increased motorization, the streets and roads of LMICs are taken over by motorized vehicles. The safety threats to the nonmotorized users are on the rise due to a lack of planning and design in general, and the lack of speed management in particular. In the context of LMICs, complete street design, especially for the mixed use, is very relevant.

Complete streets may address a wide range of elements, such as sidewalks, cycle lanes, bus lanes, public transportation stops, crossing opportunities, median islands, accessible pedestrian signals, curb extensions, modified vehicle travel lanes, streetscape, and landscape treatments (see relevant separate sections for details of these measures; see figure 2.19 as an example of a cross-section in line with the complete streets concept). They also reduce motor vehicle–related crashes and pedestrian crashes, as well as cyclist risk when well-designed cycle-specific infrastructure is included. They can promote walking and cycling by providing safer places to achieve physical activity through transportation, which may in turn have positive impacts on health, including reduced obesity. One study found that 43 percent of people reporting a place to walk were significantly more likely to meet current recommendations for regular physical activity than were those reporting no place to walk.

The process starts by considering the function and form of the street and developing a hierarchy of use by different modes. This hierarchy can change depending on the street function and the complexity/mix of users. The concept is particularly relevant to LMICs where the consistency of place and function is often very indistinct (see section 2.2 regarding road function and land use).

Street design is not simply a technical or quantitative exercise that should remain fixed for generations. Rather, street design requires an observation of how people use the space, from drivers to people sitting on steps and porches. It is with these observations that the best design can then be crafted.

Unlike highway design, street design is iterative. At freeway speeds, one needs uniformity and consistency. As speeds slow, options expand. With more possibilities comes the need to experiment and adjust based on how users react. The design of a street can always be improved. Successful streets cannot be imposed but need a collaborative effort between the highway authority or municipality and the local community which they serve.

Further Reading

Intersection Treatments; Designing for All Ages & Abilities.


### 2.5. Community Engagement

Community refers to people whose homes, workplaces, education institutions, shops, and social, recreational, and religious facilities are located in a defined geographic area, including their representative organizations such as nongovernment organizations (NGOs), community-based organizations (CBOs), cultural and sporting groups, and service and religious organizations. These are the people who are directly affected and possibly benefiting from a project. NGOs may include those whose activities are not limited to road safety as well as those that are dedicated primarily, if not solely, to road safety.

Community engagement is a systematic process of involving the local community in the development and implementation of road safety programs, policies, and projects. It can occur at many levels, ranging from information sharing and consultation, through to active involvement in decision-making processes. The various levels are summarized in Figure 2.20.

In road projects, community engagement is an inclusive process conducted throughout the project life cycle: during conceptualization, design, construction, maintenance, and operation. It is important that at the start of each project phase the road user and stakeholder requirements are clearly documented so that the designer can understand how to develop a...
design that addresses these needs and requirements. The process should be well thought through and planned, with clear programs for facilitators and experts. If done well, it will enhance local ownership and create an interface between the road implementing organizations and the community. The benefits of community engagement include:

- Providing an opportunity to inform the community about why there is a need for the project, including the safety and broader benefits. That way the community can understand the options and make informed decisions.
- Good decision-making resulting from accessing good/additional information.
- Establishing new networks and relationships (and further developing of existing networks).
- More local ownership of solutions to current problems and a higher level of responsibility for creating that future.
- Increased local support for change, or even the power of community in demanding change.
- Strengthening communities by keeping them informed about local issues.
- Building trust and confidence among stakeholders and the community.
- Contributing to the identification and development of leadership in community road safety.
- Providing a say to those who tend to be less involved in or have barriers to participating in decision-making processes.

Figure 2.20: Levels of community engagement

<table>
<thead>
<tr>
<th>Inform</th>
<th>Consult</th>
<th>Involve</th>
<th>Collaborate</th>
<th>Empower</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Inform" /></td>
<td><img src="image" alt="Consult" /></td>
<td><img src="image" alt="Involve" /></td>
<td><img src="image" alt="Collaborate" /></td>
<td><img src="image" alt="Empower" /></td>
</tr>
</tbody>
</table>

**Description**

**Participation**
The first two public participation levels—Inform and Consult—typically occur when a decision has already been made, and government wants to either communicate that decision to the public, or seek opinions on the decision.

**Engagement**
The third and fourth public participation levels—Involve and Collaborate—have two-way information flows, and include sharing information within and across stakeholder communities during the decision-making process. When undertaking Engagement, decision makers commit to using stakeholder feedback to inform the decision and shape the outcome. Activity that occurs at the Collaboration level is also sometimes referred to as partnering.

**Empower**
The fifth public participation level—Empower—is also often referred to as co-production, where decisions are made jointly between government and the community. This is typically when decision-making authority has been delegated to a group including members from both the government and the community.

**Objectives:**
- To provide balanced, objective information to support understanding by the public.
- To obtain public feedback on analyses, alternatives and/or decisions.
- To work with the public to ensure concerns and opinions are understood and considered.
- To engage with the public on aspects of the decision, including the development of alternatives and a preferred solution.
- To create governance structures to delegate decision-making and/or work directly with the public.

**Commitments:**
- To keep the public informed.
- To listen and acknowledge the public’s concerns.
- To work with the public to exchange information, ideas, and concerns.
- To seek advice and innovations from various public parties.
- To work with the public to implement agreed-upon decisions.

• Extending democratic processes to stakeholders and the community in regard to community road safety.
• Fostering a sense of belonging and empowerment from working together.

Engagement with a community can be especially important in situations where difficult decisions need to be made. As examples, decisions on land acquisition, provision of bypasses, and changes in speed limits are areas where a community has a big role in improving safety. It is important to work closely with communities on these and similar topics to ensure all stakeholders have inputs to decisions and understand the broad implications of these decisions.

The time it takes to get community partnerships established is very worthwhile, as the people can provide valuable insights in relation to problem identification and the design of actions, and can act as “key informants,” providing qualitative data that can help prioritize the problems identified by a data analysis.

Where crash statistics are inadequate, as is the case in many low-income countries (LICs), it is even more important that road users are consulted so that local knowledge helps ensure the correct problems and appropriate, acceptable solutions are identified. For example, the community can provide information on hazardous locations (where crashes often occur) and participate in offering solutions and developing measures aimed at addressing safety issues. These may include the addition of footpaths, median barriers, bridge upgrades to accommodate pedestrians, improved lighting, signage, and fencing, as well as alignments around crossings with the purpose of reducing speed. An important outcome of this approach is the information gathered from the community, which would not have been available through the normal processes of visual assessments and data collection and analyses. At the same time, the community takes ownership of the solutions implemented to address the problem.

The importance of stakeholder engagement and information disclosure is also highlighted in the Economic and Social Framework (ESF) of World Bank (2016). To improve the process of engagement and consultation the ESF proposes a documented approach to:

1. Stakeholder identification and analysis;
2. Developing a Stakeholder Engagement Plan;
3. Disclosure of information;
4. Meaningful consultation with stakeholders;
5. Addressing and responding to grievances; and
6. Reporting to stakeholders.

Challenges associated with community engagement:

• Difficulties may arise in defining communities. Established CBOs will often include the influential and already vocal, and not usually vulnerable road users, i.e., pedestrians and cyclists, or the poor and women. Thus, special efforts and monitoring will be required to ensure the most vulnerable are consulted and considered.

• Community partnerships involve people who are affected by road safety problems and can play an important role in solving those problems, but their everyday business may not be road safety. It will take time to get everyone on board with a shared understanding of both the problem and the solution.

• There may be public demand against change/the project—perhaps through poor knowledge—which can be a major barrier to road improvements.

• There may be misunderstandings on the role and resources of community partners. For instance, few NGOs will have the capacity to undertake research studies, yet this task has often been assigned to them in a road safety action plan.

• Data collection may be linked to workplace key performance indicators, and sharing the data publicly may impact on perceptions about the efficiency or effectiveness of government departments.
Case Study: Speed management and community involvement on the N2 highway in Bangladesh

The N2 national highway connects the capital Dhaka to the Sylhet district. It is a single carriageway two-lane asphalt road. Three villages on this highway were selected as intervention locations. All villages were rural community settlements with activities on both sides of the highway. The risk of road crashes was high due to the combined effect of fast-driving buses and cars, considerable numbers of pedestrians crossing the road, the mix of low- and high-speed traffic, traffic coming from side roads, and vehicles changing speed to pick up and/or drop off people (figures 2.21 and 2.22). In addition, reliable road crash data from police and other sources were absent.

The integrated intervention program had multiple components, including a program for active community involvement, infrastructural measures, and educational interventions. The infrastructural measures consisted of speed humps, rumble strips, pedestrian crossings, bus bays, and road markings (figures 2.23 through 2.25). The program included educational interventions for school children and awareness campaigns for bus drivers and pedestrians. A measurement system was created using speed measurement with a laser-gun (also in control locations), the video recording of near accidents, and the use of local record keepers (people from the local community who record road crash data).

The interventions resulted in a reduction of the average speed of motorized traffic from 63.6 kph to 51.1 kph—a reduction of 12.5 kph (19.7 percent). The number of fatalities fell by 67 percent, and the number of serious injuries declined by 59 percent. There was strong support from the local communities for the program. Key innovative successes included the integrated intervention program, the active

**Figure 2.21:** Village settlement along the highway.

**Figure 2.22:** Fast-driving buses and overtaking near settlement.

**Figure 2.23:** Rumble strips.

**Figure 2.24:** Speed hump.

**Figure 2.25:** Pedestrian crossing.
involvement of the local communities, and the use of local record keepers for road crash data recording. Replication of the intervention program in other countries is possible and requires a good baseline assessment, customization of the intervention program dependent on the outcome of the baseline assessment, appropriate funding, creation of a strong implementation team, and approval by the authorities as needed.

Safe Crossings (www.safe-crossings.org) initiated and managed the intervention program. Implementation was done together with the Centre for Injury Prevention and Research Bangladesh (CIPRB) (www.ciprb.org). For more information see:


Further Reading


2.6. Innovation

As identified in section 1.3, it may be many years and up to two decades from when new solutions or approaches are identified, introduced and evaluated, and then adopted into formal design guidance.29 In other cases, there may be a need to identify new solutions, because no solution currently exists, or existing solutions are not fit for purpose (e.g., not producing the required safety benefits; costing too much; or changing demands, including from road users). For these reasons, there is often a need to go beyond what is currently included in design guidance in order to achieve objectives. Innovation is often needed to deliver safety and other project outcomes. However, this innovation must be done in a considered, evidence-based manner. Risks (whether safety related, financial, or other) need to be minimized, and so a robust process is required. There is also a need to document this process, and share the results of this learning—whether positive or negative. Many widely applied safety designs used today were not known 20 or even 10 years ago, and have only reached broad application because the knowledge of their effectiveness has been shared.

There are a number of reasons that some very effective designs and interventions are not used

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in some countries. The PIARC Road Safety Manual\(^{30}\) suggests the following reasons in regard to road safety interventions:

- Lack of knowledge regarding the treatment and its effectiveness
- Lack of experience of how to install and maintain a treatment
- Issues regarding transferability and differences in local conditions
- Concern about legal liability if something goes wrong
- Concern about public understanding or acceptability.

There is a need to take care when trying innovative approaches, and new designs should be tested and shown to have positive benefits with no unacceptable negative impacts before they are implemented more widely. This may involve identification of positive case studies from other jurisdictions and further analyses (including reviews of literature on effectiveness and broader impacts; communication with those who have tried an innovative approach), small-scale trials (on-road, or off-road if risks are high), larger-scale implementation (including as part of demonstration projects), and then eventually full adoption. Each stage requires careful monitoring and documentation; based on the learnings from each stage, refinements might need to be made.

**Tactical urbanism**

Tactical urbanism (also known as guerrilla or pop-up urbanism) is a citizen-led approach to community building characterized by short-term, low-cost, and scalable interventions intended to catalyze long-term change. It is commonly applied in demonstration projects and pilot/interim projects for defined time periods to engage the public in city making and to test the designs before investing. Tactical urbanism has also proved to be a powerful tool for cities in responding to the COVID-19 pandemic due to their low cost and quick to implement nature. For example, cities have been transforming their streets using paint, chalk, barricades, and other low-cost materials to increase space for walking and cycling designed to help people move around while maintaining physical distance.

**Case Study: HP intersection improvement, Mumbai, India**

WRI India partnered with the Mumbai Traffic Police and the Mumbai Municipal Corporation in 2017 to audit and improve high-risk intersections across the city as part of the Bloomberg Philanthropies Initiative for Global Road Safety. The HP Petrol Pump intersection in Mumbai was selected for the first trial. Many decades ago, there was a roundabout at the intersection that connected three arterial roads which was later removed to increase traffic capacity. However, the intersection remained very large, which made it hazardous to cross for both motorists and vulnerable road users. Prior to the transformation, mobility patterns at the intersection were studied which showed that over 5,000 vehicles and an equivalent number of pedestrians traversed the intersection during peak hours. Unfortunately, there was no infrastructure provided for vulnerable road users, and city authorities had been primarily concerned with vehicular capacity up to that point.

The proposed redesign involved creating dedicated pedestrian infrastructure and redistributing space to accommodate all road users. This included expanding the sidewalks, extending the medians and introducing pedestrian refuge areas at the medians, reclaiming space from the residual areas of the intersection to create refuge islands, reclaiming space from slip lanes to create public spaces, and streamlining the traffic lanes to ensure a smooth flow of traffic. This design created a compact intersection area and reduced pedestrian crossing distances by 50 percent.

A trial (using chalk, paint, and barricades that were

\(^{30}\) [https://roadsafety.piarc.org/](https://roadsafety.piarc.org/).
applied and installed overnight) was first tested for a span of 45 days. This allowed a series of interviews with pedestrians, traffic police, residents, and shopkeepers to be conducted to solicit feedback and input that fed into the final design. Crash conflict at the intersection was also analyzed during the trial, which showed that average vehicle speeds dropped by 15 percent and high, medium, and low risk conflicts reduced by 71 percent, 68 percent, and 60 percent, respectively. Additionally, the data collected showed that traffic capacity was not adversely impacted, and in some instances traffic flow improved due to more streamlined and clear movements. Following the successful trial, city authorities decided to permanently implement the recommended design in December 2018. Figures 2.26 through 2.28 show the transformation of the intersection.

As suggested above, a thorough, documented process is required when innovating. The following steps are adapted from the PIARC Road Safety Manual:

- Know your problem. Identify the target crash type, the road user type, and the locations that need to be targeted.

- Identify possible solutions. This can include solutions that are used overseas, or it can be an adaptation of an existing treatment.

- Assess the solutions. It is important to research treatments thoroughly to ensure they are likely to be beneficial for safety outcomes in this new context, and their likely application elsewhere, as well as for other policy objectives. This assessment can be based on documented experience from other road agencies. For newer treatments, driver simulators are sometimes used to determine the likely effects. In some instances, treatments can be installed in a controlled environment (e.g., off-road, or in a low-speed area) to determine the likely effects.

- Trial the selected solution. A demonstration project can be an effective way to test the treatment within a specific context and in a controlled environment. This can also help prepare for a wider rollout.

Figure 2.26: Before the HP intersection improvement in March 2017.

Figure 2.27: Shops taking over the footpath and temporary low-cost interventions implemented (using paint, chalk, and barricades) during the trial (April 2017).

Figure 2.28: The changes were made permanent in December 2018.
Intelligent transport systems

Intelligent Transportation Systems (ITS) is defined as a set of information and communication systems that work in harmony to provide transport and traffic management services. ITS brings together various technologies such as data collection, communication, data mining, machine learning, artificial intelligence, and database management to provide applications intended to improve the efficiency and safety of transport systems.

The use of ITS on the highway and street system continues to grow in coverage and diversity of technology and applications such as speed feedback signs, rural intersection active warning systems, computerized traffic signal control, incident management systems, traffic enforcement systems, intelligent speed adaptation, connected and autonomous vehicles, and emergency management systems. ITS considerably modifies interactions among road users, and there is potential for ITS solutions to contribute to road safety. For example, Advanced Traffic Signal control (ATSC) systems, which aim to optimize the traffic light cycle with respect to the traffic flow, have been found to reduce angle crashes at intersections by up to 19.3% in Michigan USA\(^a\) and to reduce total crashes by 34% and fatal and injury crashes by 45% in Pennsylvania USA.\(^b\) Although the evidence on safety of these new infrastructure solutions is still increasing, practitioners should be open to the possibilities that ITS solutions can deliver significant safety outcomes. (see 3.2, Speed management and traffic calming for an example of speed feedback signs, Woolley, J., Stokes, C., Turner, B., and Jurewicz, C. 2018. Towards safe system infrastructure: a compendium of current knowledge (No. AP-R560-18), Austroads, for a number of ITS infrastructure examples).

- Monitor, analyze, and evaluate the trial. Ensure that the outcomes are as expected, and that there are no adverse effects to any road user’s safety. This evaluation should include an assessment of the cost-effectiveness of the new treatments, especially when compared to an existing option.
- Roll out the solution on a wider scale. Continue to monitor and evaluate the treatments, including crash analysis once sufficient data have been collected. Include design and operational information in guidance documents.
- Inform others. If the new treatment is effective, it is important to let others know of this. Information on treatments that have not performed well is also very important for the international road safety community.

Further Reading

