



GUIDE FOR GEOMETRIC DESIGN OF TRANSIT FACILITIES ON HIGHWAYS AND STREETS

July 2014

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1 Introduction

In This Chapter:

- 1.1 Purpose and Scope
- 1.2 Audience
- 1.3 Organization of Guidelines
- 1.4 Using the Guide
- 1.5 References

Public transportation is important to communities in contemporary America. It provides high passenger capacities in heavily-traveled corridors, and allows high employment concentrations in city centers. It permits compact urban developments that are pedestrian friendly, and helps reinforce urban design objectives. It provides mobility for people that are unable to drive or do not have access to motor vehicles. From an environmental perspective, it has lower emissions and energy consumption on a per-capita basis than personal motor vehicles.

Transit vehicles operate in a wide range of environments—both on-street and off-street. Commuter rail and rapid transit operate in exclusive rights-of-way that are frequently grade-separated from intersecting roadways. However, bus routes on public streets and highways and light rail or streetcar operations may share or intersect with the street environment.

Streets and highways often must accommodate transit vehicles as well as motor vehicles, bicyclists, and pedestrians. Transit provisions are best accomplished when incorporated into all phases of street planning, design, and operation. This is essential especially where agencies at the state, county, and municipal level are required to plan, design, or modify streets and highways to accommodate public transportation vehicles and facilities.

Planning and design guidelines, standards, and practices have evolved over the past decade. These include reports prepared by the American Association of State Highway and Transportation Officials (AASHTO), Transportation Research Board (TRB), and Institute of Transportation Engineers (ITE), and those prepared by individual planning and transit agencies. Most, however, encompass a specific mode, such as bus stops, rapid transit, and light rail transit (LRT) and are sometimes prepared in response to specific agency needs. Even so, there are few comprehensive publications that an agency can use for designing streets and highways that accommodate transit services and facilities. Thus, agencies often must develop their own standards. The absence of

a single reference guide makes it difficult to communicate basic design standards to consultants when contracting out work, especially if the consultant is in a different state than the client. The practitioners' need for a single, comprehensive resource that documents and builds upon past and present experience is the basis for this guide.

1.1 PURPOSE AND SCOPE

This guide provides a single, comprehensive reference of current practice in the geometric design of transit facilities on streets and highways. The facilities covered include:

- Local buses, express buses, and bus rapid transit operating in mixed traffic, bus lanes, and high-occupancy vehicle (HOV) lanes, and bus-only roads within street and freeway environments; and
- Streetcars and LRT running in mixed traffic and transit lanes, and within medians along arterial roadways.

These guidelines are based on a review of relevant AASHTO, TRB, and ITE documents, and of design reports provided by various transit agencies. They incorporate findings from targeted investigations conducted specifically to fill voids in the assembled information.

1.2 AUDIENCE

This guide is written for use by public agencies, practitioners, and developers who need to know basic information about planning, locating, sizing, designing, and implementing transit facilities along roadways. The target audience includes:

- Policy makers;
- Highway planners, engineers, designers;
- Traffic/transportation engineers;
- Transit service planners;
- Urban planners;
- Site planners and engineers; and
- Land developers.

The guide provides clear and uniform guidance for the placement and design of facilities and amenities. Transit and highway agencies can adapt these guidelines to meet their specific needs. Practitioners can apply transit provisions to meet specific needs in their plans.

1.3 ORGANIZATION OF GUIDELINES

Chapter 2 contains planning and decision-making guidelines associated with most transit facilities being developed.

Chapter 3 presents bus design parameters and controls. It describes vehicle types and characteristics; geometric design controls; highway and transit capacity considerations and guidelines; and general transit infrastructure considerations.

Chapter 4 addresses bus transit facilities found in controlled-access highway settings (freeways).

Chapter 5 describes bus transit facilities along streets.

Chapter 6 contains guidelines for light rail and streetcar transit operations on streets and roadways.

Chapter 7 contains guidelines for pedestrian and bicycle access.

The appendices contain supporting information, such as information on detailed bus dimensions and turning paths, busways, off-line stations and facilities, and pedestrian and bicycle access. References are provided at the end of each chapter. A complete listing of references is found in the appendices along with a transit facility glossary.

1.4 USING THE GUIDE

Information about each type of facility or treatment is presented in one place to make the guide as user-friendly as possible. Each specific facility presentation provides general planning and design guidance, identifies implementation and operational issues, and provides case studies and examples. The appendices contain additional technical information for selected topics.

The guide presents desirable guidelines, but in restrictive situations, minimum guidelines have been used successfully and may be necessary.

1.5 REFERENCES

1. AASHTO. *A Policy on Geometric Design of Highways and Streets, 6th Edition* (The Green Book). Technical Committee on Geometric Design. The American Association of State Highway and Transportation Officials, Washington, DC, 2011.
2. Fellows, R., et al. *Geometric Design for Transit Facilities on Highways and Streets*. NCHRP Project 20-7, Task 31. Parsons Brinkerhoff Quade & Douglas, Houston, 2002.
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2 Planning and Decision-Making

In This Chapter:

- 2.1 Regional and Corridor Planning Processes
- 2.2 Integrating Transit Projects into Roadway Planning Process
- 2.3 Summary
- 2.4 References

Transit facilities in public rights-of-way present a challenge for planning and decision-making. They must meet the functional requirements of the transit agency and its customers, but they are placed in a street or highway environment owned and regulated by a different agency with its own standards and a broader set of users and constituents. Roadway and transit agency staff must make decisions cooperatively to meet the functional requirements of transit while reflecting other requirements of the public right-of-way.

Decision-making occurs at all stages of transportation facility development. In most organizations, decisions can be grouped into two types:

- Planning and programming decisions, which define what projects to include in the design and construction program and what functional characteristics these projects should include (discussed in this chapter); and
- Project decisions, which are made during the design and implementation process that establish the physical design of a project (discussed in subsequent chapters).

This chapter provides information about the planning and programming (decision-making) process that may be necessary to determine functional requirements of projects and to obtain funding or project approval. This chapter contains the following sections:

- Section 2.1 provides a brief introduction to federal planning requirements, system planning, and corridor planning processes.
- Section 2.2 discusses how roadway and transit planning and programming processes may be integrated to better achieve cooperative decision-making between transit and roadway agencies.
- Section 2.3 is a summary of key points of the chapter.

For designers, this chapter provides background on the continuing, cooperative, and comprehensive planning processes that result in the approval of projects for design, and useful information about the context within which decisions about transit facilities on highways and streets are made.

2.1 REGIONAL AND CORRIDOR PLANNING PROCESSES

2.1.1 Federal Planning and Decision-Making Requirements

2.1.1.1 Responsibility for Planning and Decision-Making

Transportation planning and decision-making is conducted by several governmental levels (4).

- The U.S. Department of Transportation (U.S. DOT) oversees the transportation planning processes required for each state. The statewide planning process establishes a framework for making transportation investment decisions throughout the state and is administered jointly by two U.S. DOT agencies: the Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA). The federal government also supplies funding needed for transportation planning and project development. The U.S. DOT is managed along modal lines. For any specific transit project, either FHWA or FTA will usually act as lead agency if federal funding is anticipated. FHWA usually is the lead for highway and HOV projects and can also fund park-and-ride lots, especially if they will be built in freeway rights of way. FTA is usually the lead for high-capacity transit projects and transit facilities that are not in highway rights-of-way. Each agency has its own rules and procedures. It is important to involve the federal lead agency early in the development of a major project that is expected to involve federal funds.
- State departments of transportation (state DOTs) develop transportation plans and projects consistent with the transportation goals for the state. To accomplish this, the state DOT works with all the state's transportation organizations and local governments. The state DOT is responsible for planning safe and efficient transportation between cities and towns in the state.
- Metropolitan Planning Organizations (MPOs) represent areas with a population of 50,000 people or more. The mission of an MPO is to provide short- and long-term solutions to transportation and transportation-related concerns. Transportation policy for each metropolitan area is set by a policy board, which is comprised of locally elected officials and representatives of local agencies responsible for implementation of transportation projects. Often the MPO establishes a technical advisory committee (TAC) comprised of professional staff and technical experts from local transportation and planning agencies. The TAC typically meets regularly to review projects and programs and to make recommendations to be considered by the policy board. Other groups, such as non-profit organizations, community organizations, or environmental organizations, can also influence the direction an MPO follows through a public involvement process.
- Local governments carry out many transportation planning and programming functions, such as scheduling improvements and maintenance for local streets and roads.
- Transit agencies are public and private organizations that provide transportation for the public. Public transportation includes buses, heavy rail, light rail, commuter rail, monorail, passenger ferryboats, trolleys, inclined railways, and people movers.

Federal rules located in 23 Code of Federal Regulations (CFR) 450 and 500 and 49 CFR 613 outline the requirements for state DOTs, MPOs, and public transportation operators to conduct a continuing, comprehensive, and coordinated transportation planning and programming process in each state and in metropolitan areas.

2.1.1.2 Statewide Planning

Federal regulations rely on the statewide transportation planning process as the primary mechanism for cooperative transportation decision-making throughout each state. The federal regulation stipulates that each state DOT has responsibility for implementing a statewide multimodal transportation planning process that will promote consistency between transportation improvements and state and local planned growth and economic development patterns. Statewide planning must be coordinated with metropolitan planning, with statewide trade and economic development planning activities, and with related multi-state planning efforts. State DOTs are also responsible for considering and implementing projects, strategies, and services that support the economic vitality of non-metropolitan (rural) areas (3).

2.1.1.2.1 Statewide, Long-Range Transportation Plan

Each state is responsible for developing a 20-year statewide, long-range transportation plan in consultation with MPOs and local and regional transportation agencies. The statewide long-range plan should describe a multimodal transportation system of roadways, public transit services, and bicycle/pedestrian facilities. The long-range plan addresses the following objectives:

- Support the economic vitality of the state.
- Increase the safety of the transportation system.
- Improve security for users of the transportation system.
- Increase the accessibility and mobility for people and freight.
- Protect and enhance the environment, promote energy conservation, and improve quality of life.
- Enhance the integration and connectivity of all modes of the transportation system.
- Promote efficient transportation system management and operation.
- Preserve the existing transportation system.
- Promote consistency between transportation improvements and planned growth and economic development.

The plan should address estimated transportation, socioeconomic, environmental, and financial impacts of the future transportation system. The statewide plan should include capital, operations and management strategies, investments, procedures, and other measures to ensure the preservation and most efficient use of the existing transportation system.

2.1.1.2.2 State Transportation Improvement Program

The statewide transportation planning process also requires preparation of a State Transportation Improvement Program (STIP). The STIP includes an annual list of projects programmed for funding from available federal funds and other revenue sources. It comprises projects from the statewide transportation

plans and programs as well as transportation improvement projects recommended by the MPOs and public transportation providers in the state. Federal policy emphasizes fiscal constraint and public involvement in the development of the STIP.

The STIP covers a four-year period and must be updated every four years (more frequently if the governor of the state requires more frequent updates) (4).

2.1.1.3 Metropolitan Transportation Planning

As noted, an MPO is a transportation policy-making organization comprised of representatives from local government and transportation authorities. An MPO is designated for any urbanized area with a population greater than 50,000. An MPO must ensure that existing and future expenditures for transportation projects and programs are based on a continuing, cooperative, and comprehensive planning process. Federal funding for transportation projects and programs is channeled through the planning process (3).

2.1.1.3.1 Role of the MPO

In accordance with federal regulations, the MPO must conduct metropolitan transportation planning in cooperation with the state and with operators of publicly owned transit services. In air quality nonattainment or maintenance areas, the MPO is also responsible for coordinating transportation and air quality planning.

Transportation planning must be cooperative, because no single agency has responsibility for the construction, operation, or maintenance of the entire transportation system. For example, some roads that are part of the Interstate Highway System are subject to certain standards and are usually maintained by a state DOT. Others are county arterials or city streets designed, operated, and maintained by counties or local municipalities. Transit systems often are built, operated, and maintained by a separate entity. The MPO is responsible for seeking the participation of relevant agencies and stakeholders in the planning process. Most MPOs are not the actual implementing agencies for projects, but they must provide an overall coordination role in planning and programming funds for projects and operations (7).

2.1.1.3.2 Metropolitan Planning Process

Transportation planning in metropolitan areas is a collaborative process, led by the MPO with participation from other key stakeholders in the regional transportation system. Transportation planning activities include visioning, forecasting population and employment, identifying major growth corridors, projecting future land use, assessing needs, developing capital and operating strategies to move people and goods, and developing a financial plan. The required planning processes are designed to foster involvement by interested parties, such as the business community, community groups, environmental organizations, and the general public, through a proactive public participation process.

There are three key documents produced by the metropolitan planning process:

- The *Unified Planning Work Program* (UPWP) lists the transportation studies and tasks to be performed by MPO staff or a member agency. Because the UPWP reflects local priorities, its content differs from one metropolitan area to another. The UPWP contains several elements:
 - The planning tasks and studies that will be conducted over a one- to two-year period;
 - Federally funded studies as well as all relevant state and local planning activities conducted without federal funds;

- Funding sources identified for each project;
 - A schedule of activities; and
 - The agency responsible for each task or study.
- The long-range transportation plan, often referred to as the *Metropolitan Transportation Plan* (MTP), defines the methods the region will use to invest in the transportation system. The plan must “include both long-range and short-range program strategies/actions that lead to the development of an integrated intermodal transportation system that facilitates the efficient movement of people and goods” (23 CFR 450C, Sec.450.322).

The MPO is responsible for developing the long-range transportation plan in cooperation with the state DOT and with public transportation coordinators and operators in the area. The metropolitan planning area should include at least the urbanized area and the contiguous geographic areas expected to become urbanized within the 20-year forecast period covered by the long-range transportation plan. The MTP must be updated at least every five years (every four years in air quality non-attainment or maintenance areas).

As required by federal regulation, the MTP should include a discussion of potential environmental mitigation activities. A financial plan is required with resources identified from both private and public sources. The MPO, transit operators, and the state DOT must work cooperatively to develop estimates of funds to support implementation of the MTP. Operations and management strategies are required that improve the performance of existing facilities while relieving vehicle congestion and improving safety.

- The *Transportation Improvement Program* (TIP) is a financially constrained, four-year program covering the most immediate implementation priorities for transportation projects and strategies from the MTP. It is the region’s method of allocating its limited transportation resources among the various capital and operating needs of the area, based on a clear set of short-term transportation priorities. Federal requirements for the TIP include the following:
 - Covers a minimum four-year period of investment;
 - Is updated at least every four years;
 - Is realistic in terms of available funding (known as a fiscally constrained TIP) and is not just a “wish list” of projects; and
 - Is incorporated into the STIP.

If the region is a non-attainment or maintenance area, the TIP must also conform to the State Implementation Plan (SIP) for air quality (see further discussion below).

2.1.1.4 Other Federal Planning Requirements

Transportation project designers often must provide information to meet federal requirements such as the National Environmental Policy Act (NEPA), air quality conformity, and congestion management, or to qualify for federal funding under the FTA Capital Investment Program. This section provides introductory-level

information about these processes. The most up-to-date information and guidance for these programs can be found at <http://www.fhwa.dot.gov> or <http://www.fta.dot.gov>.

2.1.1.4.1 National Environmental Policy Act (NEPA) (2, 8)

The National Environmental Policy Act (NEPA) was signed into law on January 1, 1970. The Act establishes national environmental policy and goals for the protection, maintenance, and enhancement of the environment and provides a process for implementing these goals within the federal agencies. NEPA requires federal agencies to consider the potential environmental consequences of their proposals, to consult with other interested agencies, to document the analysis, and to make this information available to the public for comment before the implementation of the proposals. NEPA is only applicable to federal actions, including projects and programs entirely or partially financed by federal agencies or that require a federal permit or approval.

In 1978, the Council on Environmental Quality (CEQ) issued regulations for implementing NEPA (40 CFR, Sections 1500-1508). To address the NEPA responsibilities established by CEQ, the Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA) issued regulations (23 CFR Section 771), Environmental Impact and Related Procedures. Additional guidance and information on the NEPA process and other environmental requirements may be found on the AASHTO Center for Environmental Excellence website at: http://environment.transportation.org/environmental_issues/nepa_process/

For transportation projects, NEPA requires FHWA and other transportation agencies to consider potential impacts to the social and natural environment. Key elements of the environmental review process include: determining the project's purpose and need and the range of alternatives to be considered; determining potential environmental impacts; coordinating with relevant agencies; involving the public; determining mitigation for unavoidable impacts; and documenting the analysis and decisions supported by the administrative record.

There are three options under NEPA, depending on whether or not an undertaking significantly affects the environment. These three options include: categorical exclusion (CE); environmental assessment (EA); and environmental impact statement (EIS). The process for environmental documentation under NEPA is summarized in the figure below.

2.1.1.4.2 Air Quality Conformity

The designation of a metropolitan area as an air quality nonattainment or maintenance area creates additional requirements for transportation planning. Most importantly, transportation plans, programs, and projects must conform to the state's air quality plan, known as the State Implementation Plan (SIP).

Transportation conformity assures that transportation funds will be spent on projects that are consistent with air quality goals in areas that do not meet, or previously have not met, air quality standards for ozone, carbon monoxide, particulate matter, or nitrogen dioxide. Each state's environmental protection agency must prepare a SIP that sets an emissions "budget" (or limit) for each pollutant, and for mobile, stationary, and area-wide sources.

It is advantageous for regional and local transportation agencies to work as closely as possible with the state's environmental protection agency. Regions must project the emissions that will result from transportation projects in the TIP and certify that projected emissions levels are consistent with the SIP.

Conformity may need to be certified at the project level in areas that do not meet, or previously have not met, standards for carbon monoxide or particulates. In those cases, “hot spot” analyses are required as part of the NEPA documentation process.

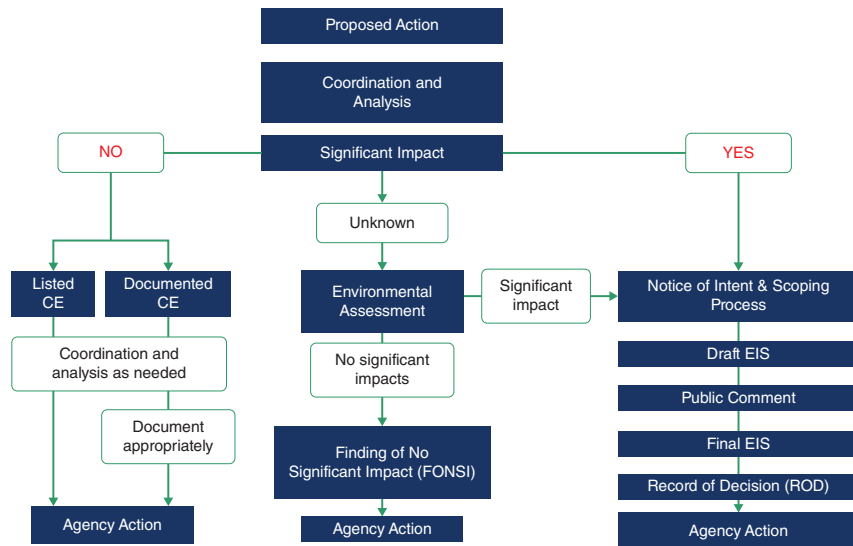


Figure 2-1. NEPA Process and Documentation Options

Under NEPA, transportation projects that do not individually or cumulatively have significant environmental effects are classified as categorical exclusions (CEs). Where the significance of the environmental impacts is unknown, a federal agency may prepare an environmental assessment (EA) to determine whether or not an environmental impact statement (EIS) is necessary (i.e., if the action would significantly affect the environment.) If the answer is no, the agency issues a “finding of no significant impact” (FONSI). The FONSI may address measures that an agency will take to reduce (mitigate) potentially significant impacts. If it is determined that the environmental consequences of a proposed federal undertaking are significant, an environmental impact statement (EIS) will then be prepared.

Currently, only a very small number of projects processed by state transportation agencies require EISs. An EIS includes a detailed evaluation of the proposed action and alternatives. The public, other federal agencies, and outside parties may provide input into the preparation of an EIS and then comment on the draft EIS when it is completed. After a final EIS is prepared and at the time of its decision, a federal agency will prepare a public record of its decision addressing how the findings of the EIS, including consideration of alternatives, were incorporated into the agency’s decision-making process. The purpose of an EIS is to serve as a tool to promote environmentally sensitive decision-making.

2.1.1.4.3 Congestion Management System

Areas with populations over 200,000 are called transportation management areas (TMA). TMAs must have a Congestion Management Process (CMP) that identifies congestion and strategies to reduce congestion. CMP strategies often include transit services or transit facility enhancements. In non-attainment areas, projects that increase capacity for single-occupancy vehicles (by adding new roads or widening existing roads) must be addressed through the CMP.

2.1.1.5 Federal Transit Administration (FTA) New Starts Criteria (6)

The FTA Capital Investment Program is the primary grant program for funding major transit capital investments, including rapid rail, light rail, bus rapid transit, commuter rail, and ferries. In July 2012, a new authorization was enacted entitled the Moving Ahead for Progress in the 21st Century Act (MAP-21) that changed several aspects of the program, including defining a new category of eligible projects, known as core capacity projects, which expand capacity by at least 10% in existing fixed-guideway transit corridors that are already at or above capacity today, or are expected to be at or above capacity within five years. The program also includes provisions for streamlining aspects of the New Starts process to increase efficiency and reduce the time required to meet critical milestones.

State and local government agencies, including transit agencies, are eligible to receive grants under the New Starts program, which requires project sponsors to undergo a multi-step, multi-year process to be eligible for funding. Projects that are eligible for funding include:

- New fixed-guideways or extensions to fixed guideways (projects that operate on a separate right-of-way exclusively for public transportation, or that include a rail or a catenary system).
- Bus rapid transit projects operating in mixed traffic that represent a substantial investment in the corridor.
- Projects that improve capacity on an existing fixed-guideway system.

The maximum federal share for these project is 80%.

With the passage of MAP-21, this program and its requirements changed significantly from the previous federal transportation bill, and as of the printing of this document not all of the new procedures have been finalized. Thus, for the latest information on the FTA requirements for transit capital investments, please see the FTA web page at <http://www.fta.dot.gov>.

2.1.2 Regional Multimodal Transportation Planning and Decision-Making

In some regions, the MPO is responsible for all long-range transportation planning, and implementing agencies create short-range implementation plans. In other regions, the MPO is the regional coordinator, leaving project-level planning and development to implementing agencies. The intent of the federal planning process is to develop a comprehensive multimodal plan, but it is difficult to consider the system needs for all modes simultaneously. Often the planning for individual modes or subsystems is performed first by implementing agencies then combined into a regional plan by the MPO.

2.1.2.1 System Planning

System planning can help to ensure that the individual transportation projects will work together as planned when complete. It can help to identify priorities within improvements of a similar type. Not every transit agency prepares long-range system plans, but a long-range plan can help ensure that capital facilities for other modes will be built to meet the operational needs of the planned transit service. For example, a system plan for transit use of HOV lanes can ensure that future transit service will be able to gain access to HOV lanes safely, and HOV access facilities can then be built into highway projects at locations where they will be most useful for transit. Park-and-ride studies can systematically examine park-and-ride demand and capacity needs, and resolve policy issues about where park-and-ride lots are most desirable and effective.

Figure 2-2 illustrates the transportation systems planning process for MPOs. The process involves coordination by all participants to create a plan that all agencies and stakeholders can support. Note that land use policies and preferences drive the transportation planning process, since transportation systems should be designed to meet land use objectives.

Historically, The MPO acts as a coordinator to develop transportation policies and strategies that local governments, implementing agencies, and stakeholders can support. The MPO combines projects proposed by others into alternative packages that represent a mix of policies, strategies, modal balance, spending levels, or other variables. The alternatives are evaluated and a preferred transportation plan is selected. The regional planning process identifies corridors that require further study (see Section 2.1.2.2). When those studies are completed, the results are incorporated into the MTP.

The MTP, when adopted, becomes the region's formal transportation plan, and all projects using federal funds must be consistent with its findings. The MTP describes the region's preferred strategy to preserve transportation facilities and provide for mobility of people and goods in the context of other regional policies and priorities. It addresses the magnitude of transportation needs, the desired balance between roads and transit and between highways and arterials, specific projects and programs that comprise the preferred strategy, and the corridors that require further analysis to develop specific solutions.

2.1.2.2 Multimodal Corridor Planning

The object of multimodal corridor studies is to identify the best combination of actions that address the variety of travel needs present in the corridor. When the best solution to a major corridor transportation problem is not clear, a corridor transportation study may be initiated to develop and assess the effectiveness, costs, and impacts of alternative solutions. Often the solutions assessed are mode specific—that is, the alternatives proposed are either road or transit projects. In other cases, proposed solutions include both transit and highway elements, or evaluate roadway and transit alternatives against each other. Even a transit-focused corridor study may be multimodal, comparing transit guideways against managed lanes or HOV lanes. In all cases, transportation system management (TSM) and transportation demand management (TDM) elements should be considered.

Figure 2-3 illustrates a typical corridor planning process. Because each corridor is unique, the specific details will differ depending on the size, complexity, and level of controversy surrounding the project. A large and complex project where several alternatives have supporters may require an EIS process at the corridor planning stage, necessitating a higher level of engineering development during corridor planning. A staged analysis may be required. For example, a first stage could determine a preferred mode, and a second analysis stage could determine the best alignment and station locations. At the end of a corridor study, a single project may emerge as the preferred alternative, or several projects may be initiated by different agencies. No two corridor studies are exactly the same.

Multimodal corridor studies require the participation of all potentially affected implementing agencies and the MPO, at both the project management and decision-making levels. If the corridor study is part of an EIS process, then environmental resource agencies must also be engaged. At the initial stage of the study, the lead agency should develop a clear statement of purpose and need for the project, describing the problems in the corridor that the study will address, and the reason it is important to address them. The purpose and need statement provides a basis for defining the range of options that the study will address, the agencies and stakeholders that may be affected, and a plan for involving them in the project. These elements define the framework of the study, and the process and ground rules others will rely on to interact with the study effort.

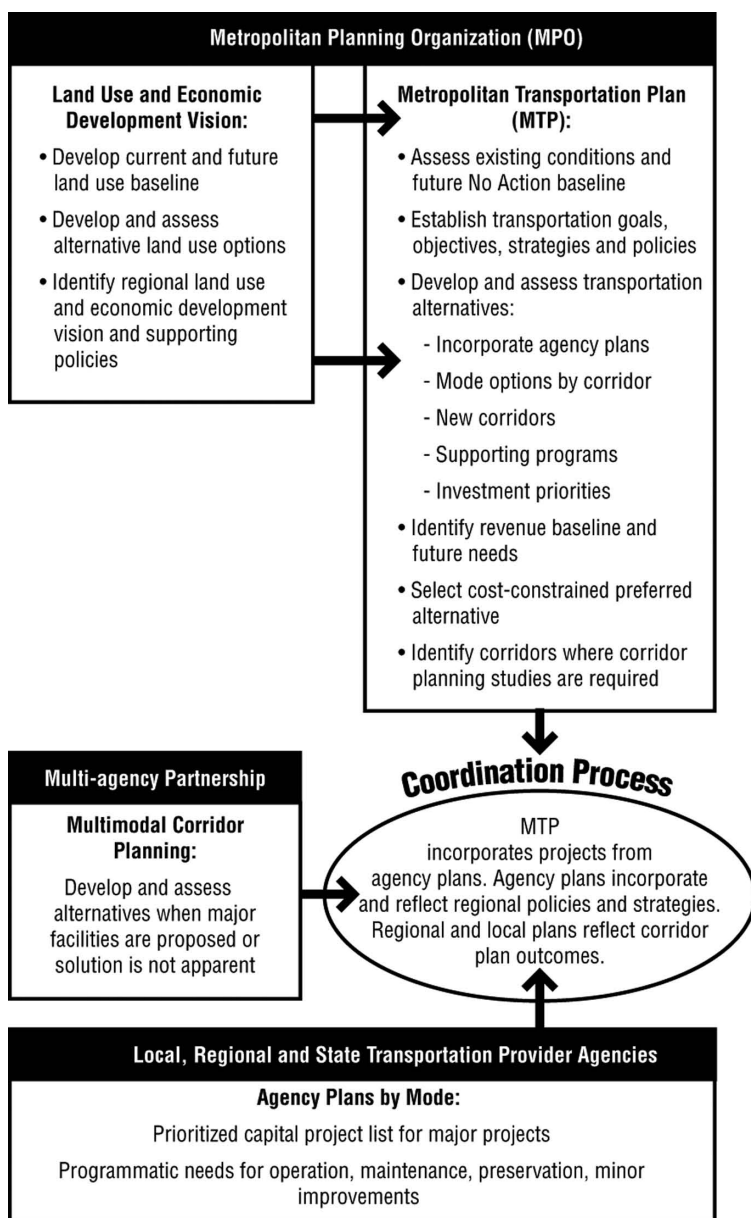


Figure 2-2. Transportation System Planning Process

The magnitude, complexity, and visibility of the study should influence the project management structure and the outreach effort. For most corridor projects, a steering committee is formed representing key affected agencies charged with making major decisions and resolving disputes that cannot be resolved at a staff level. A steering committee may include elected officials or senior agency managers, depending on the visibility of the project and the level of controversy surrounding it. Most projects also form a TAC to oversee and evaluate the technical work performed.

There is no single approach to involving the public and key stakeholders that is best for every situation, and most public outreach programs employ a variety of techniques. Common techniques include forming a standing community advisory committee, attending meetings of existing community organizations,

conducting public meetings, conducting public opinion research and focus groups, soliciting feedback through a web site, and interviewing opinion leaders.

As Figure 2-3 shows, corridor studies generally include the following steps:

- **Purpose and Need.** At the outset of a corridor study, it is important to clearly identify the problem the study is to address and the reason the study is being conducted. The statement of purpose and need should provide a grounding point that governs the scope of the project, the methodology, the decision-making process, and the involvement of other agencies.
- **Existing and Future Baseline Conditions.** Relevant data are collected to describe the conditions in the corridor, including information on transportation use, performance, and environmental factors likely to be assessed. Problems and needs should be identified. This step often involves calibrating and refining the regional transportation travel demand model to increase the level of detail within the study area, and to assemble geographic information systems data that will be used. The model is used

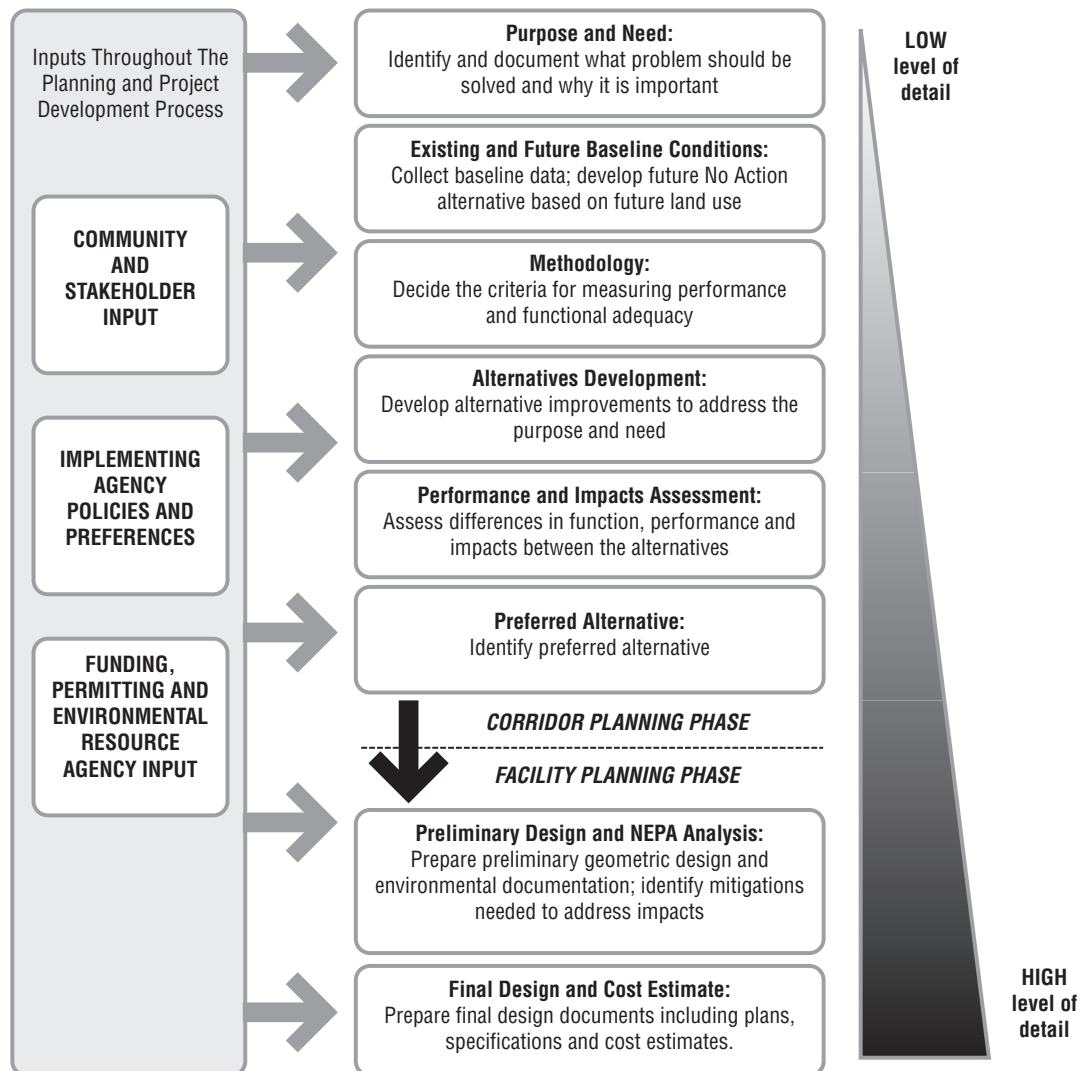


Figure 2-3. Typical Corridor Planning and Project Development Process

to prepare a No Action forecast of future conditions, assuming that only funded projects will be completed by the forecast horizon year. For most projects, the No Action alternative should be the baseline against which other proposed corridor investments will be compared. However, for FTA-sponsored alternatives analysis, the baseline alternative should include low-cost TSM enhancements to maximize transit use without a major corridor capital investment.

- **Methodology.** The methodology that will be used to measure performance and functional adequacy should be defined before analyzing alternatives. The methodology should define the criteria for evaluation and identify the key performance measures.
- **Alternatives Development.** Alternatives are defined to a level of detail sufficient to allow corridor options to be compared to one another. For corridor studies, design details rarely influence decisions at this point. More important are the modal elements, the number of lanes, the access points, special transit facilities, transit or HOV priority treatments, transit operating characteristics, alignment, station location and spacing, and other factors that will influence the relative performance, cost, and accessibility for each travel mode at the corridor scale.
- **Performance and Impacts Assessment.** Using a travel demand model and other tools, a value is developed for each performance measure developed during the methodology step, and other materials are prepared that describe the impacts and effect of each proposed alternative. If the corridor study is part of an EIS process, then a greater level of design detail is needed to develop precise estimates of the impacts of each alternative. Costs, usage, and benefits of each option should be indicated.
- **Preferred Alternative.** After all alternatives have been measured and evaluated against the baseline and to each other, a preferred alternative may be chosen, or a smaller set of alternatives may be carried into a more detailed EIS process.

Different alternatives have substantially different functions. Transit will generally not have the same effect at reducing delay as roadway expansion, given the amount of unmet demand for driving that is present in most congested urban areas. However, transit can have a significant effect on throughput in corridors that are congested or constrained, and transit is a prerequisite for high-density activity centers, such as major central business districts (CBDs), where space for traffic circulation and parking is constrained and parking costs are high. Transit alternatives may also be functionally different. A rail transit or bus rapid transit (BRT) line may allow local bus routes to be restructured and more destinations to be reached from each location along the line, as compared with express buses that provide fast service between two points. These differences are not always captured by composite measures of effectiveness, but they may be important in assessing the differences and making decisions among alternatives.

Measures of effectiveness should be elements relevant to both roadway and transit users. In addition, the differences in function among alternatives should clarify the roles that roadway and transit elements play in each alternative, and how benefits and impacts are distributed between transportation users and communities.

2.2 INTEGRATING TRANSIT PROJECTS INTO ROADWAY PLANNING PROCESSES

Transit-related projects occur in a roadway environment in one of three ways:

- The transit improvement is constructed by a state or local government.
- The improvement is made by the transit agency, with local government permits and approvals.
- A developer makes the improvement as a condition of development.

This section addresses the first circumstance when the transit improvement is incorporated into a local government project or a transit project is funded and implemented by the local government. The purpose of this section is to highlight opportunities for a transit agency to influence the elements of a project to benefit transit and describes a typical roadway planning process. Actual planning and programming processes may differ among agencies.

Figure 2-4 illustrates how transit considerations can be integrated into roadway planning and programming efforts. The figure illustrates a typical roadway agency planning and programming process, and the basic life cycle of a roadway development project. Inputs from transit agencies that can influence decisions at each stage of the process are shown to the left. The process illustrated is typical of a highway agency, but similar, less formal process steps also occur in local jurisdictions.

A project develops incrementally in the following steps.

- **System Planning.** The system plan begins with an inventory of places where a roadway is not fully adequate and then proposes solutions to address each deficiency. Examples of deficiencies may include poor pavement conditions, roadways that do not meet geometric design standards, and locations with high accident rates or traffic congestion and delay. This is the stage at which initial project ideas are formed and placed on a list. Although every agency may not have a formal system planning process, every agency should develop lists of projects that may be candidates for further development.

Transit agencies can have an influence on the project lists developed by roadway agencies in several ways. For example, transit agencies can provide:

- Data about places where transit service is regularly delayed;
 - A list of places where transit facilities are needed;
 - A list of places where transit accidents are above average;
 - A list of the types of places or geometric configurations where accidents occur;
 - A list of places where pedestrian access facilities (sidewalks) are missing; and
 - Proposed standards for transit performance or facilities.
- **Scoping.** This process develops a detailed description and cost estimate for projects that have a chance of being programmed. The level of detail developed during scoping varies greatly among agencies, but the project elements, schedule, and cost estimate developed become budget targets at the programming stage. It is important that they be achievable.
- At the scoping stage, transit agencies can affect the specific elements included in the project definition. If transit elements are desired as part of a project, it will be easier to include them at the scoping stage than to try to add them after the project budget and scope have been set.
- **Programming.** As budget time nears, projects are prioritized and added to a proposed design and construction program, a process known as programming. After a program is funded through the budget process, projects progress to the design and construction stages and the focus moves from defining and prioritizing projects to delivering them.

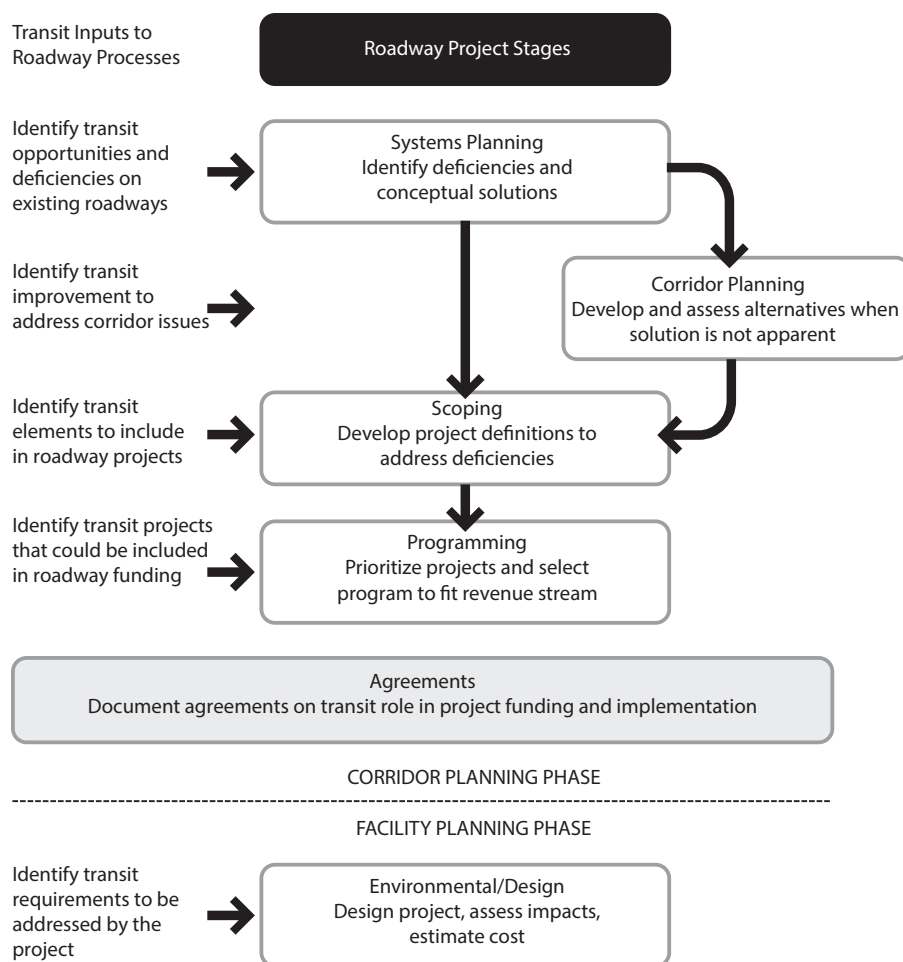


Figure 2-4. Transit Inputs into Typical Roadway Planning and Development Process

Some roadway agencies will solicit transit-related projects as they develop the design and construction program. If the transit agency has funding to contribute to a desired project, then a partnership effort may be proposed. In some agencies, contributions from other agencies will increase a project's score in the prioritization process.

A strong, ongoing communication between local roadway and transit agencies is essential to coordinate facility design for transit purposes. Good relationships are needed to coordinate the timing of transit inputs, and to promote receptiveness to making project and program changes because of those inputs.

2.3 SUMMARY

Planning and decision-making are important in all phases of transportation system development and design. The objectives are to provide facilities that reflect present and future needs; complement and reinforce existing infrastructure; improve mobility and safety; support land development, economic growth, and environmental objectives; are affordable and implementable; and are acceptable to the community. From a public transportation perspective, facilities and services should reduce travel times, improve reli-

ability, attract new riders, and reduce operating costs. These objectives are best achieved through a planning, decision-making, and project development process that objectively assesses demands, costs, and benefits.

The planning and decision-making process is a pragmatic one that reflects specific local circumstances, needs, resources, and precedents. It is usually performed at both the regional and corridor levels. At the regional or planning and programming level, an objective analysis of modal options is essential. Corridor or project planning and decision-making involve identifying alternatives and proposed alignments, developing designs and operational plans, and assessing them in terms of workability, impacts, fatal flaws, and community acceptance.

Federal rules outline the requirements for state DOTs, MPOs, and public transportation operators to conduct a continuing, comprehensive, and coordinated transportation planning and programming process in each state and in metropolitan areas. All relevant agencies should be involved in the decision-making process, and continuous participation is essential.

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3 Design Parameters and Controls

In This Chapter:

- 3.1 Transit Vehicle Characteristics and Controls
- 3.2 Roadway Design Controls and Criteria
- 3.3 Transit Quality of Service and Capacity Considerations
- 3.4 Transit Operations and Infrastructure
- 3.5 References

The physical and performance characteristics of buses and rail transit cars operating in the roadway environment, and the need to accommodate automobiles, trucks, bicyclists, and pedestrians provide the basis for establishing geometric design controls along streets and highways. Facilities for transit vehicles should be compatible with established roadway design standards. Capacities of both roadways and transit facilities should suit their expected usage.

This chapter provides basic vehicle characteristics and their implications on roadway design, summarizes basic roadway design requirements, and contains general capacity guidelines. The controls and guidelines apply to bus facilities operating on freeways, streets, and in separate rights-of-way. They also cover streetcar and light-rail operations within street rights-of-way. Additional technical information on transit vehicles and bus transit capacity computations is contained in Appendices C and D, respectively (15).

3.1 TRANSIT VEHICLE CHARACTERISTICS AND CONTROLS

The design of transit facilities should reflect the dimensions and capabilities of the vehicles they serve. This section outlines general vehicle characteristics and their roadway design implications. It covers vehicle dimensions, performance, and turning capabilities for standard transit buses, guided buses, and light rail transit, covering most in-roadway operating settings. These characteristics form the basis for establishing design requirements such as cross-section, clearance, curvature, and grade stop conditions along streets and freeways.

3.1.1 Standard Bus Vehicle Characteristics (4)

Many types of buses operate in urban transit service. Buses widely used are 12.2- and 13.7-m (40- and 45-ft); and 18.3-m (60-ft) articulated buses are often found in heavy-traveled corridors.



Figure 3-1. Typical 12.2-m (40-ft) Urban Transit Bus

Specialized BRT vehicles—such as the CIVIS Bus used in Las Vegas—operate in several cities. As a rule, roadway or guideway space for a large bus usually can accommodate a small bus.

Figure 3-1 shows a typical 12.2-m (40-ft) urban bus. Tables 3-1 and 3-2 show selected design and performance characteristics for typical 12.2- and 13.7-m (40- and 45-ft) regular buses, and 18.3-m (60-ft) articulated buses. Specific dimensions vary slightly among various bus models and manufacturers, therefore dimensions and physical characteristics of the transit fleet should be verified with the bus operators. Facility designs should have the maximum operating flexibility and not use minimum design criteria. Section C.2 provides examples of bus transit design vehicles. These exhibits illustrate the following roadway-related controls.

3.1.1.1 Length and Height

The standard single-unit urban transit bus is 12.2 or 13.7 m (40 or 45 ft) long, and the design articulated bus is 18.3 m (60 ft) long. Buses are generally 3.3 to 3.8 m (11 to 12.5 ft) high, including air conditioning on top. Accordingly, a minimum vertical design envelope of 4.0 m (13 ft) is suggested. This translates into a 4.4-m (14.5-ft) minimum vertical clearance, when allowance is made for pavement resurfacing. A higher clearance is needed for electric trolley buses where overhead catenaries and power pick-up must be accommodated.

An intercity bus, as used by various private carriers, is 13.7 m (45 ft) long, 2.6 m (8.5 ft) wide, and 3.5 m (11.5 ft) high (Figure 3-2). A 4.4-m (14.5-ft) vertical clearance will accommodate this vehicle.

A modern double-decker bus is 4.2 m (13.8 ft) high (Figure 3-3). Its width and length are similar to those of other standard transit buses.

Table 3-1. Standard Bus Design Characteristics (1, 5, 9, 12)

Item	Regular Bus		Articulated Bus
	12.1 m (40 ft)	13.7 m (45 ft)	18.3 m (60 ft)
Length	12.2 m (40 ft)	13.7 m (45.0 ft)	18.3 m (60.0 ft)
Width Without Mirror ^a	2.5–2.6 m (8.2–8.5 ft) ^a	2.6 m (8.5 ft) ^a	2.6 m (8.5 ft) ^a
Height (to Top of Air Conditioning) for Design	3.0–3.5 m (9.9–11.5 ft) ^b	3.8 m (12.5 ft) ^b	3.3 m (11.0 ft) ^b
Overhang			
Front	2.1 m (7.2 ft)	2.4 m (7.9 ft)	2.7–2.7 m (8.8–8.9 ft)
Rear	2.4 m (9.3 ft)	3.0 m (9.8 ft)	2.6–3.0 m (8.6–9.7 ft)
Wheel Base (Rear)	7.7 m (25.0 ft)	7.0 m (22.9 ft)	7.1–7.5 m (23.3–24.5 ft)
Driver's Eye Height	2.1 m (7.0 ft) ^c	2.1 m (7.0 ft) ^c	2.1 m (7.0 ft) ^c
Weight			
Curb Weight	12.2–12.8 mt (27,000–28,200 lbs)	17.3 mt (38,150 lbs)	17.2 mt (38,000 lbs)
Gross Weight	16.7–8.1 mt (36,900–40,000 lbs)	25.0 mt (55,200 lbs)	30.2 mt (66,600 lbs)
Ground to Floor Height ^d	0.7 m (2.3 ft) typical 0.4 m (1.2 ft) low floor	0.7 m (2.3 ft) typical 0.4 m (1.2 ft) low floor	0.7 m (2.3 ft)
Passenger Capacity			
Seats	30–50, depending on orientation for standees	50	76
Standees (Crush load)	20	28	38
Turning Radius			
Inside	7.5–9.1 m (24.5–30 ft)	7.5–9.1 m (24.5–30 ft)	8.3 m (27.3 ft)
Outside	12.8–14.3 m (42.0–47 ft)	12.8–14.3 m (42.0–47 ft)	12.1–12.8 m (39.8–42 ft)
Outside with Overhang	13.9–15.5 m (45.5–51 ft)	13.9–15.5 m (45.5–51 ft)	13.5 m (44.3 ft)
Doors—Number (typical)	2	2	2–3
Width of Each Door	0.7–1.6 m (2.3–5 ft)	0.8–1.6 m (2.5–5 ft)	0.8–1.6 m (2.5–5 ft)
Angles			
Approach	10°	10°	10°
Breakover	10°	10°	10°
Departure	9.5°	9.5°	9.5°

Note: Exact dimensions may vary by bus manufacturer. Dimensions do not include bike racks on buses.

^a With mirror, envelope dimensions become 3.0 to 3.2 m (10 to 10.5 ft).

^b Use 4.4 m (14.5 ft) as minimum governing design clearance.

^c Use 1.1 m (3.5 ft) for driver's eye height for roadway design.

^d Low floor and platform design buses may represent a lower minimum requirement.

3.1.1.2 Width

Most modern urban transit buses are 2.6 m (8.5 ft) wide. However, when outside mirrors are added on both sides, the bus envelope typically becomes 3.0 to 3.2 m (10 to 10.5 ft). Therefore, 3.6 m (12 ft) lanes are desirable, and 3.3 m (11 ft) is suggested as the desired minimum lane width. If the mirror-to-mirror

Table 3-2. Bus Performance Characteristics (3)

Maximum Attainable Speed		
Acceleration	km/h/Sec.	MPH/Sec.
0–10	5.36	3.33
10–30	3.57	2.22
30–50	1.53	0.95
Deceleration	km/h/sec.	mph/sec.
Normal	3.2–4.8	2–3
Maximum	9.7–19.3	6–12
Maximum Grade (Sustained-Roadway)	6%	6%
Maximum Grade (Short Upgrade)	10–12%	10–12%

**Figure 3-2. Intercity Bus****Figure 3-3. Double-Decker Bus**

envelope can be essentially the same as that for 2.6-m (8.5-ft) buses, 3.0-m (10-ft) lanes could be used in locations where space is constrained.

3.1.1.3 Eye Height

An eye height of 1.1 m (3.5 ft) should be used in roadway design, although the driver's eye-height on most buses approximates 2.2 m (7 ft). This allows a factor of safety for potential new equipment and for possible use of bus lanes and busways by other design vehicles.

3.1.1.4 Transit Vehicle Maneuverability

Maneuverability is an important element in the roadway and at parking facilities. Maneuverability and access restrictions include:

- Turning radii and design of adequate curb returns;
- Acceleration capabilities of transit vehicles and maximum negotiable grades;
- Provision of adequate clear sight distances at intersections; and
- Design of driveways, raised pathways, and traffic-calming devices such as speed humps and speed tables.

3.1.1.5 Turning Radii and Design of Curb Returns

Figure 3-4 shows the minimum turning path for a typical 12.2-m (40-ft) bus when maximum exerted force is placed on the bus steering wheel. The outside turning radius is about 14 m (46 ft) and the inside turning radius 7.6 m (25 ft). A 13.7-m (45-ft) bus would have a slightly longer inside and outside turning radius, depending on the manufacturer. The minimum outside turning radius of the front overhang of a bus is about 15.2 m (50 ft). A slightly larger minimum outside radius (e.g., 16.8 m [55 ft]) should be used for design purposes to allow smoother maneuvering if it is needed to accommodate intercity buses. As vehicles age, the turning radius changes, and different vehicles may exhibit slightly different turning radii. Section C.2 has the characteristics and turning paths of the AASHTO design vehicles used in transit operations from AASHTO's *A Policy on Geometric Design of Highways and Streets* (the Green Book). (1) Verifying the turning radius by coordinating with the affected bus manufacturers and operators is a good practice before designing transit facilities or planning for transit services along the affected streets. Consulting the latest source documents from bus manufacturers is also recommended.

Table 3-3 is an illustrative example of the likely overhang associated with different radii in the street environment. At many urbanized street intersections, such turning radii are not possible; thus, a right-turning bus must encroach further into an intersection and occupy more than a single lane width for the intersecting street. As the radius expands, the overhang decreases.

Based on the turning maneuverability of a standard transit bus (AASHTO Green Book) the following edge-of-traveled-way designs in Table 3-4 are appropriate for 90-degree turns at intersections with 3.6-m (12-ft) lanes, assuming no parking lanes. To avoid encroachment with lane widths less than 3.6 m (12 ft), edge-of-traveled-way designs greater than the minimum radii shown in these tables will be required. Minimum designs may be required for locations with low turning speeds, low turning volumes, high pedestrian volumes, and high adjacent land acquisition costs.

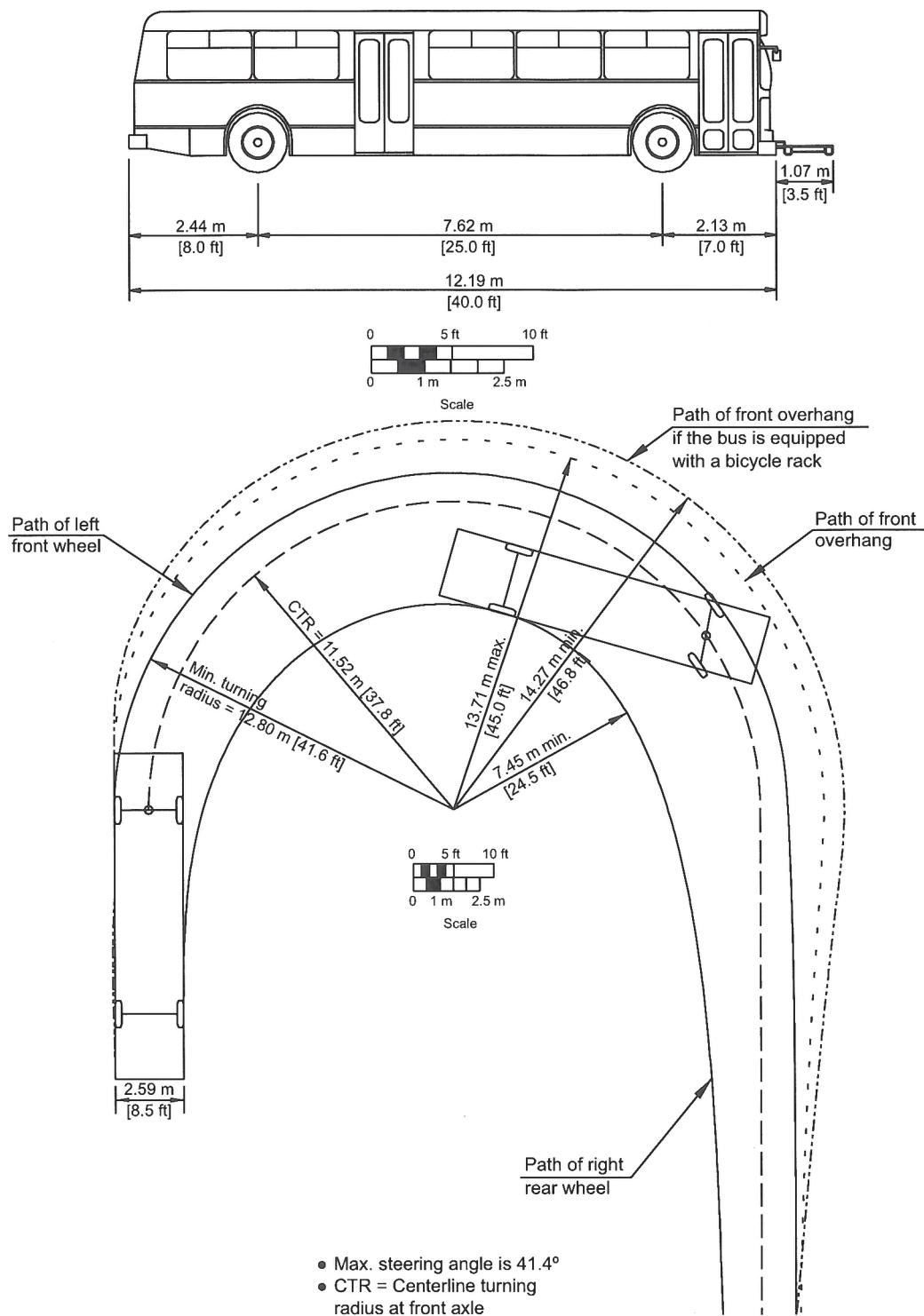


Figure 3-4. Minimum Turning Path for a Typical Transit Design Vehicle

Table 3-3. Turning Radius for 12.2 m (40 ft.) Bus (1)

Turning Radius	Vehicle Overhang (Inside of Curve)	Vehicle Overhang (Outside of Curve)
25 m (82 ft.)	2.1 m (6.8 ft)	2.8 m (9.3 ft)
30 m (100 ft.)	2.0 m (6.5 ft)	2.65 m (8.7 ft)
300 m (1,000 ft.)	1.8 m (5.8 ft)	2.0 m (6.5 ft)

A bicycle rack on the front of a bus can affect minimum turning radii. Variations may exist in the impact to the turning radii based on specific rack designs and bus designs. Figure 3-6 is a template for a two-rack design, which is most typical. The impact of the rack may be contained within the minimum outside radius of 13.87 m (45.5 ft) noted in Figure 3-4, or may be as much as 0.3 m (1 ft) greater, depending on the specific bus and turning radius. Accounting for this added dimension is particularly critical on driveways, in bus transit centers, and in neighborhoods with limited turning maneuverability.

3.1.1.6 Acceleration, Deceleration, and Maximum Negotiable Grades

Because of their increased mass, buses require greater distances to accelerate to required travel speeds and, likewise, greater distances to break and stop. Buses decelerate faster on an upgrade and accelerate more quickly on a downgrade. The design of ramps to freeways and arterials serving park-and-ride lots should incorporate appropriate allowances for the reduced acceleration and maneuverability characteristics of buses and, to the extent possible, take advantage of opportunities to create ramps that are upgrades exiting and downgrades entering a freeway.

Normal bus acceleration rates of 3.2 km (2.0 mi) per hour per second and normal deceleration of 2.4 km (1.5 mi) per hour per second should be used. These rates reflect the performance capabilities of most urban transit buses, and they permit buses to accelerate to 48 km (30 mi) per hour in about 15 seconds.

Maximum deceleration in emergencies should not exceed 8.0 to 9.7 km (5 to 6 mi) per hour per second where there are standing passengers.

Sustained, short upgrades of up to 6 percent do not unduly interfere with bus operations and, as noted in Table 3-2, short distance grades on ramps may be up to 10 percent. It is desirable to limit downgrades if sharp horizontal curvature and heavy truck and bus traffic are present. Electric trolley buses will tend to have greater hill-climbing ability.

Table 3-4. Minimum Travel Way Designs for 12.2-m (40-ft) Bus (1)

Curve Type	Recommended Minimum Radius
Simple Curve	15 or 17 m (50 or 55 ft)
Simple Curve with Taper	12 m (40 ft.) with 1-m (2-ft) offset
3-Centered Compound Curve	36 m (120 ft.), 12 m (40 ft) with 1-m (2-ft) offset

Note: A minimum radius of 15 to 17 m (50 to 55 ft) is required to keep a bus from encroaching into an adjacent or opposing lane. In many urban/suburban areas, this type of radius is impractical because it lengthens pedestrian crossings and has significant right-of-way impacts. In many cases, some off-tracking by buses is tolerable. In many urban areas, a 7.5- to 9-m (25- to 30-ft) radius is common. The presence of bike lanes and/or on-street parking will increase the effective radius of a curve and serve to minimize off-tracking.



Photo courtesy of Peter Martin and Sportworks NW, Inc.

Figure 3-5. Example of Bicycle Rack on Standard Bus

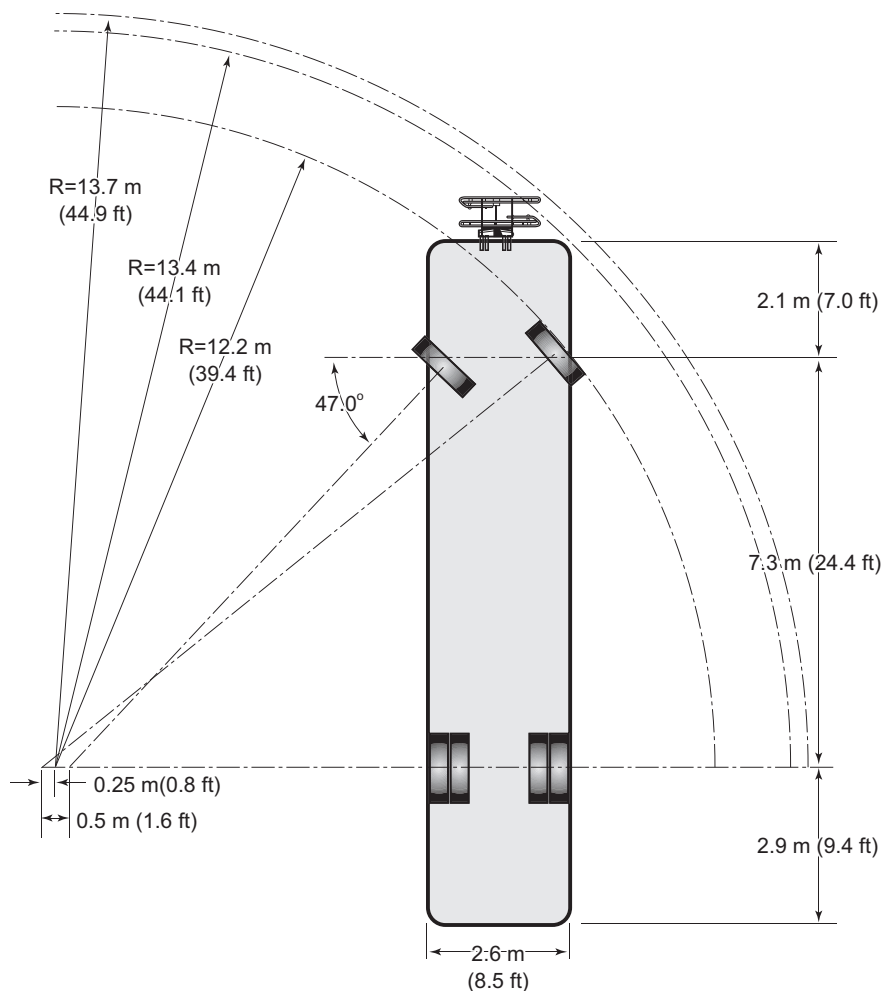
For a left-turn maneuver from a stop-controlled minor street or driveway, a time gap in traffic on a four-lane undivided major road of 10 seconds is sufficient for a standard bus to accelerate from a stop and complete a left turn without unduly interfering with traffic flow. The time gap acceptance does not vary with approach speed on an arterial. A 10-second time gap is equivalent to an Intersection Sight Distance (ISD) of 140 m (450 ft) on a 48 km/h (30 mph) design speed roadway.

A time gap sufficient for a standard bus to accelerate from a stop at a stop-controlled minor street or driveway and complete a left-turn without unduly interfering with traffic flow on an arterial might not be feasible at a given location. Minimum safe sight distances of roughly 61 m (200 ft) should be maintained, assuming a 48 km/h (30 mph) average travel speed on the intersecting arterial. This is the stopping sight distance for a vehicle traveling at 48 km/h (30 mph) with a 2.5-second reaction time and with a deceleration rate of 3.4 m/s^2 (11.2 ft/s^2). At 48 km/h (30 mph), a 61-m (200-ft) clear sight standard allows for a minimum vehicle gap of about 4.5 seconds.

3.1.1.7 Traversing Driveways, Raised Pedestrian Pathways, Railroad Crossings, and Traffic Calming Devices

Transit vehicles must be able to negotiate a vertical profile change at a driveway or traffic-calming device without dragging their undersides or front and rear bumpers. Figure 3-7 depicts three road clearance angles for a bus that should be considered in the design of transit facilities, railroad crossings, driveways, and streets with raised surfaces serving transit. Dimensions will vary for each angle for each bus manufacturer. For the vehicle-dimension data presented above, current bus designs have approach angles that range from 8.2 to 9.0 degrees, departure angles that range from 8.1 to 9.0 degrees, and breakover angles that range from 8.3 to 15.2 degrees. These data resulted from a sample of four bus manufacturers and 12 vehicle models. Low floor buses will be particularly critical to accommodate, and as such, may justify their own guideway or limited routings where such conditions can be minimized.

Section 3.3 presents more detailed information addressing transit bus roadway design and general criteria. Appendix C, Section C.2 provides additional bus design vehicle information.



MAX TURNING RADIUS WITH BICYCLE RACK=13.7 m (44.9 ft)

MAX TURNING RADIUS WITHOUT RACK=13.4 m (44.1 ft)

TYPICAL 12.2 m (40 ft) BUS, LOW FLOOR, MAX STEERING ANGLE=14.3 m (47 ft)

Source: Sportworks NW, Inc.

Figure 3-6. Minimum Turning Path for a Typical Bus with Bicycle Rack

3.1.2 Guided Bus Guideway Characteristics

Creating a running way exclusively for transit buses can reduce right-of-way requirements, improve service reliability, and promote operational safety. In addition, passenger comfort may also be enhanced by smoother operating conditions.

There are three broad categories of guidance systems:

- mechanical
- optical
- grid system