

## Chapter 5

# GEOMETRICS

### *Introduction*

Geometrics as discussed in this chapter refers to the layout of intersections, interchanges, access drives, special-purpose facilities, and their operational characteristics. Design of horizontal and vertical alignments are dealt with in Chapter 4, "Alignment and Typical Sections."

Geometric design is the extension of the planning process. This is the point at which the layouts envisioned in the planning phase are given dimension. The requirements of design and ultimately of operation must be incorporated at the planning stage. The designer must employ established criteria that are based on operational requirements, evaluate tradeoffs and make decisions as to which alternatives are the more utilitarian within the constraints imposed by administrative guidelines and the basic plan established in the planning phase. The safety of the facility depends to a great degree on how well the designer utilizes existing technology and how high a priority is given to safety criteria.

The Preliminary Design Section of the Bureau of Highway Design performs or reviews most of the preliminary engineering tasks or pre-(Public) Hearing requirements related to highway geometrics. The post-hearing work, or final detail preparation is done by the Final Design Section or the Consultant Design Section. The project development process, which involves geometric design, is discussed in Chapter 2, "Project Development".

In this chapter, as well as others, sufficient design information is presented as a guide to make the designer aware of the many ramifications of the subject. The designer is advised to consult the references for detail when a problem is not clearly answered in this manual. Graphic layouts and presentation format for many common geometric design requirements are included in the "Sample Layouts" in Volume 2.

### *Geometric Design Criteria*

Without some form of established criteria, individual designers would be called upon to make subjective judgments as to the appropriate geometric characteristics of proposed highways. These decisions can have a significant effect on the level of traffic service, safety and cost of the highway investment.

Although this chapter is directed mainly to the design of State highways and to procedures to be followed by the Bureau of Highway Design, many of the guides and criteria are applicable to local roads and streets.

AASHTO has considerable influence on highway design guidelines and standards. Since 1938, AASHTO has been developing and publishing design policies for use by highway agencies and continues to update policies and standards to reflect new findings and the

current state of knowledge. The AASHTO publication, *A Policy on Geometric Design of Highways and Streets* (the "Green Book") (5) is used as the primary reference for this chapter.

The primary source for capacity information is the *Highway Capacity Manual* (14).

### **Fixed Criteria**

Some criteria are defined by the "Green Book" in terms of fixed values. Examples are lane width, shoulder width, and bridge width. Widths less than the "Green Book" values may not provide adequate levels of service and safety, and greater widths may not be an economical investment.

### **Minimum Criteria**

Many of the "Green Book" design criteria are expressed as minimum values or ranges of values for particular conditions. The NHDOT adheres to the basic framework of AASHTO design policies, but chooses to use desirable criteria whenever possible.

### **Departure from Criteria**

Occasionally there may be unusual conditions which justify departure from desirable criteria. Any proposed design which does not meet at least the minimum prescribed criteria must be documented and approved by the Highway Design Administrator and FHWA when Federal funds are involved. Allowable departure from established criteria is referred to as a "Design Exception" which is a proper design, documented as appropriate for a particular situation. See Chapter 3 for "Design Exception" procedures and an example.

## ***Design Controls***

A number of factors influence decisions as to the geometric characteristics of highways. Consideration should be given to traffic volumes, design speeds, expected operating speeds, highway capacity, highway system, access control, and environmental considerations. Chapter 3, "Design Considerations and Criteria," deals with these basic factors influencing design as they affect all facets of the project. The design controls explained in this chapter are most pertinent to geometric arrangements.

### **Traffic Volumes**

The volume and characteristics of traffic are perhaps the most significant bases for highway design criteria. Highways normally will be designed to accommodate traffic expected for a particular design year - usually about 20 years in the future. The selection of a design year varies with project type. Obviously, a resurfacing or rehabilitation project may have an earlier design year than a relocated arterial subject to industrial-commercial growth impact.

The Bureau of Transportation Planning maintains current records of traffic data and develops projections of expected future traffic. This information is made available to designers and is expressed in the following terms:

- Annual Average Daily Traffic (AADT) -- the estimate of typical daily traffic (two-directional) on a road for all days of the week, Sunday through Saturday, over the period of one year.
- Design Hour Volume (DHV) -- the hourly traffic volume (two-directional) used in the design of basic highway segments, usually represented by the 30th highest hourly volume of the year.
- Directional Design Hour Volume (DDHV) -- a measurement of the highest traffic volume in one direction during the design hour. Usually computed by multiplying the AADT by the percentage that the DHV is of the AADT, and then by the percentage of traffic in the predominant direction during the design hour. Thus, if the DHV is 15 percent of the AADT and the directional distribution at that hour is 60:40, the DDHV is  $0.15 \times 0.60 \times \text{AADT}$ , or 9% of the AADT.
- Peak Hour Volume (PHV) -- a 60 minute interval that contains the highest volume of traffic for a specific period of the day (AM, Mid-day, PM). Typically expressed as either an average weekday peak hour or a Saturday peak hour.
- Average Daily Load (ADL) -- a measurement of the amount of load placed on a pavement by traffic, especially trucks; used to design the pavement structure.
- Composition (% Trucks) -- a measure of the proportionate number of trucks in the traffic stream, expressed as a percentage of total traffic during the DHV, or the ADT. Vehicles in the Truck Class are normally those having 4000 kg or greater gross vehicle mass (GVM) rating of the manufacturer and vehicles having dual tires on the rear axle.

Prior to requesting traffic data, designers should project realistically both the construction year and the design year (observing the history of similar projects with similar characteristics).

### Design Speed

For each proposed highway improvement, a design speed is selected which establishes basic criteria for certain design elements such as horizontal and vertical curvature, superelevation, sight distance and critical length of grades. It is the maximum safe speed that can be maintained over a specified section when design features reflect minimum values for that speed. These criteria are set for the mainline before detailed geometrics are attempted.

The selected design speed should be logical and consistent with respect to the character of the terrain, the type of highway, and the anticipated improvements to the adjacent road segments. Keep in mind that the design speed for minor roads may differ from the mainline speed which is shown on the title sheet.

A highway carrying a large volume of traffic may justify a higher design speed than a less significant facility in similar topography. But, a low design speed should not be assumed for a low traffic-volume road where the topography is such that drivers are likely to travel at higher speeds. Drivers do not adjust their speeds to the importance of the highway, but to the physical limitations and traffic thereon.

A general rule-of-thumb is to set the design speed equal to 10 to 15 km/h higher than the posted speed limit. In some constrained situations a design speed equal to the posted speed limit may be acceptable, however, a consistent design speed for an overall highway section should be strived for, not short segments with varying design speeds.

On all Federal-aid projects, FHWA policy states that the selected design speed is to be equal to or exceed the posted or regulatory speed limit of the completed facility. A design exception is generally required if deviation from the policy is proposed. Some flexibility may be possible for 3R projects. Consult FHWA if there is any question.

FHWA guidance also notes that the "hard" conversion of design speeds from English units to metric could technically render a previously acceptable design element as unacceptable. For example, using a design speed of 100 km/h instead of the "old" 60 mph will require a slightly larger radius of curve. Thus retention of an existing 60 mph curve on a project would not technically meet the minimum criteria for a 100 km/h design speed. FHWA does not consider designs which were acceptable under the English system to be substandard under the metric system if the differences are strictly the result of "hard" conversion. Therefore, in this example, the 60 mph curve would not become "substandard," and no formal design exception would be required by FHWA.

Table 5-1 provides a general guide to the ranges of design speeds considered appropriate for various functional classifications of highways in New Hampshire.

Highway Functional Classification	Design Speed (km/h)
Interstates, Turnpikes, Arterials, Major Highways	
- Rural	110
- Urban	80 - 110
Collector Roads, State Highways	
-Rural	60 - 100
- Urban	50 - 80
Rural or Urban Local Roads	50 - 80

*Table 5-1*

## DESIGN SPEED RANGES

### Operating Speed

There is need to recognize conditions where actual operating speeds typically may exceed the design speed. For example, terrain conditions may limit the overall design speed to 80 km/h, but several long tangents within the section may encourage much higher speeds. This situation should be recognized, and those curves at each end of the tangent should be, if feasible, somewhat flatter than minimum criteria for 80 km/h so as to permit transition back down to the design speed.

It is also undesirable in the above situation to design vertical curves on the tangent section for 80 km/h stopping sight distance when actual operating speeds may be 100 km/h or higher.

## Capacity

The term "capacity" is used to express the maximum number of vehicles that have a reasonable expectation of passing over a given section of roadway during a given time period under prevailing traffic conditions. In a sense, the term encompasses broader relations between highway characteristics, conditions, traffic composition, flow patterns, and the relative degree of congestion at various traffic volumes from very light to those equaling the capacity of the facility.

Highways should be designed to accommodate the traffic volumes expected in the design year. The number of lanes to be provided is the principal design element affected. Decisions as to the number of mainline lanes normally are made during the preliminary design process. Chapter 4, "Alignment and Typical Sections" deals with preliminary engineering, alignment and typical section decisions.

Throughout the design process, the design volume and design capacity must be compared (volume to capacity ratio, or  $v/c$ ), and where expected volume is greater than capacity, an alternative must be considered.

There are several alternatives related to highway capacity which the geometric designer must consider:

- **Passing Sight Distance** -- The theoretical capacity of a two-lane road is greatly reduced when there is limited opportunity for overtaking and passing slower moving vehicles. In terrain where it is impractical to provide an adequate amount of passing sight distance, additional lanes may be required.
- **Auxiliary Climbing Lanes** -- The capacity of a two-lane road is significantly affected by long, steep grades with slow-moving trucks. An auxiliary climbing lane may be warranted.
- **Signalized Intersections** -- Installation of signals usually requires additional lanes at the intersection.
- **Urban Area Conflicts** -- Roadside conflicts associated with urban area developments should be considered in assuring adequate highway capacity.
- **Lateral Clearance** -- Restricted clearance between the edge of traveled way and roadside obstructions will reduce capacity.
- **Interchanges** -- Capacity in the vicinity of interchanges can be affected by the design of ramps, ramp terminals and weaving sections.
- **Access Control** -- Limitation of access will increase capacity.

The calculation for capacity analysis has progressed from the rudimentary to the complex in recent years. As more experience provides greater knowledge about the factors affecting traffic movement, computations become more inclusive.

Highway capacity information serves these general purposes:

- It is used in transportation planning studies to compare the sufficiency of existing highway networks in service to current traffic, and to estimate the time in the future when traffic growth may overtake the capacity of the highway.
- Highway capacity information is utilized in traffic operation analysis for many purposes. Capacity information is particularly useful for isolating bottleneck locations and preparing estimates of operational improvements that may be expected from spot alterations in the highway geometry or from traffic control measures.

The degree of exactness varies in the capacity data required for these several uses. The designer must consult the *Highway Capacity Manual* or a similar acceptable method of analysis or design.

## ***Design Vehicles***

The physical characteristics of vehicles using the highways are important controls in geometric design. Design vehicles are selected motor vehicles with the weight, dimensions, and operating characteristics used to establish highway design controls for accommodating vehicles of designated classes.

Two general classes of vehicles have been selected, namely, passenger cars and trucks. The passenger-car class includes all light vehicles and light delivery trucks (panels and pickups). The truck class includes single-unit trucks, recreation vehicles, buses, truck tractor-semitrailer combinations, and trucks or truck tractors with semitrailers in combination with full trailers.

In the preliminary design of any highway facility, the largest design vehicle likely to use that facility frequently or a design vehicle with special characteristics is used to determine the design of radii at intersections and turning roadways.

### **Minimum Turning Paths**

The principal dimensions affecting design are the minimum turning radius, the vehicle overhang, the wheelbase, and the path of the inner rear tire. Effects of driver characteristics and of the slip angles of wheels are minimized by assuming that the speed of the vehicle for the minimum radius turn is less than 15 km/h. Turning paths for radius design are shown in the "Green Book". Plastic templates are in Appendix 5-1 of this Manual. The templates are used directly over base layouts to verify adequate turning paths. Turns should be from proper lane to proper lane without encroaching on adjacent lanes. A comfort margin of 0.6 m (+) should be allowed between the wheel paths and the edge of pavement or curbing (if present) for stop or yield conditions and a 1.2 m (+) offset should be allowed for non-stop turning roadways. When using raised islands and curbed corner radii, wheel paths should provide for WB-15 vehicles.

Geometric design requirements for trucks and buses are much more severe than they are for passenger vehicles. Trucks and buses are wider and have longer wheelbases and greater minimum turning radii. These are the principal characteristic dimensions affecting horizontal highway design. The longer single-unit trucks (SU vehicle) and buses require greater minimum turning radii than most vehicle combinations, but because of their greater offtracking, the longer vehicle combinations also require greater widths of turning paths.

A truck combination is a truck tractor with a semitrailer, either with or without a full trailer, or a truck with one or more full trailers. Because semitrailer-combination sizes and turning characteristics vary widely, there are several semitrailer design vehicles. The WB-15 is the typical design vehicle to use at intersections where a truck tractor-semitrailer has been chosen to govern design. The WB-19 design vehicle has similar dimensions to the maximum current legal semi-trailer length on all roadways in New Hampshire (48 feet). A 53 foot trailer (WB-20 design vehicle) is legal in New Hampshire on the Interstate and on approved access routes between the Interstate and a terminal or service facility. Turning radii to accommodate the WB-19 or WB-20 design vehicle are desirable at intersections near Interstate interchanges or in other special cases.

## ***At-Grade Intersections***

Most highways intersect at-grade. Intersections should provide adequately for anticipated turning and crossing movements. Typical geometric designs and design controls for at-grade intersections are discussed in this section and illustrated in the "Sample Layouts" in Volume 2.

Proper intersection treatment is a very important part of highway design. The design affects capacity, level of service, speed, efficiency, and safety.

### **General Types**

Intersections at-grade usually are the 3-leg (T shape) or the 4-leg geometric form and may be non-channelized, or channelized as shown in the "Sample Layouts" in Volume 2. The modern roundabout (not the same as older traffic circles or rotaries) is a specialized type of at-grade intersection which can be considered in appropriate locations.

The principal factors which govern the choice of type of intersection and the design characteristics are the peak hour volumes, the turning movements, the characteristics or composition of traffic, and the design speed.

### **Crossing Alignment**

Regardless of the type of intersection, it is desirable for safety and economy that intersecting roads meet at, or nearly at right angles. Roads intersecting at significantly skewed angles cause difficult turning movements, require extensive turning roadway areas and tend to limit visibility. Skewed intersections increase the exposure time of vehicles crossing the main traffic flow and may increase the accident potential.

While a right-angle crossing is desirable, some deviation is permissible. Crossing angles above 60 degrees produce only a small reduction in visibility, and do not often warrant

realignment. Skewed intersections on major highways should be avoided where possible by relocating the approaches to intersect the main highway at an angle of no less than 60 degrees.

Intersection of highways on sharp curves should be avoided wherever possible since the superelevation complicates the intersection grades and the curvature may contribute to sight-distance problems. When a side road with significant turning movements intersects a highway within a horizontal curve, the superelevation on the main roadway should be held to 4% maximum in order to minimize snow and ice complications.

### **Pavement Widths**

Most of the simple intersections will require only the design of a simple radius on the inner edges of pavement to accommodate right turns. Other possible layouts include the taper-curve-taper and the compound curve. Taper-curve-taper intersection radii are used to set back curbs to provide more useable turning room. Compound curves are sometimes used to provide more turning room as well as minimize pavement area needed for the turn.

Occasionally, there is a need to design corner islands, or channelization, or separate turning roadways. When this happens, the designed width of the turning roadway becomes critical. The designer should refer to the "Sample Layouts" in Volume 2 of this manual and also the "Green Book".

### **Speed-Change Lanes**

Drivers who leave a highway at an intersection usually reduce speed before turning. Drivers who enter a highway from an intersecting roadway accelerate until the desired open-road speed is reached. When deceleration or acceleration takes place directly on the highway, it disrupts the flow of through traffic. To minimize these conditions, the use of speed-change lanes is standard practice on highways which have expressway characteristics and they are sometimes used on other main highways.

Warrants for use of speed-change lanes cannot be stated simply. Factors to be considered include speeds, traffic volumes, capacities, types of highways and services provided, arrangement and frequency of intersections, and accident experience.

The following conclusions generally are accepted:

- Speed-change lanes are warranted on high-speed and high-volume highways for vehicles entering or leaving the through traffic lanes.
- All drivers do not use speed-change lanes in the same manner, but they use them enough, on the whole, to improve the overall safety and operation of the highway.
- Use of speed-change lanes varies with traffic volume. Drivers use them more when volumes are heavy.
- The type of speed-change lane consisting of a long taper fits the behavior of most drivers and does not require maneuvering on a reverse-curve path.

- Deceleration lanes on approaches to at-grade intersections which also serve as storage lanes for turning traffic are particularly advantageous, and experience with them has been favorable.

Two types of speed change lanes commonly are used. One provides an additional full lane width with a relatively short taper. The other uses a directional straight-line taper for the full distance between the edge of pavement and the PC or PT of the turning-ramp roadway. Examples are shown in the "Sample Layouts" in Volume 2.

Speed-change lanes are used at most locations where it is necessary to provide storage for vehicles making turning movements. Refer to the "Green Book", Chapter 10, for speed-change lane tables.

### **Sight Distance**

For an intersection to function properly, adequate sight distance must be provided. The operator of a vehicle approaching an intersection should have an unobstructed view of the whole intersection in order to:

- recognize the intersection,
- make a safe directional decision,
- stop safely upon approaching the intersecting roadway, and
- avoid collisions.

The minimum sight distance considered safe is related to vehicle speeds and distances traversed during perception, reaction and braking times.

Wherever possible, minimum sight triangles are provided at intersections so that the area within those sight triangles can be freed of any obstructions. An assumed 600 mm depth of snow is considered in all corner sight distance analyses. Sight distance triangles are shown in Chapter 4, and in the "Green Book", Chapter 9.

The driver should have full view of any point of separation, either diverging or merging, far enough in advance of reaching that point to make the appropriate decision concerning desired direction. Table 5-2 shows recommended stopping and decision sight distances for various design speeds. The decision sight distance is measured from the driver's eye to a point on the road surface or a feature which would identify the upcoming intersection (signal head, queued vehicles, etc.). The stopping sight distance condition considers the driver's eye to be 1070 mm above the pavement and the object viewed to be 150 mm above the pavement.

The designer will use judgment in determining the most appropriate clear distance for safety at intersections, based on the above recommendations. A review of Chapter 3 of the "Green Book" is advisable before applying the principles of sight distance requirements.

### **Intersection Sight Distance**

For safety, it is necessary that the driver of a stopped vehicle see enough of the major highway to be able to enter onto or cross the major highway before a vehicle on the major

highway reaches the intersection even though this vehicle comes into view just as the stopped vehicle starts to move.

Chapter 4, "Alignment and Typical Sections", and the "Green Book", show the required sight distances along the major highway to allow a stopped vehicle to safely enter onto or cross the major highway. Distances are shown for various combinations of number of lanes to be crossed, speed on the major highway, and the type of design vehicle.

Measuring intersection sight distance is done by locating the driver's eye at 6.0 m behind the edge of the major highway's traveled way. The height of eye is 1070 mm (for passenger cars) and the height of object is 1300 mm above the pavement.

### **Intersection Spacing**

The proper spacing of intersections requires a careful analysis of safety and capacity conditions.

The safety problems occur when insufficient maneuvering time is allowed, combined with driver distraction and high traffic volumes. The problems can be corrected by using access control, frontage collector roads and synchronized traffic signals. Capacity analysis is needed first to identify the problem, then a combination of the designer's resources can be applied.

Design Speeds -- (km/h)	Stopping Sight distance -- (m)	Decision Sight Distance -- (m)
50	57.4 -- 62.8	145 -- 200
60	74.3 -- 84.6	175 -- 235
70	94.1 -- 110.8	200 -- 275
80	112.8 -- 139.4	230 -- 315
90	131.2--168.7	275 -- 360
100	157.0 -- 205.0	315 -- 405
110	179.5 -- 246.4	335 -- 435

*Table 5-2*

### STOPPING AND DECISION SIGHT DISTANCE

#### **Storage Lanes**

Turn lanes, both left and right, provide storage space for turning vehicles, as well as space for deceleration. By moving these turning vehicles out of the through-traffic lanes, two objectives are accomplished: a safety factor is introduced by removing stopped or slow-moving vehicles from traffic lanes, and the design capacity of the highway can be maintained or improved.

The length of a storage lane for either signalized or unsignalized intersections is determined by the number of vehicles to be stored, the types of vehicles and the type of traffic control governing the turning movement, and the deceleration requirement. A capacity analysis is needed to properly identify the requirements.

If the intersection is controlled by traffic signals, the number of vehicles waiting to turn will be determined by the length of the signal cycle and signal phasing. For preliminary work, a *Highway Capacity Manual* signalized intersection analysis is performed to determine the level of service. Queue lengths can be approximated by dividing the peak hour turning movement volume by the number of signal cycles per hour. This simple calculation can yield unrealistically long queue lengths for movements that receive a large percentage of green time. Numerous methodologies and computer software packages exist with more complex queuing calculations. The Preliminary Design Section commonly uses an in-house developed EXCEL spreadsheet (Appendix 5-2) for signalized queuing calculations. Designing intersection geometrics for the 99th percentile queue length (the queue length which would be exceeded only 1% of the time during the peak hour) is desirable where feasible. Engineering judgment must be used to evaluate the results and decide what condition will be used for design purposes.

If the intersection is unsignalized, the storage length may be approximated based on the number of turning vehicles likely to arrive in an average 2 minute period within the peak hour.

Deceleration length is based on design speed.

Taper lengths for storage lanes depend on the design speed of the approach roadway. They are intended to separate the turning vehicle from through traffic as quickly and effectively as possible and therefore reduce conflicts.

Additional guidance on storage length, deceleration length, and tapers is provided in the "Green Book".

The intersection area and the area where vehicles store while waiting to enter the intersection should be designed with a relatively flat grade; the maximum desirable grade on the approach leg should be 4 percent. Cross slope (superelevation) should also be held to 4 percent maximum. Starting and stopping in winter is a major consideration.

At intersections in residential areas, areas where there are heavy pedestrian movements, and in areas of possible severe property impact, the minimum radius for the design vehicle should be used. This minimum curbed radius will require traffic to move slower and provide pedestrians with less distance of exposure while crossing the street.

Storage lanes should be 3.6 m wide (no less than 3.0 m) with 0.6 m of curb offset. An absolute minimum width of 3.6 m should always be used when a restrictive curb is adjacent to the lane.

### **Channelization**

Most at-grade intersections with local roads will be simple non-channelized intersections. Intersections with heavy movements should be channelized by pavement markings, raised islands or both.

Potential conflicts between vehicles and between vehicles and pedestrians may be reduced through channelization of traffic movements. The traffic paths may be fixed to separate and direct traffic movements into specific and clearly defined vehicle paths.

The edges of traffic paths are formed and delineated by traffic islands. Islands may be formed by curbs or other raised devices or may be marked out simply in paint on the pavement surface. One of the most desirable treatments is a raised island with mountable curbs. However, installation of curbs should generally be avoided in areas where high speeds may be expected. Within an intersection area, medians and outer separations are also considered as islands. Islands are useful to:

- segregate traffic movements with different requirements in terms of speed, direction, and stop or right-of-way control.
- locate and protect traffic control devices such as signs and signals where the most desirable location for these devices is within the intersection area.
- provide pedestrian refuge.

### **Principles of Channelization Design**

Channelization design does not lend itself to standardization. Traffic volumes, pedestrian patterns and physical conditions vary, requiring individual treatment of each intersection. The "Green Book" presents guides for various elements of the design, but the combination of elements within a specific design requires engineering judgment.

Good design should adhere to the following principles:

- The proper traffic channels should seem natural and convenient to drivers and pedestrians.
- There should be no choice of vehicle paths leading to the same destination.
- The number of islands should be held to a practical minimum to avoid confusion and to minimize complications with snow removal.
- Islands should be large enough to be effective. Islands that are too small are ineffective as a method of guidance and often present problems in maintenance. The smallest curbed island that normally should be considered is one with an area of 5 m<sup>2</sup> for urban and 7 m<sup>2</sup> for rural intersections, however, 9 m<sup>2</sup> is preferable for both. Accordingly, triangular islands should not be less than 3.5 m, and preferably 4.5 m, on a side after the rounding of corners. Divisional islands should not be less than 1.2 m wide (1.8 m is desirable) and 6 to 8 m long.
- Channelization should be visible. It should not be introduced where sight distance is limited. When an island must be located near a high point in the roadway profile or near the beginning of a horizontal curve, the approach end of the island should be extended so that it will be clearly visible to approaching drivers. Lighting should be considered where islands are introduced. Delineator posts can assist plowing operations.

- The major traffic flows should be favored. In channelizing the roadways, those which have the heaviest traffic volumes or the fastest speeds should be redirected the least.
- Conflicts should be separated so that drivers and pedestrians deal with only one conflict and make only one decision at a time.
- Islands, approach end-treatment, and delineation should be carefully designed to be consistent with the speed characteristics of the roadway design.

Channelization may be used for one or more of the following purposes:

- To prevent vehicle conflicts caused by the overlapping of maneuver areas. This separation makes it possible to present the drivers with only one important decision at a time.
- To control the angle of conflict and reduce relative speeds in merging, diverging, weaving and crossing maneuvers. The potential severity of conflict may be decreased substantially by reducing the angle between the vehicle paths.
- To reduce excessive pavement areas caused by skewed and flared intersection arrangements. Large areas of open pavement may confuse drivers and cause erratic and improper maneuvers.
- To control speed of vehicles approaching stop conditions or reduce speed differentials prior to merging, weaving or crossing maneuvers.
- To protect pedestrians by providing a safe refuge between traffic streams.
- To protect and store turning and crossing vehicles by enabling them to slow or stop out of the path of other traffic flows. This is sometimes referred to as "shadowing".
- To block prohibited movements by making it difficult to perform illegal, improper or unsafe maneuvers.

Islands can be grouped into three (3) functional classes. Most islands serve at least two of these functions:

1. Directional islands control and direct traffic movement and guide the motorist into the proper channel.
2. Divisional islands separate opposing traffic flows, alert the driver to the crossroad ahead, and regulate traffic through the intersection. These islands are often introduced on undivided highways at intersections and are particularly advantageous in controlling left turns at skewed intersections and in preventing wrong-way turns into right-turning traffic lanes.
3. Refuge islands at or near crosswalks aid or protect pedestrians crossing the roadway. Such an island may be required for pedestrians at intersections where complex signal phasings are used. Refuge islands may also serve as areas for installation of traffic control devices. Rarely would an island be designed for the "refuge" function alone.

### **Delineation of Islands**

Delineation is critical in good channelization design. Island delineation can be divided into two types:

1. Raised islands outlined by curbs are the most positive type. Mountable curbs should be used in all but special cases.

Use 150 mm granite slope curb in urban areas for traffic islands and edges of paved shoulders where sidewalk is not to be constructed. Use 100 mm granite slope curb for ramps or other high-speed conditions.

2. Islands delineated by pavement markings on paved areas are used in urban areas where space is limited, or in rural areas to overcome maintenance and driver expectancy problems.

### **Island Offset**

Raised islands in particular should be offset from the edges of the traveled way. Failure to offset can make an island appear more restrictive than it actually is and can have a psychological effect on drivers, causing them to make erratic movements as they approach the intersection.

Refer to the "Sample Layouts" in Volume 2 for examples of island treatment.

### **Median Openings**

Median crossovers are provided for emergency vehicles only on interstate and other limited-access highways. The location and spacing is determined by maintenance or law-enforcement requirements. Good sight distance is essential. Coordination is always required with the Bureau of Highway Maintenance before designing median crossovers. Approval of FHWA is required on Federally-funded highways. FHWA requires minimum sight distance of 450 m and crossover side slopes of 12:1 (H:V) or flatter. If 450 m is not available, an exception from FHWA is necessary.

Median opening spacing on controlled-access highways and along commercial frontage is dictated by safety considerations. The spacing of public intersections will control the location and frequency of left-turn access to commercial establishments. Chapter 7 of *Design of Urban Streets* (17) deals with the recommended spacing of median openings.

If median openings are not practicable, jug handles or turn-arounds may be used to accommodate commercial access.

Median opening geometry is treated extensively in the "Green Book".

## **Traffic Control Signals**

Traffic signals provide orderly flow of traffic movements through intersections. They significantly affect traffic and pedestrian movement and therefore careful study is needed before each signal installation is considered. They do not always result in improved intersection capacity unless additional lanes and storage are provided. However, traffic signals do provide for more orderly and safe operation of the intersection.

### **Procedure**

The need for a signal is established by meeting warrants listed in the *Manual on Uniform Traffic Control Devices* (MUTCD)(13). The information necessary to answer the warrant questions is provided by the Systems Analysis Section of the Bureau of Transportation Planning upon request.

Development of a signal layout plan involves the following:

- The initial lane-use and capacity analysis is prepared by either the Preliminary Design Section or Consultant Design Section. Operational aspects are reviewed with the Bureau of Traffic.
- After the Public Hearing process and Design Approval, the Bureau of Traffic or a consultant prepares a detailed signal design.
- Signal hardware, supports and power supply details are selected by the Bureau of Traffic, coordinated through the Design Services Utilities Section, and furnished to the Final Design Section or the consultant.
- The Final Design Section or the consultant uses the assembled information to draft the signal plan which is given a final review by the Bureau of Traffic and Utilities Section before including it in the contract plans.

Pavement markings in the area of the intersection, discussed next in this chapter, are normally shown on the signal plan (for reference only).

## **Signing and Pavement Marking**

Signing and pavement marking are directly related to the design of the highway or street and are features of traffic control and operation that the designer must consider in the geometric layout of such a facility. The signing and marking should be designed concurrently with the geometrics. The possibility of future operational problems can be reduced significantly if signing and marking are treated as an integral part of design. The extent to which signs and markings are used depends upon the traffic volume, the type of facility, and the degree of traffic control required for safe and efficient operation. On major highways, signs and markings are employed extensively. On lesser facilities, the use of traffic control devices may be limited.

Although safety and efficiency of operation depend to a considerable degree on the geometric design of the facility, effective signing is essential. Signing plans coordinated with horizontal and vertical alignment, sight-distance obstructions, operating speeds and maneuvers should be worked out early enough to provide others with sufficient time to complete associated

work, e.g., Materials and Research to investigate soil conditions for certain overhead sign structure foundations and for Bridge Design to review the foundation design itself. The type, size and location of sign supports must also be coordinated with the other project features.

Highway signs are of three (3) general types:

1. regulatory signs, used to indicate the required method of traffic movement;
2. warning signs (a.k.a. advisory signs), used to indicate conditions that may be hazardous to highway users; and
3. guide signs, used to direct traffic along a route or toward a destination.

For details regarding design, location, and application of signs, reference should be made to the MUTCD. Uniformity in the use of signs and other traffic control devices is the main objective of the MUTCD.

## ***Interchange Design***

An interchange is a grade-separated intersection with interconnecting roadways (ramps) for turning traffic between highway approaches.

Use of interchanges normally is limited to freeways or expressways with high traffic volumes where at-grade intersections would disrupt the flow of traffic and create hazardous conditions.

Because interchanges are expensive, careful analysis and planning must be performed to define their locations and justify their construction. Normally, these decisions are made during the planning process and no attempt will be made in this manual to discuss general warrants and criteria. Rather, emphasis will be placed on alerting designers to problems and the need to consult the references. The "Green Book" should be consulted throughout the design process. "Sample Layouts" in Volume 2 contains examples of interchange lane geometry, for use as guide references only.

### **Types of Interchanges**

Interchanges are classified in a general way according to the number of approach roadways or intersection legs, as three-leg, four-leg, and multi-leg interchanges. These are further separated into more specific types, such as the trumpet interchanges for the three-leg; diamond, single point diamond (a.k.a. urban interchange), cloverleaf and directional interchanges for the four-leg; and directional interchanges for the multi-leg.

### **Trends in Design**

Interchanges have changed in form, shape and adaptability over the years. The trend today is toward simplicity, uniformity, and single exits with no left exit ramps.

Designers who are looking for a compact, high-volume intersection should consider the single point diamond interchange (urban interchange) layout. This configuration combines the two ramp intersections of a conventional diamond interchange into one signalized

intersection. Design guidance is more fully explained in several Transportation Research Board and other publications found in the Preliminary Design library.

Operational uniformity is a consistent arrangement by which drivers exit in a uniform manner along a freeway, an essential feature of design. Regardless of the interchange at which the driver departs the freeway, the driver should always be confronted with the same type of exiting procedure. Considering the need for high capacity, appropriate level of service, and maximum safety in conjunction with freeway operations, it is necessary and justifiable to provide this uniformity.

### **Spacing**

Spacing of interchanges has a pronounced effect on the operation of freeways. Proper spacing usually is difficult to attain in areas of concentrated urban development because of traffic demand for frequent access.

Generally, a minimum spacing of 1.5 km is considered appropriate in urban areas. For conditions of heavy weaving or in conjunction with major interchanges, longer distances may be required. In rural areas, 3.0 km is a desirable minimum interchange spacing.

### **Collector-Distributor Roads**

A collector-distributor (C-D) road is an auxiliary roadway, separated laterally from and positioned generally parallel to the freeway traveled way. It collects and distributes traffic from several access connections between a selected point of ingress to and a selected point of egress from the freeway traveled way. It provides greater capacity and permits higher speeds to be maintained on the through traveled way. C-D roads may be appropriate within an interchange, through two adjacent interchanges, or continuously for some distance along freeways through several interchanges.

### **Speed-Change Lanes**

A speed-change lane is an auxiliary lane, including tapered areas, provided primarily for the acceleration or deceleration of vehicles entering or leaving the through traffic lanes. Speed-change lanes are required on expressways, and usually are warranted on high-speed and high-volume highways at important intersections. At some minor intersections, widened shoulders are sometimes used as informal speed-change lanes. The length of a speed-change lane depends on the relative design speed of highway and ramp, and on gradient.

Additional information about speed change lanes is provided earlier in this chapter, under "At-Grade Intersections".

### **Lane Balance**

The number of lanes on a freeway beyond the point of merge should be equal to or greater than the number of lanes on the freeway in advance of the point of merge, plus the number of lanes on the entrance ramp, minus one. The number of lanes on a freeway in advance of the point of divergence should be equal to or greater than the number of lanes on the freeway beyond the point of divergence, plus the number of lanes on the exit ramp, minus one.

Design traffic volumes and a capacity analysis will determine the basic number of lanes to be used on the highway and the minimum number of lanes on the ramps.

Proper lane balance at a ramp exit will always provide an "optional lane" on which a driver has the choice of proceeding either on the freeway or on the ramp.

Interchanges should be designed so that the through lanes extend past the interchange ramp before a lane is dropped. Entrance and exit maneuvers should not be complicated by the maneuvering of through drivers negotiating the lane drops. Whenever a lane drop is proposed, adequate taper, proper signs, and pavement markings are essential to safe traffic operation.

### **Weaving Sections**

Weaving sections permit the crossing of traffic streams moving in the same general direction by merging and diverging maneuvers. Weaving sections occur frequently along expressways and freeways in urban areas. They are inherent to some interchanges, such as the cloverleaf and those with semi-direct connections, and are also found between the ramps of successive interchanges.

Weaving sections should be designed so that the service volume or capacity is greater than the design hourly volume. The operational features and capacity of a weaving section are dependent upon its length, number of lanes, speed of operation, and relative volumes of individual movements.

Lengths of weaving sections should be designed using the *Highway Capacity Manual* or the "Green Book" for required minimum distance between successive ramps.

### **Ramp Spacing**

On urban freeways, there are frequently two or more ramp terminals in close succession along the through lanes. To provide sufficient maneuvering length and adequate space for signing, a reasonable distance is required between terminals.

Spacing between successive ramp terminals is dependent on the classification of the interchanges involved, the function of the ramp pairs (entrance or exit), and weaving potential, when applicable. The "Green Book" provides recommended minimum ramp terminal spacing distances based on these variables.

The term "systems interchange" is used to identify an interchange that transfers traffic freeway to freeway. A "service interchange" is the designation for an interchange between a freeway and a local arterial.

Where an entrance ramp is followed by an exit ramp (EN-EX), the absolute minimum distance between the successive noses is governed by weaving requirements. A notable exception to this length guideline for EN-EX ramp combinations is the distance between loop ramps of cloverleaf interchanges. For these interchanges, the distance between EN-EX ramp noses is primarily dependent on loop ramp radii and roadway and median widths. A recovery lane beyond the nose of the loop ramp exit is desirable.

When the distance between the successive noses is less than 450 m, the speed-change lanes should be connected to provide an auxiliary lane. This auxiliary lane is provided for improved traffic operation over relatively short sections of the freeway route and is not considered as an addition to the basic number of lanes. See the "Green Book" for detailed information on this subject.

### **Ramp Design Speed**

Except for directional-type interchanges of major highways, it is rarely feasible to provide ramps on which turning traffic can travel in the same range of speeds as on the through roads. But it is desirable that drivers be able to use ramps at as high a speed as practicable so that they will require little conscious effort to decrease from or increase to the speed of through traffic. The design speed of the ramps, therefore, should be related to the design speeds of the intersecting roadways and the type of ramp terminal (queues at signals, grades, yield conditions, etc.). See the "Sample Layouts" in Volume 2 and the "Green Book" for further guidance.

### **Ramp Alignment**

Ramp alignments should be designed using the same general controls and guidelines given in Chapter 4 "Alignment and Typical Sections". Loop ramps may require the use of compound curves. If a compound curve is used it is desirable to introduce the sharper curve first, in the direction of travel. A maximum compound ratio of 2:1 is acceptable. A maximum superelevation rate of 6% is typically used for ramp design.

### **Ramp Grades**

Ramp grades should be as flat as practical to minimize the driving effort required in maneuvering from one road to the other and maximize available sight distance throughout.

The profile of a typical ramp usually consists of a central portion with an appreciable grade, coupled with terminal vertical curves and connections to the profiles of the intersection legs. The steeper central portion of the ramp usually is relatively short and has only moderate operational effect. Even so, ramp grades should generally be limited to a range of values as shown below:

	<u>Ramp design speed, km/h</u>			
	30-40	40-50	60	70-80
Ramp gradient, percent	6-8	5-7	4-6	3-5

The values above apply to both up-grade ramps and down-grade ramps. Exceptions in special cases may be granted by the Highway Design Administrator.

Profile grades should be established for the ramp edge of pavement or edge of travelway and coordinated with the extension of the cross slope of the main roadway. Desirable terminal profiles are more readily produced graphically from the edge of pavement as a base line.

## **Ramp Section**

The pavement width for ramps should be generally consistent with the criteria previously discussed in this chapter and the example drawings in the "Model Plans" section of Volume 2.

## **Ramp Terminals**

The intersection of ramp terminals with minor crossroads at diamond interchanges requires special design considerations. Although it would appear that this situation would be treated as any other normal intersection, there are two unique features not usually found in other intersections in rural areas.

First, the ramps at diamond interchanges are always one-way, and second, there is invariably a structure in the vicinity which may restrict sight distance. This restriction may control the location of the ramp terminal where signals are not used.

The horizontal sight triangle should be checked with regard to piers, abutments, railings or other obstructions, and the vertical sight distance should be checked in terms of snow cover (600 mm), length of vertical curve and algebraic difference of grades. The check is usually done graphically. Typical conditions at a diamond-interchange ramp terminal are shown in Figure 5-1 where " $d_a$ " is the measured available sight distance.

If the available sight distance is less than the requirement, one or more of the following adjustments should be made:

- revise the profile,
- relocate the ramp terminal farther from the structure,
- install traffic signals at the ramp terminal intersection, and/or
- consider a loop ramp.

One additional factor should be considered. An inherent problem of diamond interchanges is the possibility that, in spite of signing, a driver may enter one of the exit terminals from the crossroad and proceed along the freeway in the wrong direction. Attention to several details of design at the intersection can discourage this hazardous maneuver.

In Figure 5-2 a small corner radius is provided at the junction of the left edge of the ramp pavement and the right edge of the through pavement. This tends to discourage improper right turns into the one-way ramp.

Islands can be used to channelize traffic into proper paths. Where economical, a raised median island provides an effective deterrent to left-turn movements into the exit ramp.

Figure 5-1

MEASUREMENT OF SIGHT DISTANCE AT DIAMOND RAMP TERMINALS

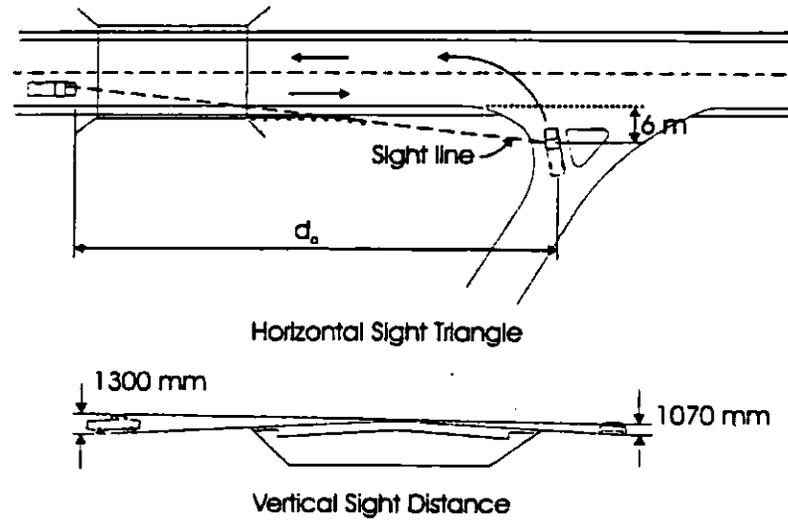
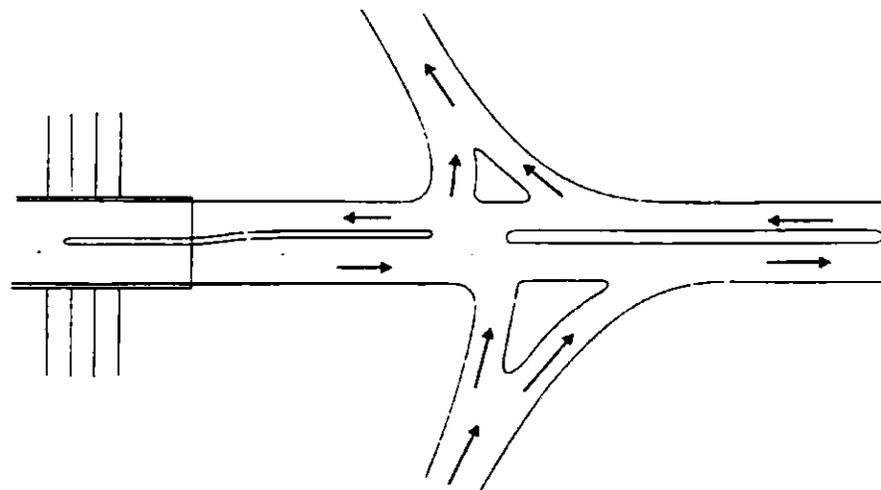


Figure 5-2

DETERRENTS TO WRONG-WAY TURNS AT DIAMOND INTERCHANGE RAMP TERMINALS



## ***Driveway Access and Service Facilities***

Unless the right of an abutting property owner has been legally denied, the property owner has a right to "reasonable" access to an abutting highway. The interpretation of these rights has created much courtroom litigation. The problem of interpretation has caused regulations to be written, both by highway officials and by public zoning bodies.

The regulation which guides the State of New Hampshire is titled *Administrative Rules for the Permitting of Driveways and Other Accesses to The State Highway System* (Adopted January 1, 1993) (9).

The regulation's purpose is best explained by the following excerpts from that publication:

"The purpose of this part is to provide maximum safety and protection to the traveling public through the orderly control of traffic movement on or to any class I, III or the state maintained portion of class II highways; to maintain the serviceability of affected highways, which could require alterations to the existing highway; to provide a uniform practice throughout the state for the application for and issuance of driveway permits; and to monitor the design and construction of driveway entrances and exits."

RSA 236:13 Driveways and Other Accesses to the Public Way.

I. It shall be unlawful to construct, or alter in any way that substantially affects the size or grade of, any driveway, entrance, exit, or approach within the limits of the right-of-way of any class I or class III highway or the state maintained portion of a class II highway that does not conform to the terms and specifications of a written permit issued by the commissioner of transportation. (Amended 1985, 402:6, I(b)(7).)

A sample driveway permit application and a sample driveway permit are found in Appendix 5-3 and 5-4.

### **Driveway Access**

The Bureau of Highway Design is responsible for reviewing the more complex driveway permit applications for compliance with the administrative rules. The designer who is assigned the review should use as a first reference, the *Administrative Rules for the Permitting of Driveways and Other Accesses to the State Highway System*, then the "Green Book", the *Highway Capacity Manual*, and other pertinent traffic and transportation publications.

Appendix 5-5 shows a flow diagram of the typical steps involved in reviewing an application for a major commercial driveway access permit.

The designer should consult with the Bureaus of Traffic and Transportation Planning and should be particularly aware of the potential for traffic build-up beyond the capacity of the servicing highway as described in the *Highway Capacity Manual*. Estimating the amount of site-generated traffic is done using methods from the Institute of Transportation Engineers (ITE) *Trip Generation Manual* (20).

Generally, the permit applicant pays all costs related to the access drive design and construction, including the cost of any improvements to the State highway system as necessary to mitigate the development's impact.

Construction should be in accordance with the *Standard Specifications for Road and Bridge Construction* (7). Good geometric design judgment should be used.

### **Public Relations**

The designer may come in contact with very persuasive members of the private and public sectors who often attempt to influence access plan review for various reasons. The designer should adhere to the following rules when dealing with the public:

- Carefully and objectively review all development plans without prejudice or favoritism;
- Require reasonable compliance. If in doubt, consult your supervisor;
- Be factual. Do not provide information you are not sure of. If information is requested regarding future highway work, defer the request to your Section chief or the administrator;
- Do not engage in lengthy design discussions with the driveway applicant at your work area. Arrange for a conference room;
- Recognize the appropriate level of authority you can deal with and ask your supervisor for help if you are in doubt; and
- Be courteous and cautious at all times.

### **Drainage**

Design of the drainage system related to the access concept must be carefully reviewed. Inadequate drainage facilities will cause flooding of the pavement, overloading of the existing system and possibly severe outfall erosion. The developer is responsible for obtaining releases from downstream abutting property owners. On major commercial paved areas with high rates of runoff, on-site detention and/or retention basins or areas should be investigated. The Bureau of Highway Design Hydraulics Section should be consulted in all instances where a major change in land use is involved. Refer to the Drainage Manual and Chapter 6 of this manual for more detailed information.

### **Service Facilities**

Safety rest areas and scenic overlooks, carpool lots, and safety inspection areas are constructed as necessary appurtenances to highway operation. All public access areas must follow guidelines from the current Americans with Disabilities Act (ADA).

### **Rest Areas**

The provision of safety rest areas on the rural arterial system is a desirable feature particularly on the interstate system. Rest areas provide the high-speed, long-distance traveler with the necessary opportunity for short periods of relaxation, which relieves driver fatigue. Public

recognition of the fatigue problem and the use of the rest area indicate that they provide a desirable safety feature.

Sites of special interest or visual quality provide additional reasons for the motorist to stop and usually extend their length of stay. The spacing of rest areas is dependent upon many considerations. Construction and operating costs are significant, but driver safety must always be considered. Rest areas on the interstate system should be spaced at 30 to 60 minutes of travel time. Design of each rest area should be treated individually using standard engineering practice. Design guidance can be found in the Preliminary Design library.

### **Parking Facilities (Park-and-Rides)**

The demand for parking facilities near interchanges and intersections for car-pooling purposes is increasing. In response to this demand, the NHDOT provides park-and-ride lots on State-owned land, on land that can be obtained easily or, if necessary, through the Public Hearing process.

The lots are designed on the basis of existing need plus anticipated expansion and available land. Parking design is adapted to the size and shape of the lot. Intermodal use can be a factor in determining the location of a proposed facility. Access to a railroad line (with potential for passenger service) or inclusion of a bus station in the facility will promote intermodal transportation.

Drainage design should follow the topography of the layout with surface runoff properly treated and channeled into a ditch or a receiving watercourse. Paving should be sufficient for light passenger-type vehicles. Lighting and telephone service should be provided. Accommodations for bicycles should be considered.

AASHTO's *Guide for the Design of Park-and-Ride Facilities* (45) provides general design guidance. Appendix 5-6 shows a basic parking layout for passenger vehicles. Appendix 5-7 shows parking layouts for trucks and passenger vehicles. Entrance and exit from the main highway should conform with ramp criteria.

### **Bicycle Facilities**

An increase in bicycle usage in recent years has created a demand for suitable facilities. In response, the NHDOT established planning and design criteria for bicycle facilities. Routes were selected for the statewide bike route system, which will be made up of shared roadway bike lanes (roadway shoulders used by bicyclists), as well as separate bike path facilities. In areas with shared roadway bike lanes, design criteria suggest a minimum 1.2 m paved shoulder be provided. Separate bike paths are recommended to be at least 2.4 m wide. The publications, *Guide for Development of Bicycle Facilities* (16), and *New Hampshire Statewide Bicycle and Pedestrian Plan* (11) provide in depth information on bicycle facilities.

### **Safety Inspection Areas**

Safety inspection areas are developed cooperatively with the Department of Safety, FHWA, the Bureau of Highway Maintenance, and the Bureau of Highway Design.

The acceleration and deceleration lanes or tapers should be designed for trucks and the grades are correspondingly designed. The layout should be designed with an area for the truck inspections and an area for parking of trucks found to have deficiencies.

### **Local Streets**

When local streets are bisected by new highway construction, a parallel frontage road can provide continued access to the local streets without having numerous, closely-spaced local road intersections. Under certain circumstances they must be dead-ended and provided with a turnaround at the end. Several turnaround layouts (cul-de-sacs) are shown in the "Sample Layouts" in Volume 2 and in the "Green Book".

Local zoning codes which deal with subdivision layouts regulate the length of street to be terminated by a cul-de-sac. The principal reason is that fire apparatus have difficulty in negotiating small cul-de-sacs and must back out of the street. The designer should consider local zoning codes, snow storage, and lighting when developing preliminary plans.

### **Special Purpose Roads**

Special purpose roads include recreational roads, resource development roads, and local service roads. Roads in the special purpose category are generally lightly traveled and of low speed and for these reasons deserve special consideration relative to their appropriate design features.

Roads serving recreational sites and areas have special criteria which are intended to protect the existing aesthetic, ecological, environmental, and cultural amenities that distinguish each recreational site or area.

Visitors to a recreational site need access to the general area, usually by a statewide or principal arterial highway. Secondly they need access to the site. For continuity beyond this point, design criteria require that the visitor be made aware of the nature of the area and these roads should consequently become an integral part of the recreational area. The design of these roads is usually approached by a multidisciplinary team of persons with varied backgrounds and experience.

## ***Preliminary Study Procedure***

The development of intersections, interchanges, and special geometric layouts should follow these general steps. Chapter 2 shows the flow diagram for the entire project development process.

- Assemble and evaluate all information including old plans of the area, photographs, aerial photos, photogrammetry, maps, survey notes, traffic projections, prior recommendations, and instructions.
- Establish the criteria to be used for alignment and typical sections.
- Prepare sketch layouts of possible alternatives to accommodate the expected traffic. Prepare capacity analyses.

- Choose the most appropriate alternative(s) and develop graphic layouts to scale.
- Follow the review and coordination process as shown in the Chapter 2 flow diagram to obtain approval to proceed.
- Refine the recommended alternative. prepare a cost estimate and proceed to a Public Hearing, if necessary.

After a successful Public Hearing, the geometric layouts are finalized as plan sheets, and detail and construction items are added.

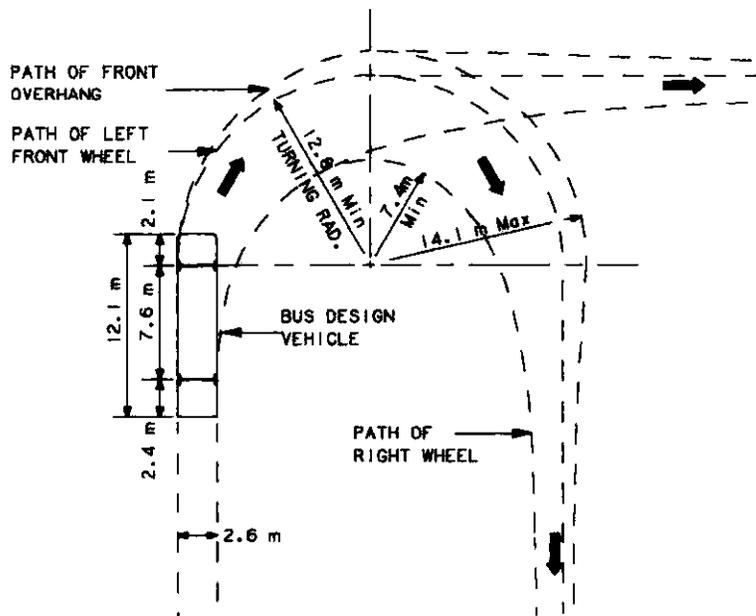
Every geometric layout is different in some ways from other projects but the work can be simplified by organizing the similarities.

- Coordination with others should begin when sketch layouts are prepared. Refer to the *Public Involvement Procedures for New Hampshire Transportation Improvement Projects* (15) requirements.
- Utilities information should be obtained early and coordination through the Design Services Section with utilities groups should be initiated early. The utilities plan their expansion programs years in advance. Timely notification of the utilities will prevent wasted work.
- Environmental information should be obtained early and coordination should be initiated early.
- Preliminary capacity analysis may be a close approximation at first, but all critical data and computations must be refined at an early date.
- As soon as a survey detail plan is available, abstracting limits can be set and requested. From the Bureau of Right-of Way. See Chapter 10 "Right-of Way" for details of the right-of-way process.
- All projects have check points. Do not prepare unnecessary detail for preliminary review, and do not refine the conceptual level alternatives until preliminary approvals have been received.

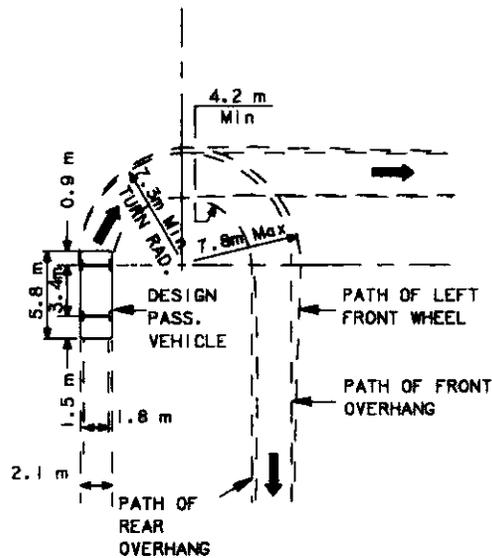
## APPENDIX LIST

- 5-1 Turning Templates
- 5-2 Queue Length Calculations
- 5-3 Application for Driveway Permit
- 5-4 Driveway Permit
- 5-5 Major Commercial Access Permit Flow Diagram
- 5-6 Parking Stall Layout Elements
- 5-7 Truck Parking Layout

APPENDIX 5-1  
TURNING TEMPLATES

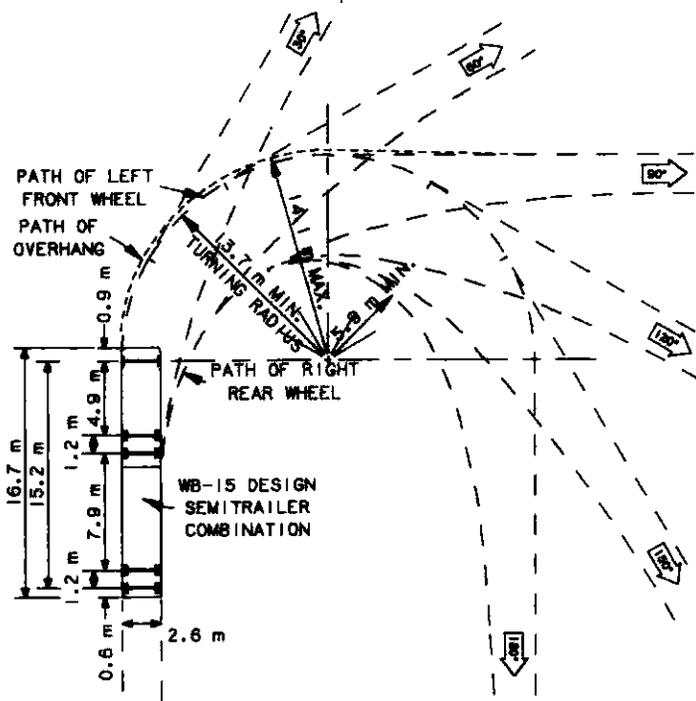


MINIMUM TURNING PATH FOR  
 BUS DESIGN VEHICLE  
 SCALE 1:500

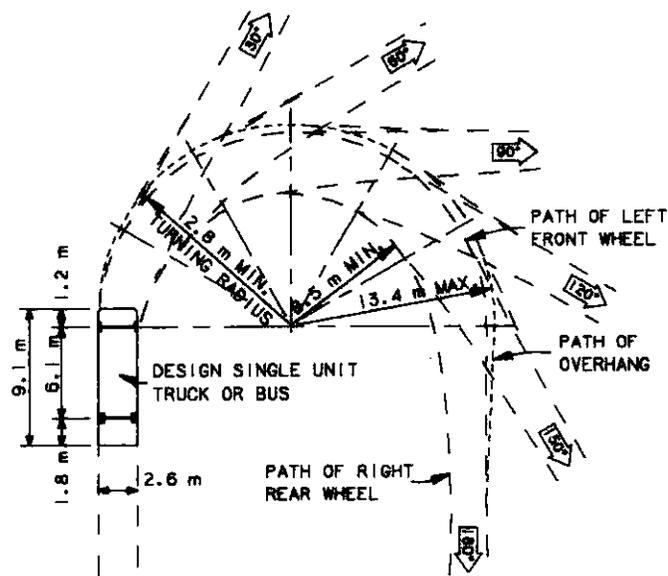


MINIMUM TURNING PATH FOR  
 P DESIGN VEHICLE  
 SCALE 1:500

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TURN500M	NHMASTER:DOTLIB

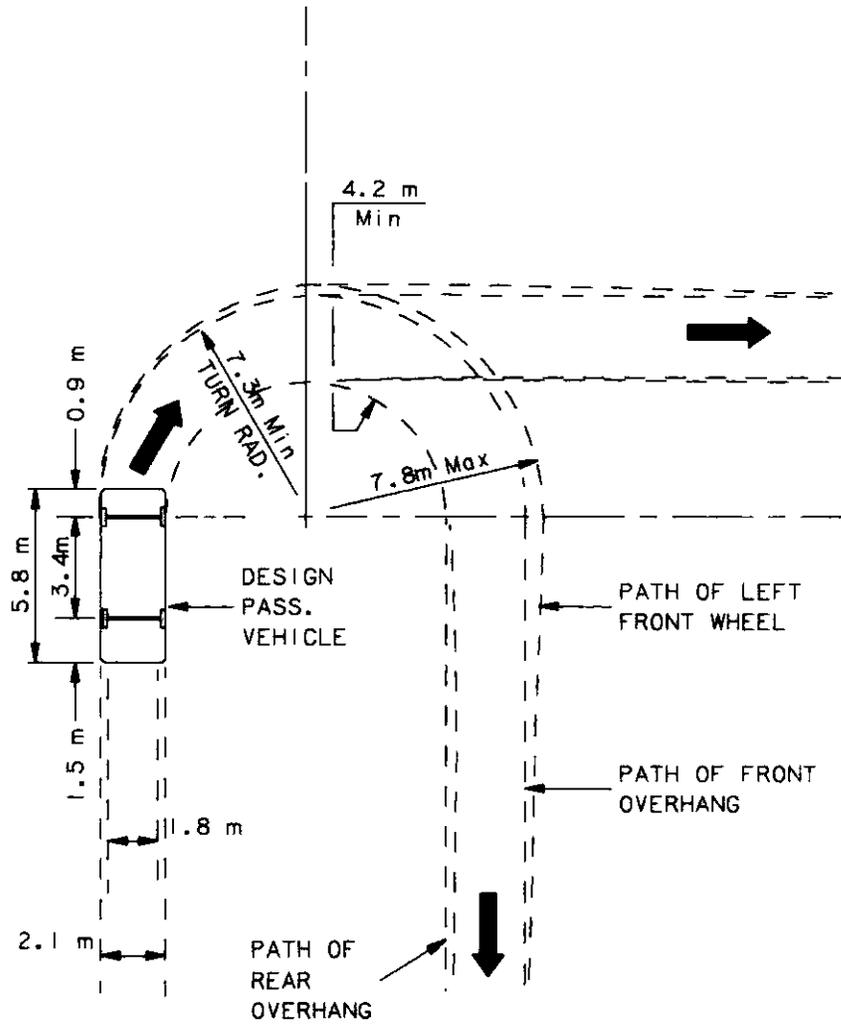


MINIMUM TURNING PATH FOR  
WB-15 DESIGN VEHICLE  
SCALE 1:500



MINIMUM TURNING PATH FOR  
SU DESIGN VEHICLE  
SCALE 1:500

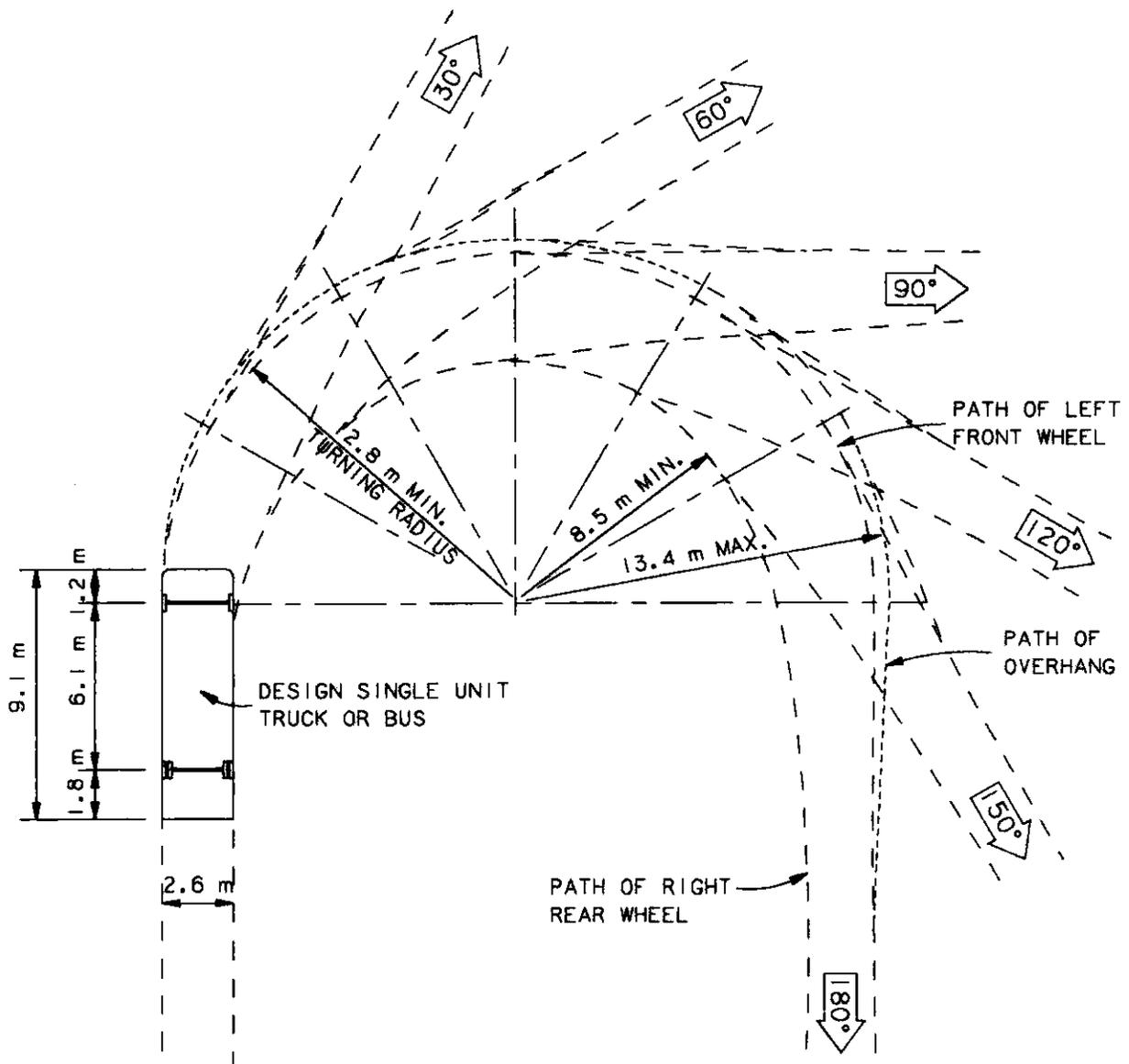
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TURN-500	NHMASTER-DOTLIB



## MINIMUM TURNING PATH FOR P DESIGN VEHICLE

SCALE 1:250

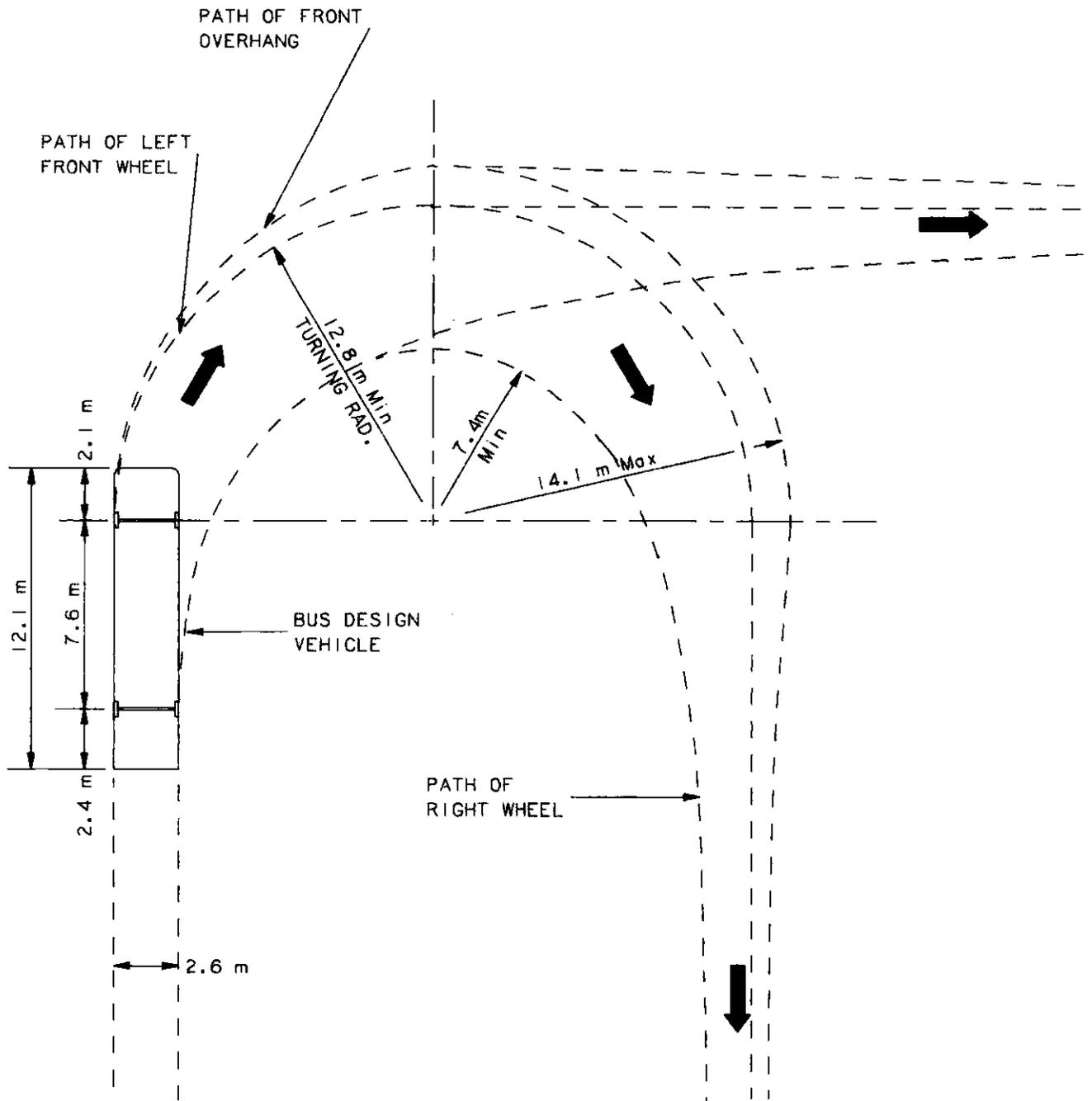
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TURN-P-M	NHMASTER.DOTLIB



# MINIMUM TURNING PATH FOR SU DESIGN VEHICLE

SCALE 1:250

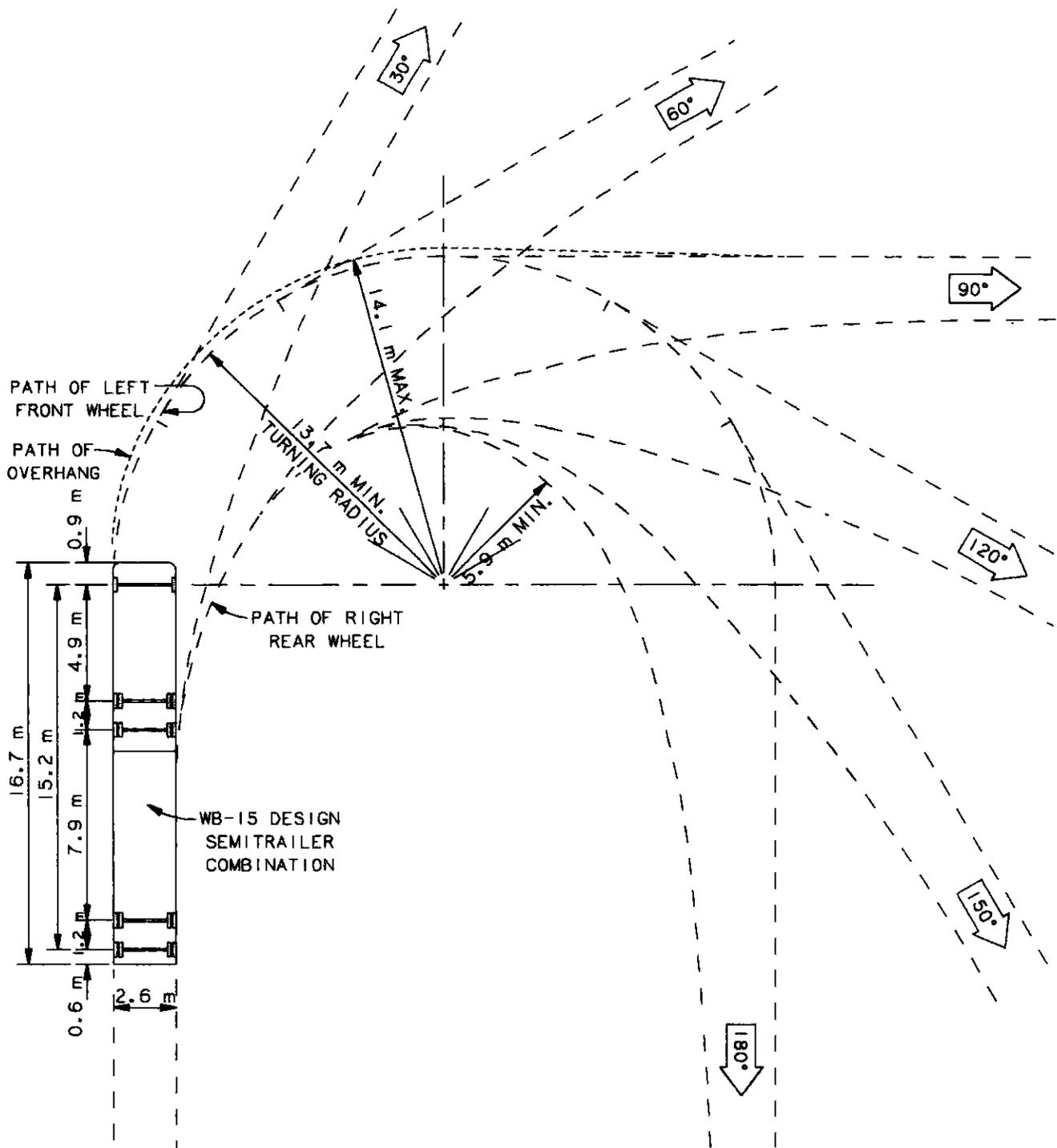
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# MINIMUM TURNING PATH FOR BUS DESIGN VEHICLE

SCALE 1:250

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# MINIMUM TURNING PATH FOR WB-15 DESIGN VEHICLE

SCALE 1:250

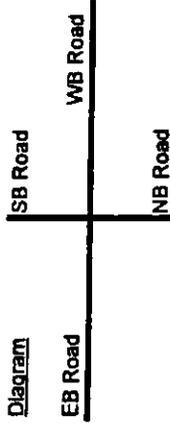
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TURNWB15	NHMASTER.DOTLIB

APPENDIX 5-2

G:\PRELIM\QUEJECAL.XLS

QUEUE LENGTH CALCULATIONS

Project Name:  
Project Number:



Intersection:  
Condition:  
LOS/Delay/Sat.:

Approach	Number of Lanes	Volume (vph)	PHF	Cycle Length (sec)	Green Time (sec)	Average Delay <sup>2</sup> (sec)	I.T.E. Queue (veh) <sup>1</sup>		Queue Length (m)		NHDOT Queue (veh) <sup>3</sup>		NHDOT Queue (m)	
							Average	99% <sup>4</sup>	Average	99% <sup>4</sup>	Average	99% <sup>4</sup>	Average	99% <sup>4</sup>
Eastbound														
Left														
Through														
Right														
Westbound														
Left														
Through														
Right														
Northbound														
Left														
Through														
Right														
Southbound														
Left														
Through														
Right														

1) Queues computed by method presented in I.T.E. Transportation and Traffic Engineering Handbook, Second Edition (1982), p. 502 (equations 16.19 and 16.20). Average queue is computed as the larger result of the equations:

$$n = \frac{qR}{R} \quad \text{and} \quad n = \frac{q(R/2 + d)}{R}$$

where  
 n = average queue length, number of vehicles  
 q = approach flow, veh/s  
 R = red time, s  
 d = average individual delay (from equation 16.18 or HCS program)

3) Average queue is computed as:

$$n = \frac{Q}{c}$$

where  
 n = average queue length, number of vehicles  
 Q = approach flow, veh/hr  
 c = cycles per hour (3600/Cycle length)

4) The 99<sup>th</sup> percentile queue is computed by a bi-linear approximation of the Poisson distribution, where:

$$n^{99} = 1.5n + 2.5 \quad \text{for } n < 12:$$

$$n^{99} = 1.23n + 5.6 \quad \text{for } n \geq 12:$$

2) Use average vehicle delay as calculated by HCS program.

APPENDIX 5-3



THE STATE OF NEW HAMPSHIRE  
DEPARTMENT OF TRANSPORTATION

Application For Driveway Permit

District Engineer  
N.H. Dept. of Transportation  
District 5, P.O. Box 16476  
Hooksett, N.H. 03106

Pursuant to the provisions of Revised Statutes Annotated, Chapter 236, Section 13 (printed on reverse side of application) and amendments thereto, and Administrative Rule Tra 302, permission is requested to construct (alter) \_\_\_\_\_ driveway entrance(s) to my property on the \_\_\_\_\_ side of Route \_\_\_\_\_ or \_\_\_\_\_ Road in the Town of \_\_\_\_\_ at a location which will meet the requirements for safety specified in said statutes.

The driveway(s) requested is for access to \_\_\_\_\_  
Residence, Business, Subdivision, Other

Describe nature and size of industry, business or subdivision \_\_\_\_\_

This parcel is shown on Tax Map \_\_\_\_\_ Lot Number \_\_\_\_\_

As the landowner (applicant), I agree to the following:

1. To construct driveway entrance(s) only for the bonafide purpose of securing access to private property such that the highway right-of-way is used for no purpose other than travel.
2. To construct driveway entrance(s) at permitted location(s).
3. To construct driveway entrance(s) in accordance with statutes, rules, standard drawings and permit specifications issued by New Hampshire Department of Transportation.
4. To defend, indemnify and hold harmless the New Hampshire Department of Transportation and its duly appointed agents and employees against any action for personal injury and/or property damage sustained by reason of the exercise of this permit.
5. To furnish and install drainage structures that are necessary to maintain existing highway drainage and adequately handle increased runoff resulting from development and obtain all easements thereto.

_____ Signature of Landowner (Applicant)	_____ Mailing Address
_____ Printed Name of Landowner	_____ Town/City, State and Zip Code
_____ Date	_____ Telephone Number(s)

Contact Person/Agent, if not Landowner: \_\_\_\_\_

NOTE (1): Attach sketch or plan showing existing and proposed drive(s) and the adjacent highway indicating distance to town road, townline or other readily identifiable feature or landmark and also to the nearest utility pole (indicate pole numbers).

NOTE (2): For new driveway(s) include, if applicable, subdivision history since July 1, 1971 of the tract from which the applicant's land was subdivided.

## APPENDIX 5-3

### DRIVEWAY STATUTE

#### RSA 236:13 Driveways and Other Accesses to the Public Way.

I. It shall be unlawful to construct, or alter in any way that substantially affects the size or grade of, any driveway, entrance, exit, or approach within the limits of the right-of-way of any class I or class III highway or the state maintained portion of a class II highway that does not conform to the terms and specifications of a written permit issued by the commissioner of transportation. (Amended 1985, 402:6, I(b)(7).)

II. Pursuant to this section, a written construction permit application must be obtained from and filed with the department of transportation by any abutter affected by the provisions of paragraph I. Before any construction or alteration work is commenced, said permit application shall have been reviewed, and a construction permit issued by said department. Said permit shall:

- (a) Describe the location of the driveway, entrance, exit, or approach. The location shall be selected to most adequately protect the safety of the traveling public.
- (b) Describe any drainage structures, traffic control devices, and channelization islands to be installed by the abutter.
- (c) Establish grades that adequately protect and promote highway drainage and permit a safe and controlled approach to the highway in all seasons of the year.
- (d) Include any other terms and specifications necessary for the safety of the traveling public. (Amended 1985, 402:6, I(a)(7).)

III. For access to a proposed commercial or industrial enterprise, or to a subdivision, all of which for the purposes of this section shall be considered a single parcel of land, even though acquired by more than one conveyance or held nominally by more than one owner:

- (a) Said permit application shall be accompanied by engineering drawings showing information as set forth in paragraph II.
- (b) Unless all season safe sight distance of 400 feet in both directions along the highway can be obtained, the commissioner shall not permit more than one access to a single parcel of land, and this access shall be at that location which the commissioner determines to be safest. The commissioner shall not give final approval for use of any additional access until it has been proven to him that the 400 foot all season safe sight distance has been provided.
- (c) For the purposes of this section, all season safe sight distance is defined as a line which encounters no visual obstruction between 2 points, each at a height of 3 feet 9 inches above the pavement, and so located as to represent the critical line of sight between the operator of a vehicle using the access and the operator of a vehicle approaching from either direction.

IV. No construction permit shall allow:

- (a) A driveway, entrance, exit, or approach to be constructed more than 30 feet in width, except that a driveway, entrance, exit, or approach may be flared beyond a width of 30 feet at its junction with the highway to accommodate the turning radius of vehicles expected to use the particular driveway, entrance, exit or approach.
- (b) More than 2 driveways, entrances, exits or approaches from any one highway to any one parcel of land unless the frontage along the highway exceeds 300 feet.

V. The same powers concerning highways under their jurisdiction as are conferred upon the commissioner of transportation by paragraphs I, II, III and IV, shall be conferred upon the planning board in cities and towns wherein the planning board has been granted the power to regulate the subdivision of land as provided in RSA 676:35 and, they shall adopt such regulations as are necessary to carry out the provisions of this section. (Amended 1985, 103:4, effective Jan. 1, 1986; 402:6, I(b)(7).)

RSA 236:14 Penalty. Any person who violates any provision of this subdivision or the rules and regulations made under authority thereof shall be guilty of a violation if a natural person, or guilty of a misdemeanor if any other person; and, in addition, shall be liable for the cost of restoration of the highway to a condition satisfactory to the person empowered to give such written permission.

APPENDIX 5-4

THE STATE OF NEW HAMPSHIRE  
DEPARTMENT OF TRANSPORTATION

DRIVEWAY PERMIT

Permit Number: \_\_\_\_\_  
District: \_\_\_\_\_  
Town: \_\_\_\_\_  
Road/Route: \_\_\_\_\_  
Date: \_\_\_\_\_

TO:

Permission is hereby granted to construct (alter) a driveway, entrance, exit or approach adjoining \_\_\_\_\_, pursuant to the location and specifications as described below. Failure to adhere to the standards and engineering drawings previously approved shall render this instrument null and void. Failure to start or complete construction of said facility within one calendar year of the date of this permit shall require application for permit extension or renewal in accordance with the driveway access Rules. Facilities constructed in violation of the permit specifications or the Rules shall be corrected immediately upon notification by a Department representative. Any cost by the State to correct deficiencies shall be fully borne by the landowner. The landowner shall defend, indemnify and hold harmless the Department and its duly appointed agents and employees against any action for personnel injury and/or property damage sustained by reason of the exercise of this permit.

LOCATION:

SPECIFICATIONS:

1. This permit requires that the area adjacent to the highway be graded such that the surface will slope from the edge of pavement to a line \_\_\_\_\_ feet distant from and parallel to the pavement and \_\_\_\_\_ inches below the edge of pavement (for the entire frontage of property) which line will serve as a drainage gutter.
2. \_\_\_\_\_ driveway entrance(s) is (are) permissible, each not to exceed \_\_\_\_\_ feet in width. The driveway entrance(s) may be flared as they approach the pavement.

3. Other access to the highway from the premises is to be prevented by construction of a barrier or barriers, such as a grass plot, low hedge, curbed island, etc. The front face of this barrier island shall be            feet from the edge of pavement and the rear edge at the right-of-way line. No part of the right-of-way may be used for any purpose other than travel.
4. No structures, including buildings, permanent or portable signs, lights, displays, fences, walls, etc. shall be permitted on, over or under the highway right-of-way.
5. The highway right-of-way line is located            feet from and parallel to the centerline of highway pavement.
6. No parking, catering or servicing shall be conducted within the highway right-of-way.
7. The applicant shall comply with all applicable ordinances and regulations of the municipality and other State agencies.
8. Drive(s) shall approach the highway at or about 90 degrees.
9. No additional surface drainage will enter upon the highway.
10. This permit to act relates solely to the use of the State right-of-way, and is not determinative of any rights of flowage between private land owners.
11. This permit is for a            . Any change in use or further development shall require a new permit.
12. A copy of this permit shall be present at the site during construction of the drive(s).
13. This permit is for the purpose of overlaying an existing driveway or road.
14. This permit supersedes permit no.            .
15. Driveway and related roadway modifications are to be constructed as shown on plans prepared by            for            , on file in the District Five Office.
16. All work to be done by the applicant at no cost to the State of New Hampshire.
17. This permit does not include or approve the location of/or installation of underground utilities.
18. This applicant shall be responsible for the electric cost for street lights and traffic signals.
19. During construction within the State right-of-way of            , traffic shall be maintained in accordance with M.U.T.C.D. standards and as directed by the District Engineer.

20. The signals shall be installed to New Hampshire Department of Transportation specifications and by a New Hampshire Department of Transportation approved contractor.
21. A yellow centerline shall be maintained at all times as approved by the District Engineer. When temporary tape is used, it will be removable.
22. The applicant shall reimburse the State of New Hampshire for the services of a State Inspector(s) when assigned to this project to ensure compliance with the terms of this permit.
23. The applicant shall furnish an approved continuing Surety Bond in the amount of \$ \_\_\_\_\_, payable to the State of New Hampshire, guaranteeing the fulfillment of the provisions, instructions and regulations prescribed in this permit and later instructions issued by the District Engineer during the performance of the work and satisfactory maintenance of the work area for a period of two (2) years following State acceptance of the project.
24. No work in the State right-of-way shall be performed between November 15 and April 15, or during periods of inclement weather or as directed by the District Engineer.
25. All work to be completed in accordance with this permit and accepted by the State prior to use of the drive by the public.
26. Notify the District Five Office at (603) 485-9526, forty-eight (48) hours prior to construction in the State right-of-way.
27. All materials and structures shall conform to the State of New Hampshire standard specifications for road and bridge construction.
28. Should a review indicate that warrants for a more sophisticated approach configuration are realized, the applicant, their successors, assigns or heirs shall, at no expense to the State of New Hampshire, alter the approach and the affected portion of \_\_\_\_\_. Such alteration shall be as approved by the New Hampshire Department of Transportation and may include, but not be limited to, traffic islands, driveway and highway widening, acceleration and deceleration lanes, storage lanes, and signalization.
- 29.
- 30.

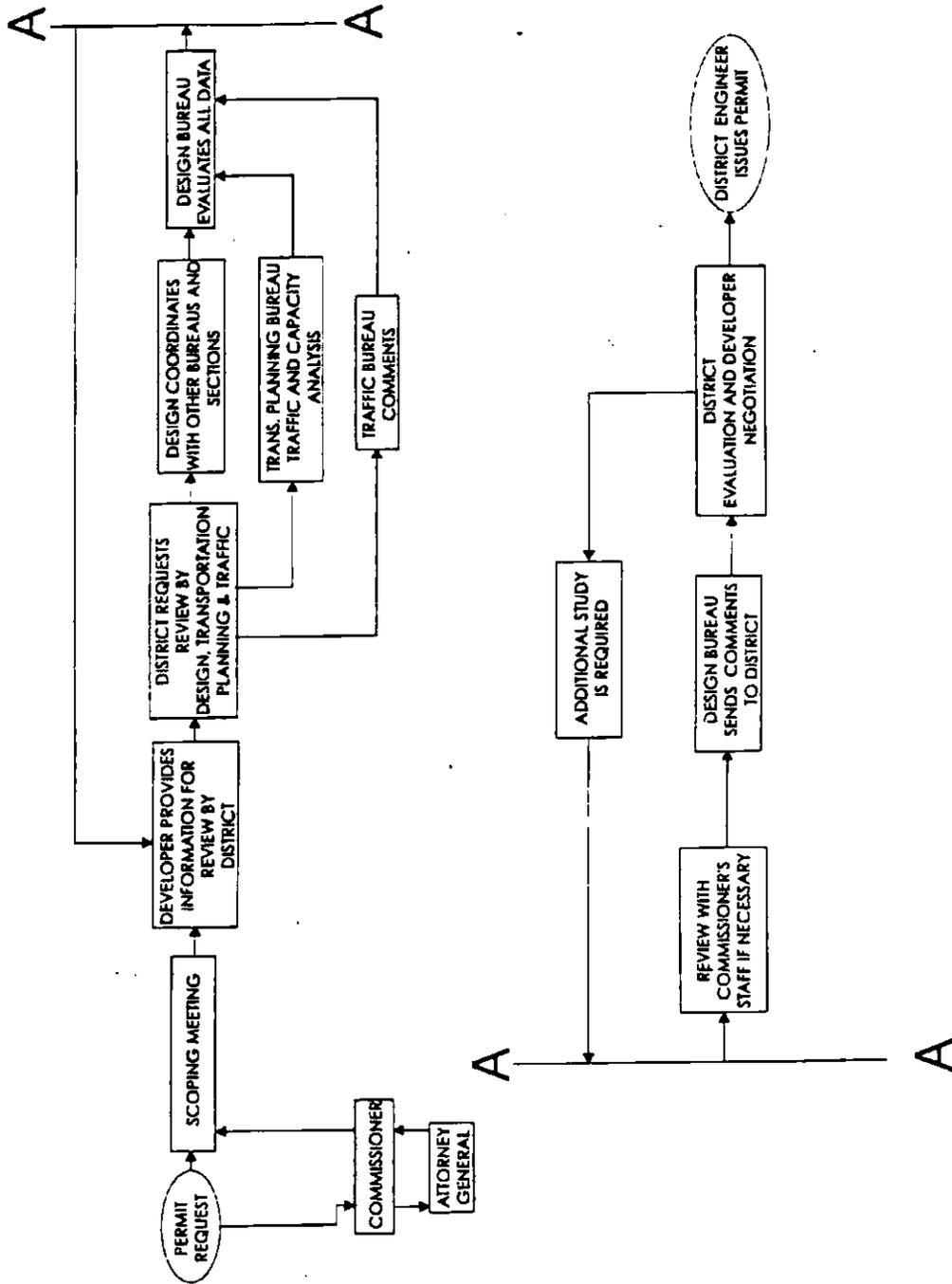
Additional Information Attached

Copies:       Contractor,  Town,       Patrolman,  District

Approved \_\_\_\_\_  
Assistant District Engineer  
For Director of Administration

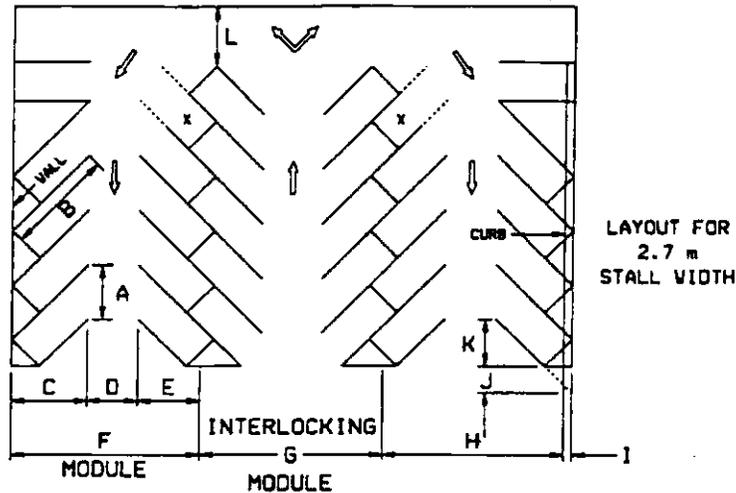
APPENDIX 5-5

MAJOR COMMERCIAL ACCESS PERMIT FLOW DIAGRAM



Time Frames for these activities vary with the complexity and impacts of the Development.

APPENDIX 5-6



STALL LAYOUT ELEMENTS  
X = STALL NOT USEABLE IN CERTAIN LAYOUTS

DIMENSION	ON DIAGRAM	45°	60°	75°	90°
STALL WIDTH PARALLEL TO AISLE	A	3.85	3.15	2.85	2.70
STALL LENGTH OF LINE	B	7.50	6.60	6.00	5.70
STALL DEPTH TO WALL	C	5.35	5.75	5.95	5.70
AISLE WIDTH BETWEEN STALL LINES	D	3.60	4.80	6.90	7.80
STALL DEPTH, INTERLOCK	E	4.65	5.35	5.75	5.70
MODULE, WALL TO INTERLOCK	F	13.60	15.85	18.60	19.20
MODULE, INTERLOCKING	G	12.90	15.50	18.40	19.20
MODULE, INTERLOCK TO CURB FACE	H	13.00	15.15	17.85	18.45
BUMPER OVERHANG (TYPICAL)	I	0.60	0.70	0.75	0.75
OFFSET	J	1.90	0.80	0.15	0
SETBACK	K	3.30	2.50	1.50	0
CROSS AISLE, ONE WAY	L	4.2	4.2	4.2	4.2
CROSS AISLE, TWO-WAY	-	7.2	7.2	7.2	7.2

Parking layout dimensions (in meters) for 2.7 m stalls at various angles

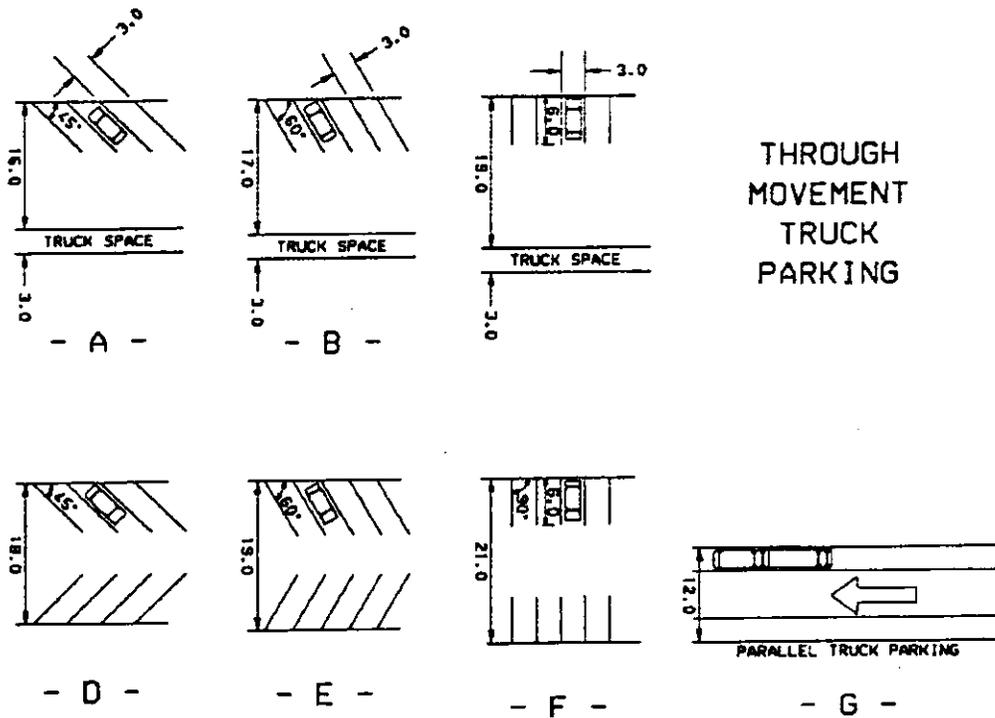
PARKING ANGLE (DEGREES)	STALL WIDTH PARALLEL TO AISLE	STALL DEPTH TO WALL	STALL DEPTH TO INTERLOCK	D AISLE WIDTH	MODULES		
					2C+D WALL TO WALL	G INTERLOCK TO INTERLOCK	
45	2.5 m STALL	3.60	5.35	4.65	3.90	14.60	13.20
	2.7 m STALL	3.85	5.35	4.65	3.60	14.30	12.90
	2.9 m STALL	4.10	5.35	4.65	3.30	14.00	12.60
60	2.5 m STALL	3.00	5.75	5.35	5.40	16.90	16.10
	2.7 m STALL	3.15	5.75	5.35	4.80	16.30	15.50
	2.9 m STALL	3.30	5.75	5.35	4.50	16.00	15.20
75	2.5 m STALL	2.70	5.95	5.75	7.50	19.40	19.00
	2.7 m STALL	2.85	5.95	5.75	6.90	18.80	18.40
	2.9 m STALL	3.00	5.95	5.75	6.60	18.50	18.10
90	2.5 m STALL	2.60	5.70	5.70	8.40	19.80	19.80
	2.7 m STALL	2.70	5.70	5.70	7.80	19.20	19.20
	2.9 m STALL	2.90	5.70	5.70	7.50	18.90	18.90

Dimensions (in meters) for variable stall widths 2.5m to 2.9m

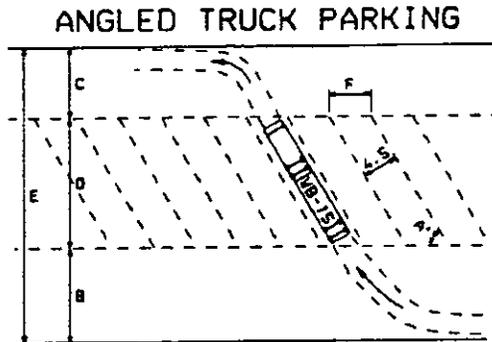
NOTES:

1. THESE DIMENSIONS ARE FOR 5.7 M STALL, MEASURED PARALLEL TO VEHICLE, AND ARE BASED ON RESULTS OF A SPECIAL STUDY TO EVALUATE THE EFFECTS OF VARIED AISLE AND STALL WIDTH FOR THE DIFFERENT PARKING ANGLES SHOWN. THE STUDY WAS CONDUCTED IN DECEMBER OF 1970 BY THE FEDERAL HIGHWAY ADMINISTRATION AND PAUL C. BOX ASSOCIATES
2. THE METRIC VALUES GIVEN ABOVE ARE APPROXIMATE CONVERSIONS FROM THE ORIGINAL ENGLISH UNITS STUDY.
3. 3.0 M BY 6.0 M STALLS ARE DESIRABLE IN HIGH TURNOVER AREAS.

APPENDIX 5-7



LEGEND	
A	ANGLE OF PARKING
B	ENTRANCE ROADWAY WIDTH
C	EXIT ROADWAY WIDTH
D	PARKING WIDTH
E	TOTAL WIDTH
F	WIDTH AT DESIGNATED ANGLE A



DETAIL FOR PARKING SPACE (Based on WB-15 design vehicle)					
ANGLE OF PARKING (DEGREES)	ENTRANCE ROADWAY WIDTH (METERS)	EXIT ROADWAY WIDTH (METERS)	PARKING WIDTH (METERS)	TOTAL WIDTH PARKING AREA (METERS)	
A	B	C	D	E	F
30	6.0	6.0	10.5	22.5	9.0
45	9.0	7.5	15.0	31.5	6.5
60	12.0	9.0	16.5	37.5	5.3