Impacts of the 1984 AASHTO Design Policy on Urban Freeway Design

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The new AASHTO design policy contains many significant revisions and additions that directly address urban freeway design. These additions reflect continuing research on highway safety and operations as well as experience and observation of existing freeways. The latest policy not only updates certain basic design standards but also explicitly recognizes important principles of urban freeway operations and their translation into design guidelines. The focus in this paper is on three important areas in which the new policy will affect urban freeway design: *(a)* general highway design controls and criteria, *(b)* interchange design criteria and standards, and *(c)* freeway systems design principles.

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GENERAL DESIGN CONTROLS

Advances in research and evolution of the driver-vehicle system have led to important revisions of many basic design controls. In particular, changes in design for horizontal and vertical alignment, stopping sight distance, and decision sight distance are noteworthy.

Horizontal Alignment

The design curve for the side friction factor has been revised for high-speed facilities. The revision reflects a reassessment of research on vehicle operations on curves. As Figure 1 shows, design values for f are slightly lower for design speeds in excess of 50 mph. The effect is to slightly reduce the maximum allowable curvature for a given design speed and maximum superelevation rate. This represents a marginally more restrictive set of values for design.

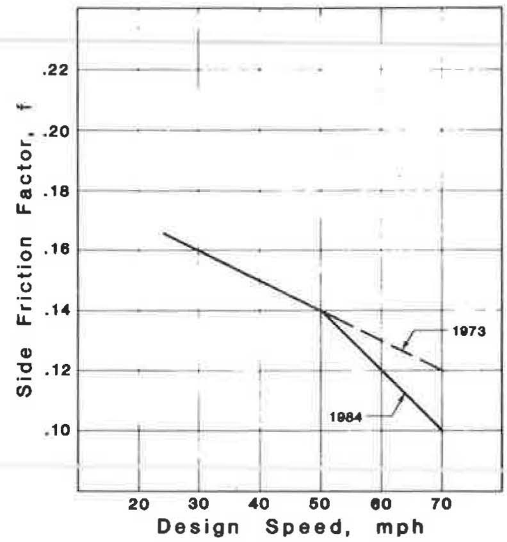

FIGURE 1 Changes in AASHTO design policy for side fraction factors for horizontal curves.

Vertical Alignment

The new policy also revises the basis for critical length of grade, resulting in a slightly more restrictive set of controls. The difference from the 1973 policy is shown in Figure 2. The old design basis was a speed reduction of 15 mph associated with a 400-lb/HP vehicle. The new policy recognizes the more

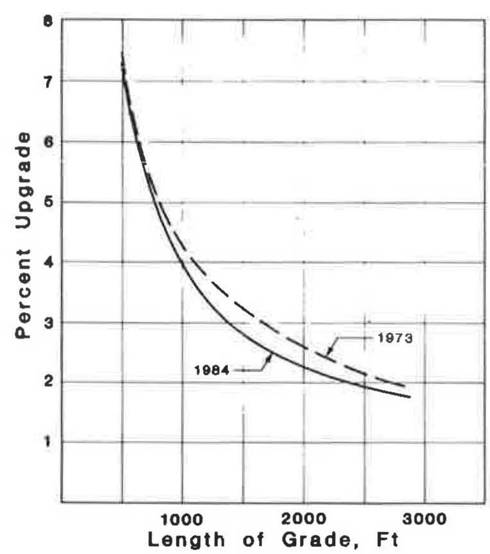

FIGURE 2 Changes in AASHTO design policy for critical length of grade.

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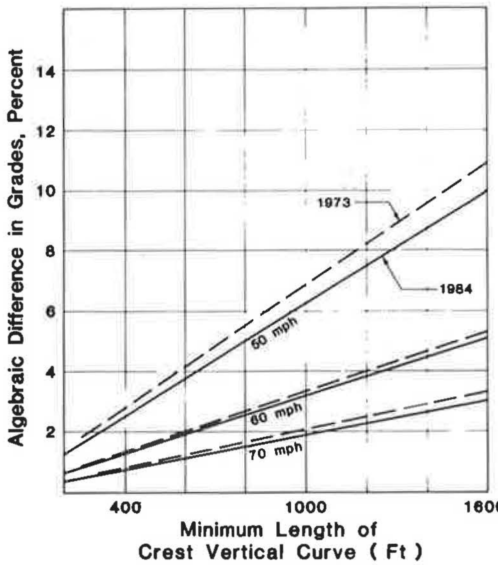


FIGURE 3 Changes in AASHTO policy for crest vertical curve design for desirable stopping sight distance.

powerful vehicle fleet (300 lb/HP) but recommends a more safety-conservative speed reduction of 10 mph. Although the differences are minor, application of the new policy would produce a slightly more restrictive design for grades.

Stopping Sight Distance

Much recent research *(1, 2)* has focused on the need to revise the design for stopping sight distance. Although the new policy retains the basic models for stopping sight distance, many of the design values have been adjusted. These include revisions in the relationship between eye height and object height, slight adjustments to design friction factors for braking, and stopping sight distance requirements and an emphasis on desirable lengths rather than minimum ones. The last assumes operation on wet pavement at design speed rather than at a lower speed assumed under wet conditions.

As noted in the new policy, the previous assumption about driver behavior under wet conditions may not be appropriate (*3*, p.140):

> In prior editions of this book it was assumed that top speeds were somewhat lower on wet pavements than on the same pavements in dry weather. In recognition of this assumption, the average running speed for low-volume conditions rather than design speed was used in formulating the limiting values for minimum stopping distance. This speed is the initial value given in the second column of Table III-1. However, more recent observations show that many operators drive just as fast on wet pavements as they do on dry. To account for this factor, design speed in place of average running speed is used to formulate stopping distance values, as shown by the higher values in the second column of Table III-1.

As with the other design controls, these revisions should produce more safety-conservative designs. The longer crest vertical curve requirements associated with new policy stopping sight distance controls are shown in Figure 3. It may also be noted that horizontal clearance requirements typical of urban freeways (e.g., median barriers, retaining walls, and piers) would also increase.

Decision Sight Distance

The importance of decision sight distance in certain circumstances is emphasized in the new policy. Decision sight distance is recommended at critical locations such as exits, lane drops, and interchanges. The longer distances associated with this design control are shown in Table 1 *(4)*.

INTERCHANGE DESIGN CRITERIA

An integral part of urban freeway design is provision for and design of interchanges. The new design policy highlights important criteria for location and design of interchanges. These criteria reflect operational and safety research and years of observation of existing urban freeways.

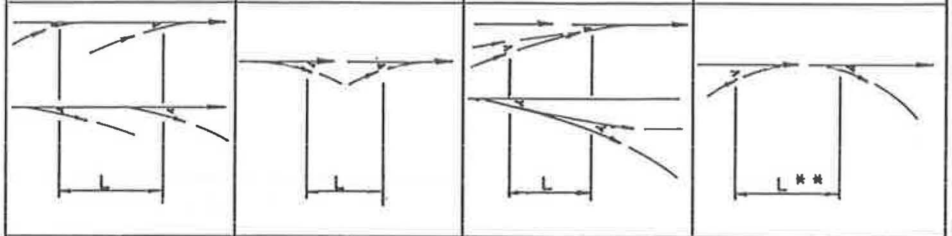
Left-Hand Ramps

The 1973 policy noted the desirability of right-hand exits and entrances. However, their use was not specifically precluded. Safety research *(5, 6)* has unequivocally demonstrated the serious safety problems with left-hand ramps. Consequently, the new policy states that "their use on high-speed, free flow ramp terminals is not recommended" (*3*, p.1031).

TABLE 1 DECISION SIGHT DISTANCE DESIGN CRITERIA *(4)*

	Time(s)			Decision Sight Distance (ft)		
	Premaneuver					
Design Speed (mph)	Detection & Recognition	Decision & Response Initiation	Maneuver (Lane Change)	Summation	Computed	Rounded for Design
30	1.5-3.0	4.2-6.5	4.5	10.2-14.0	449- 616	450- 625
40	1.5-3.0	4.2-6.5	4.5	10.2-14.0	598- 821	600- 825
50	1.5-3.0	4.2-6.5	4.5	10.2-14.0	748-1,027	750-1,025
60	2.0-3.0	4.7-7.0	4.5	11.2-14.5	986-1,276	1,000-1,275
70	2.0-3.0	4.7-7.0	4.0	10.7-14.0	1,098-1,437	1,100-1,450

*RECOMMENDED MINIMUM RAMP TERMINAL SPACING **



MINIMUM VALUES	EN-EN OR EX-EX		EX—EN		TURNING ROADWAYS		EN-EX (WEAVING)			
							SYSTEM TO SERVICE INTERCHANGE		SERVICE TO SERVICE INTERCHANGE	
	FULL FREEWAY	C-D ROAD OR FWY. DIST.	FULL FREEWAY	C-D ROAD OR FWY. DIST.	SYSTEM INTERCHANGE	SERVICE INTERCHANGE	FULL FWY	C-D ROAD OR FWY DIST.	FULL FWY	C-D ROAD OR FWY DIST.
DESIRABLE	1500	1200	750	600	1200	1000	3000	2000	2000	1500
ADEQUATE	1200	1000	600	500	1000	800	2500	1800	1800	1200
→ ABSOLUTE	1000	800	500	400	800	600	2000	1600	1600	1000 ← Requirements Noted in AASHTO Policy, 1984

* BASED UPON OPERATIONAL EXPERIENCE AND NEED FOR FLEXIBILITY

** ALSO TO BE CHECKED IN ACCORDANCE WITH PROCEDURE OUTLINED IN THE HIGHWAY CAPACITY MANUAL, 1965 (LARGER OF THE VALUES TO BE USED)

FIGURE 4 Interchange ramp spacing controls.

Ramp Spacing Controls

High-volume freeway mainline and ramp traffic demands create special problems in interchange design. The new policy presents design guidelines for ramp spacing based on those shown in Figure 4. These guidelines reflect the importance of ramp location in distribution of volumes and optimization of traffic flow. Investigation of many existing urban freeways has shown that capacity and operational problems are often due to violation of these ramp-spacing criteria.

Interchange Selection

Years of experience have contributed to revised guidelines on freeway interchange selection. An effective set of guidelines for considering alternative interchanges is shown in Figure 5. For service interchanges, simple diamonds or partial cloverleafs are usually optimal. Such interchange types have been shown to optimize both freeway ramp movements and arterial-intersection operations. System interchange types vary, but right-hand exits are always incorporated with one or more

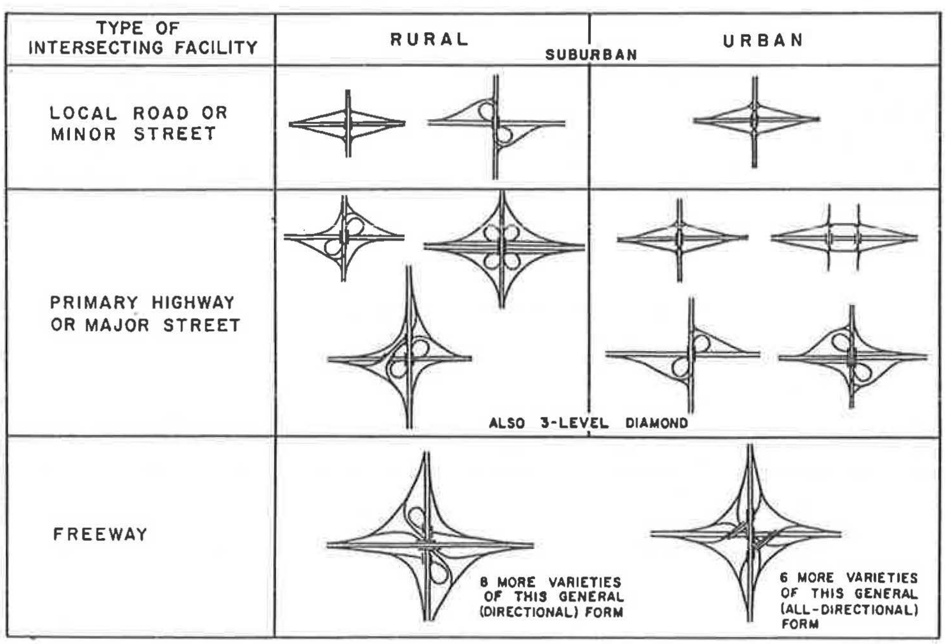


FIGURE 5 Guidelines for selection of interchange types on freeway facilities.

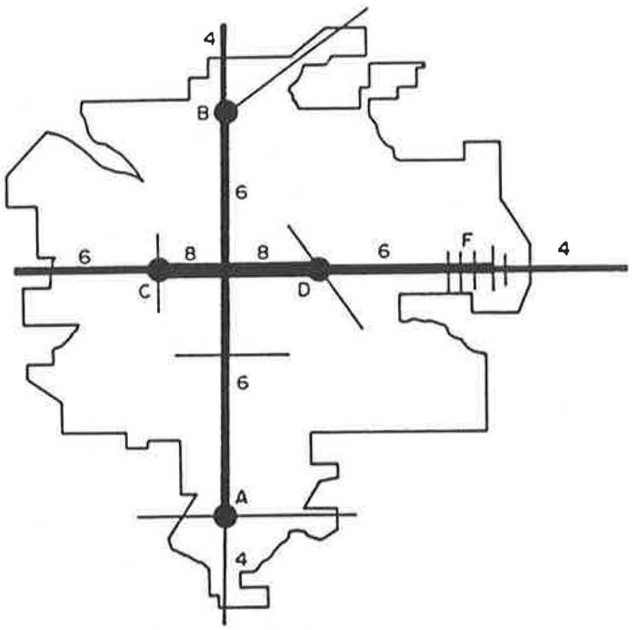


FIGURE 6 Schematic of basic number of freeway lanes.

direct connections. Minimizing or eliminating weaving sections within system interchanges is also a primary consideration.

In particular, it is pointed out in the new policy that cloverleaf interchanges in urban areas are inherently inadequate. Problems associated with weaving between the loop ramps necessitate the use of collector-distributor roads and greater distances between the loops. Such requirements result in extensive right-of-way needs, which are usually impractical or not cost-effective. As a result, the full cloverleaf is identified as being inappropriate for most urban freeway applications.

SYSTEMS DESIGN POLICIES

Perhaps the most important areas of the new policy deal with treatment of urban freeways as systems. The material presented here is not new to many freeway design and operational practitioners. Its inclusion in the new policy, however, is a significant recognition of the importance of these principles.

Basic Number of Continuous Lanes

Figure 6 shows the principle of basic number of lanes. Good operation of an urban freeway system requires that each facility be assembled logically with respect to basic number of lanes. This generally means an increase in the basic lanes as the facility approaches the highest-density, central areas of a city. Basic lanes should be continuous, enabling through drivers to remain on the freeway for long distances without having to change lanes. A constant number of basic freeway lanes should be provided for a meaningful distance regardless of minor variations in forecast traffic flow. Serious, costly operational bottlenecks have occurred on many existing freeways because planners sized the freeway strictly according to expected design-year traffic and ignored the principle of basic lanes.

Lane Balance and Continuity

Many operational problems on existing urban freeways are directly attributable to a lack of lane balance at exits and failure to maintain lane continuity. Leisch *(7)* has demonstrated the operational benefits of these principles (Figure 7). In brief, these include meeting driver expectations, accommodation of periodic short-term volume fluctuations, and minimizing lane changing.

Interchange and Ramp Uniformity

Maintaining interchange uniformity is consistent with designing for driver expectations. Single exits on the right at all interchanges satisfy such expectations. Consistent use of similar or identical interchange forms or ramp arrangements also addresses this principle.

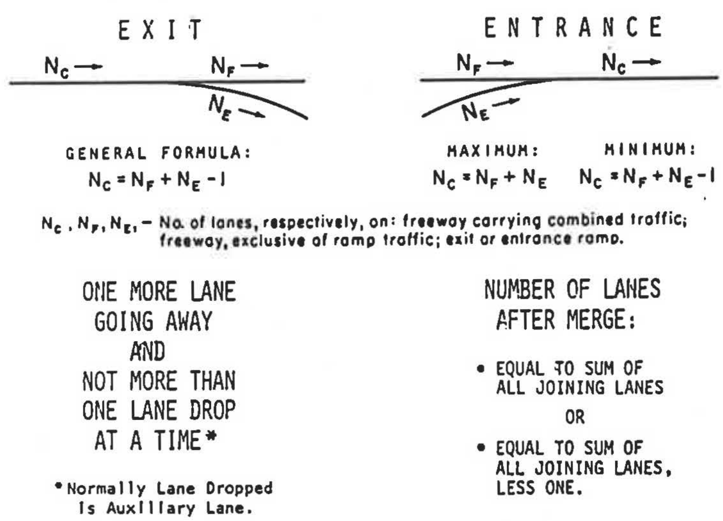


FIGURE 7 Principle of lane balance.

Importance of System Design Principles

Many existing urban freeways operate at or near level-of-service E for long periods of the day. Reconstruction solutions to improve this level of service and also accommodate expected traffic growth are extremely costly. In many cases, the practical limits of reconstruction will produce level-of-service D or E in the design year. For such cases, application of the systems design principles becomes essential. Every effort should be made to ensure smooth, orderly exiting and entering, and to limit lane changing to only that required for navigation. Designing for driver expectations and achieving consistency in the freeway's operations will produce marginally higher capacity. When the freeway is operating near possible capacity and breakdowns reflect upstream for several miles, such marginal improvements produce significant total benefits to the driving public.

IMPLICATIONS OF PRINCIPLES AND CRITERIA IN NEW POLICY

Reconstruction of congested and outmoded urban freeways has emerged as the greatest challenge currently facing the highway design profession. Older urban freeways, designed and built with imperfect knowledge of high-volume operations, do not function adequately. Moreover, their problems often stem from interchange and ramp design, and not merely from an inadequate number of lanes. Planners and designers must recognize that appropriate reconstruction solutions require more than new pavement, added lanes, and selected safety improvements. Almost without exception, existing urban freeways fall short in a comparison with the design principles and criteria discussed in the new policy.

A systematic approach to freeway reconstruction is clearly indicated. The following brief outline illustrates how the new AASHTO policy should be applied in evaluation and reconstruction of an existing urban freeway.

Consider Existing Geometry

Existing horizontal and vertical alignment may no longer meet an acceptable design standard. This does not necessarily mandate expensive geometric changes. However, it is clearly appropriate to assess the nature and extent of each geometric deficiency. Evaluation of accident patterns, field inspection, and engineering analyses should be performed to determine any need to upgrade outmoded alignment. This is not only good engineering, but it is also a necessary step toward protecting the responsible agency from future tort liability claims.

Perform Complete Capacity Analyses

Urban freeway operations are not limited to uninterrupted flow conditions. Ramp locations and sequencing may, in fact, be the controlling factor in a bottleneck situation. Critical analysis of ramp location controls, along with ramp and weaving level-of-service analyses, may reveal solutions to exisiting operational problems.

Develop System Solutions

For most freeway corridors, all elements interact to influence operations. Under heavy traffic, even minor localized flaws may cause corridorwide breakdowns. Under such conditions, the principles of lane balance and lane continuity become essential. Appropriate interchanges and ramp spacing are as important as good cross section or alignment design in maximizing capacity as well as safety.

WHAT HAS NOT CHANGED

The presentation thus far has focused on changes in the policy and their significant implications for urban freeway design. Although much has changed, it is important to note certain areas that, for very good reasons, remain unchanged. These include the concept of design speed and its application to freeways and cross-sectional design criteria for freeways.

Design Speed

The design profession and driving public are by now adapted to the politically established national speed limit of 55 mph. Despite the apparent permanence of the 55-mph limit, the appropriateness of design speeds of 60 and 70 mph for freeways remains in the policy (*3*, p.63):

> Although a lower design speed may satisfy the majority of this current slower traffic [i.e., that induced by the 55 mph limit], a design speed of 70 mph should be maintained on freeways, expressways and other major highways.

Cross Section

Much recent experimentation has taken place with cross-section revisions to increase freeway capacity. Shoulder conversions to additional conventional or high-occupancy-vehicle lanes, lane-width narrowing to 10 or 11 ft, and combinations of the two have been tested in many places *(8)*. Despite the apparent success of such innovative designs, the new policy maintains a constant stance on cross-sectional dimensions. It is clearly stated (*3*, p.631) that "through-traffic lanes should be 12 feet wide" and that "on freeways of six or more lanes, the usable paved width of the median shoulder should be 10 feet and preferably 12 feet where the truck traffic exceeds 250 DHV."

Adherence to such strict dimensions is not intended to discourage innovations in cross-section treatment. It does, however, indicate the need for serious study and evaluation of trade-offs before implementation of restricted-width designs. Designers should not easily arrive at decisions to compromise the comfort, convenience, and safety provided by full-width designs.

SUMMARY AND CONCLUSIONS

The 1984 AASHTO policy presents a challenge to planners and designers concerned with urban freeways. Revisions to many basic design controls (horizontal alignment, vertical alignment, stopping sight distance) mean that many existing freeways no longer meet current standards. Careful consideration of substandard geometry must accompany major rehabilitation or reconstruction of such freeways.

In addition, the policy clearly charts the course for a systematic approach to freeway and interchange design. Again, many older freeways require substantial planning and redesign to accommodate the operational objectives of the principles discussed in the new policy.

Finally, the policy maintains a proper stance toward the basic characteristics of freeways. The continued use of 60- and 70-mph design speeds and full-width cross-sectional elements is recommended. This should ensure the continuation of freeways as the safest, most efficient elements of the highway system.

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Impact of the AASHTO Green Book on Highway Tort Liability

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The new AASHTO design policy for highways and streets (Green Book) includes new and revised concepts on geometric design that reflect changes in design philosophy, design vehicles, roadside safety features, and driver behavior. Those concepts and how they affect highway tort liability are addressed. The consequences of design flexibility and functional roadway classification are presented; the implications of design consistency and driver expectancy are also discussed.

Many city, county, and state governments in the United States have been forced to devote extensive time and energy to defending themselves against highway tort litigation. (A tort is defined as a civil wrong, as opposed to criminal activity, and is normally classified as negligence.) Highway tort actions normally are based on plantiff accusations that the governmental agency (or its employees) responsible for design, maintenance, and operation of a roadway was negligent in performing its duties, and that this negligence caused the plaintiff to have a traffic accident that resulted in serious injury (or death). The plaintiff sues the agency in hopes of collecting an award (money) for his damages (injuries).

Proof of negligence must be clearly demonstrated by the plaintiff. One of the most effective methods to establish this proof is to show how the agency failed to design, maintain, or operate the roadway according to recognized standards, operational procedures, or policies.

Although clearly identified as design criteria policies or guidelines, the AASHTO publications entitled *A Policy on Geometric Design of Rural Highways* (Blue Book) (*1*) and *A*

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