COMPARISON OF WORLDWIDE PRACTICE IN INTERCHANGE DESIGN

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INTRODUCTION

This paper is intended to provide a general overview of freeway and interchange design worldwide. It is not an exhaustive treatise on the subject. To do so would involve a volume significantly greater than any of the geometric design policies in North American or Europe. Here, similarities and differences will be explored and recommendations made for future research and improvement.

Being compared here are the following and interchange design issues:

- Design Philosophy
- Design Elements
- Interchange Configurations and Adaptability
- Operational Guidelines for Systems of Interchanges

DESIGN PHILOSOPHY

There are many similarities around the world in freeway and interchange design and operations. In all countries freeways are designed with the highest standards or criteria. Freeways are controlled access facilities having the highest capacity and best accident experience.

In Europe and many other countries a design philosophy evolved emphasizing the quality of freeway horizontal and vertical alignment. Many facilities have been constructed with high design (or operating speeds) utilizing transition curves (clothoids) producing aesthetic high speed alignments that are compatible with the visual and physical environment. An example is shown in Figure 1. In many cases, however, the associated interchanges were secondary in design quality, resulting in somewhat poor traffic operations and accident experience.

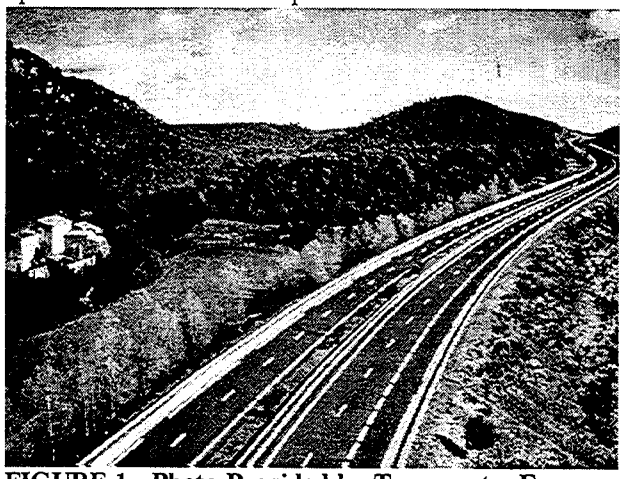

FIGURE 1 Photo Provided by Transroute, France

In North America, based on experience and research in the 1950's and 1960's, emphasis was placed as much or more on the interchange design elements. It was discovered that a majority of accidents on freeways occurred at interchanges where there were conflicts between vehicles. Consequently, emphasis on quality of design was placed on the interchanges (exits, entrances, and configurations).

These differences exist because of variations in experience and philosophies in policy and design criteria. Both North America and Europe/Far East can learn from each other.

DESIGN ELEMENTS

The basic design elements for alignment, sight distance and cross section are similar. Certainly there are slight differences worldwide; however, these are not significant.

Cross Section

Table 1 describes the ranges in values that are found between countries for the primary cross section elements of freeways and interchanges.

While there are some variations these are not significant and do represent differences in design practice primarily related to physical constraints and/or driver characteristics.

Exit and Entrance Design

The geometry of exits and entrances vary somewhat around the world. Certainly, in the past (1950's and 1960's) there were significant differences even within individual countries before standardization of design practice occurred. Some entrance ramps, as an example, were so short and the tapers almost non-existent that yield or stop signs were used. Today, interchange entrances and exits are generally sufficient in length to provide sufficient acceleration or deceleration.

Most countries use a parallel design for both the exit and entrance - probably more so for the entrance than the exit. In North America (U.S.A. and Canada) the tapered design for both is more prevalent, although the option is provided in the design policies. The parallel entrance design used in most countries is generally 200 m of parallel lane with an 80-100 m taper at the end. The tapered entrance design is generally 1:50 utilizing a 3.5 to 5.0 m lane width at the beginning of the taper. The 3.5 m or even 4.0 m lane width produces a merging length that is, however, inadequate in facilitating efficient merging maneuvers.

TABLE 1 Range of Values for Cross Section Elements

Cross Section Elements	
Element	Value
Freeway Lane Width	3.5 - 3.7 m
Freeway Shoulder Width • Right • Left	 2.5 - 3.6 m 0.5 - 3.0 m
Ramp Width • One-lane • Two-lane	 3.6 - 5.0 m 7.0 - 7.5 m
Ramp Shoulder Width • Right • Left	 1.0 - 2.5 m 0.5 - 2.0 m

The parallel exit design most commonly used is 100 - 150 m of parallel lane preceded by a 50 - 100 m taper. The tapered exit design is generally 1:10 to 1:25. Most commonly used in North America is a 1:15 or 1:20 taper. It has been found that whether the exit is a taper or parallel design the beginning of the exit taper must be clearly defined geometrically so that the thru driver does not inadvertently follow the edge of pavement of the exit.

In North America it was found that drivers do not (and should not) decelerate significantly in the diverging area of the exit. In fact, operating speeds at the ramp gore or nose are similar to those on the freeway. On ramps where the beginning of the controlling ramp curve is at or close to the gore or nose (as with a loop ramp), accident experience was found to be high. Consequently, it is preferred to place the ramp controlling curve some distance beyond the gore or nose to allow drivers to decelerate on the ramp proper. The distance is dependent on the design speed or 85th percentile speed of the ramp curve. This does not seem to be a consideration in countries outside of North America, possible contributing to the higher accident rates.

Application of Clothoids (Spiral Transition Curves)

Most countries around the world utilize transition curves (clothoids) in freeway and ramp design. In the European countries their application is common. In the U.S.A. while once prevalent, their utilization has been dramatically reduced since 1970. This is unfortunate considering their value in superelevation development and in enhancing the aesthetic quality of alignment.

INTERCHANGE CONFIGURATION

The forms of interchanges used around the world are generally similar. These basic forms are shown in Figure 2. There are, of course, many variations within these basic forms. One form not shown is a Roundabout Interchange where the ramps and crossroad form an unsignalized (or signalized) roundabout. These are found in Europe but are very uncommon in North America.

In selecting an interchange form for a particular location many countries consider traffic (volume and pattern), capacity, right-of-way, driver characteristics and construction costs. Generally, however, the guidelines of type of intersecting facility with the freeway and the environment (urban vs. Rural) provide a basis for establishing the interchange forms that are most appropriate. Figure 3 provides the basis for interchange selection in many countries, particularly in North America.

Service Interchanges

Service interchanges are those forms which are utilized where the freeway interchanges with a rural road or highways or suburban/urban street. Generally, the appropriate forms are diamonds, cloverleaf, partial cloverleafs or roundabouts. In North America the most common form is the diamond, however, there are numerous examples of the other forms with the exception of the roundabout. The cloverleaf is beginning to be phased out in North America because of its high accident experience and significant right-of-way requirement. In many countries the cloverleaf is used in rural areas where the freeway interchanges with a primary highway (not a freeway). This is consistent with driver operations on rural primary highways where relatively free flow is expected. In North America collector-distributor roads are usually used along the freeway for these cloverleafs to remove the weaving between the loop ramps from the main freeway traveled way (carriageway).

Examples of different service interchange forms are shown in Figures 4, 5, 6 and 7.

- Figure 4 is a single point diamond in Japan. The concept for this diamond form (variation) was first conceived in the U.S.A. in the 1940's but was first constructed in the late 1960's.
- Figure 5 is a cloverleaf. In fact, it's the first interchange constructed in the U.S.A. - obviously antiquated in its design.
- Figure 6 is a partial cloverleaf in Canada. This form is an excellent suburban interchange where a freeway interchanges with an arterial street. It has high capacity and generally good operational characteristics.
- Figure 7 is a roundabout interchange in France. This is a variation of a half diamond.

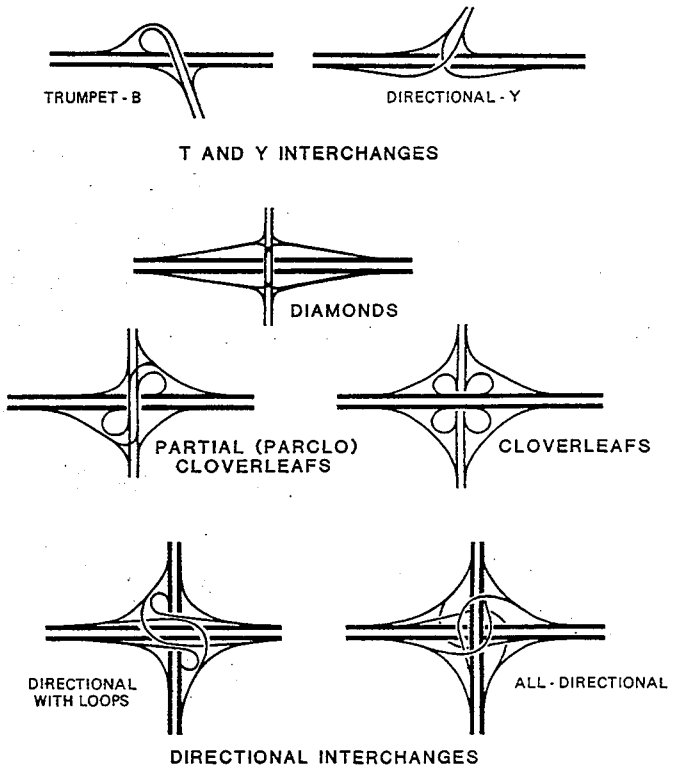

FIGURE 2 Interchanges General Types

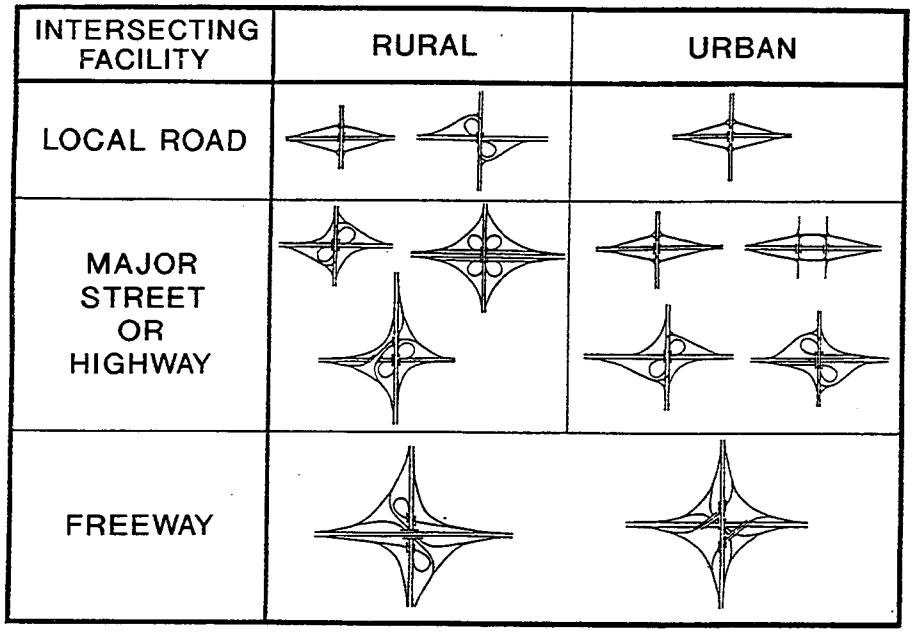

FIGURE 3 Adaptability of Interchanges

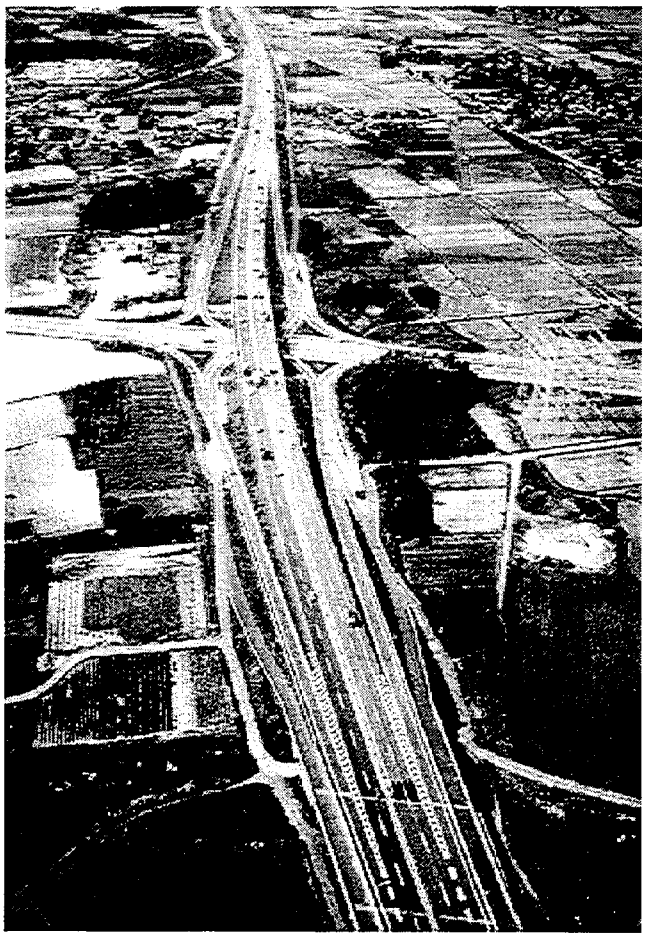

FIGURE 4 Single Point Diamond, Japan; Photo Provided by Public Works Research Institute, Japan

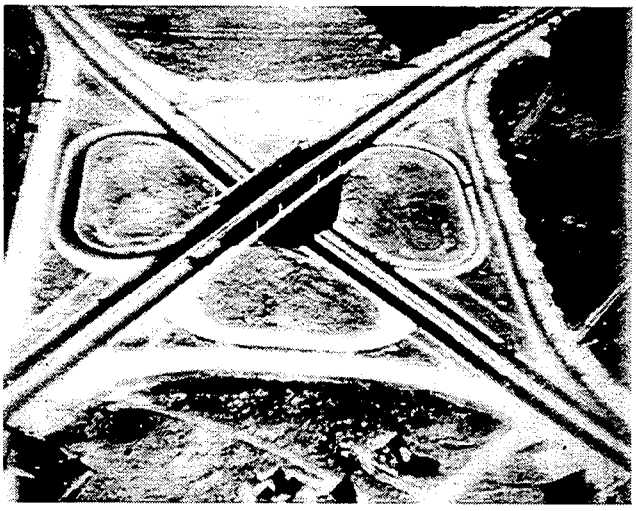

FIGURE 5 First Intersection Constructed in USA, Woodbridge, New Jersey, 1928

FIGURE 6 Partial Cloverleaf; Highway 401, Toronto, Canada

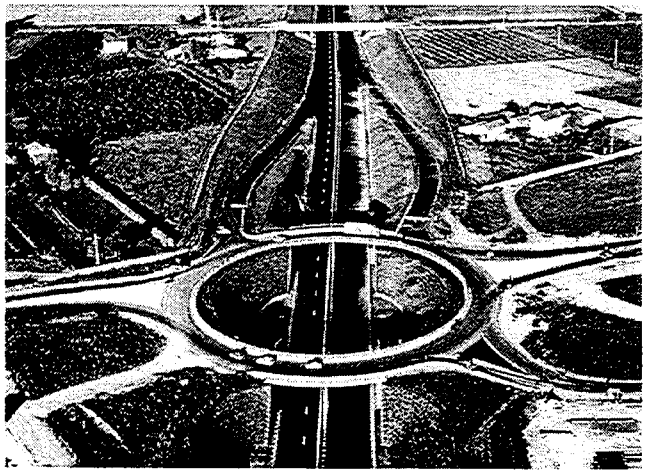

FIGURE 7 Roundabout Interchange; Photo Provided by Transroute, France

System Interchanges

System interchanges are those between two freeways. Typically these are all-directional interchanges, directionals with one, two or three loops or cloverleafs. In North America today, cloverleafs are not generally used except occasionally in rural areas. In urban areas their right-of-way requirements and poor operational characteristics under high traffic volume conditions have eliminated them from consideration. Several system interchanges are shown in Figures 8, 9 and 10.

- Figure 8 is a directional interchange with two loops (opposite quadrants) in Canada. The loops in opposite quadrants eliminate any weaving within the interchange.

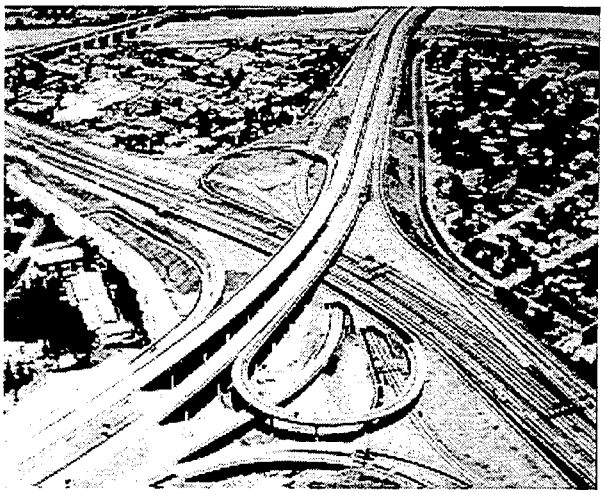

FIGURE 8 Directional Interchange with Two Loops; Highway 401, Toronto, Canada

- Figure 9 is a directional interchange in Japan along one of the toll highways.
- Figure 10 is an all-directional four-level interchange in Los Angeles, California. (No discussion of directional interchanges would be complete without this.)

The general forms of system interchanges used around the world are relatively consistent — it is the specifics of the geometrics that may vary significantly.

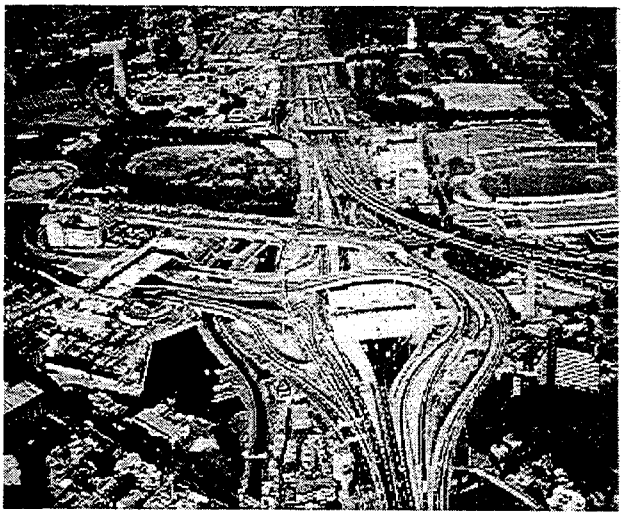

FIGURE 9 Directional Interchange, Japan; Photo Provided by Public Works Research Institute, Japan

OPERATIONAL GUIDELINES FOR SYSTEMS OF INTERCHANGES

Many countries have adopted guidelines for planning and design of freeway corridors and systems of interchanges that promote efficient, consistent and uniform operation. Since freeway facilities are high speed and decision making is made in a "tense" driving environment, simplifying the driver's task by creating uniformity in operation and signing for interchanges is important. This can be achieved by applying the following guidelines:

- Route continuity
- Right exits and entrances only (for countries that drive on the right)
- Single exit per interchange in advance of the cross road
- Lane balance at exits and entrances
- Adequate interchange and ramp spacing
- Simplified signing

Not all countries adhere to the guidelines. The following discussion not only discusses these guidelines but whether and how countries apply these.

FIGURE 10 All-Directional Interchange, Los Angeles, California, USA

Route Continuity

Route continuity refers to the provision of a directional path along and throughout the length of a designated route. The designation pertains to a route number or to the name of a freeway. Route continuity allows the driver approaching a bifurcation (interchange) to be positioned properly across the lanes, followed by a confirmation received from route marking and directional signing.

In the process of keeping the driver "on-line," particularly within and bypassing metropolitan areas, interchange configurations must not necessarily favor the heavier traffic movement at the point of bifurcation. It is the through facility (the designated route) that should always maintain its directional character. However, any predominant movement separating from the freeway should form a well aligned exit on the right, equivalent operationally to the through movement. Figure 11 illustrates the principle of route continuity as applied to a

series of route configurations. Important is that the driver, to remain on route, stays to the left; to leave or exit, the route moves to the right and exits right.

North America (U.S.A. and Canada) has generally adopted this operational guideline. Most other countries, however, have either partially adopted this guideline or not at all. For those countries that have partially adopted this guideline they use a "major fork" design for the exit with the primary route exiting on the right if it is turning right through the interchange. With more and more international travel being made throughout the world, simplification of operations by applying the guideline of route continuity is increasingly important.

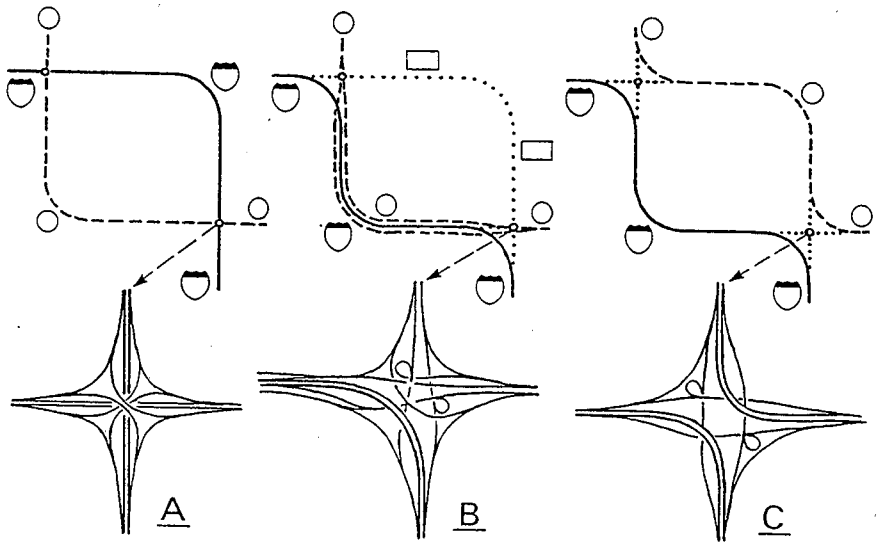

FIGURE 11 Route Continuity

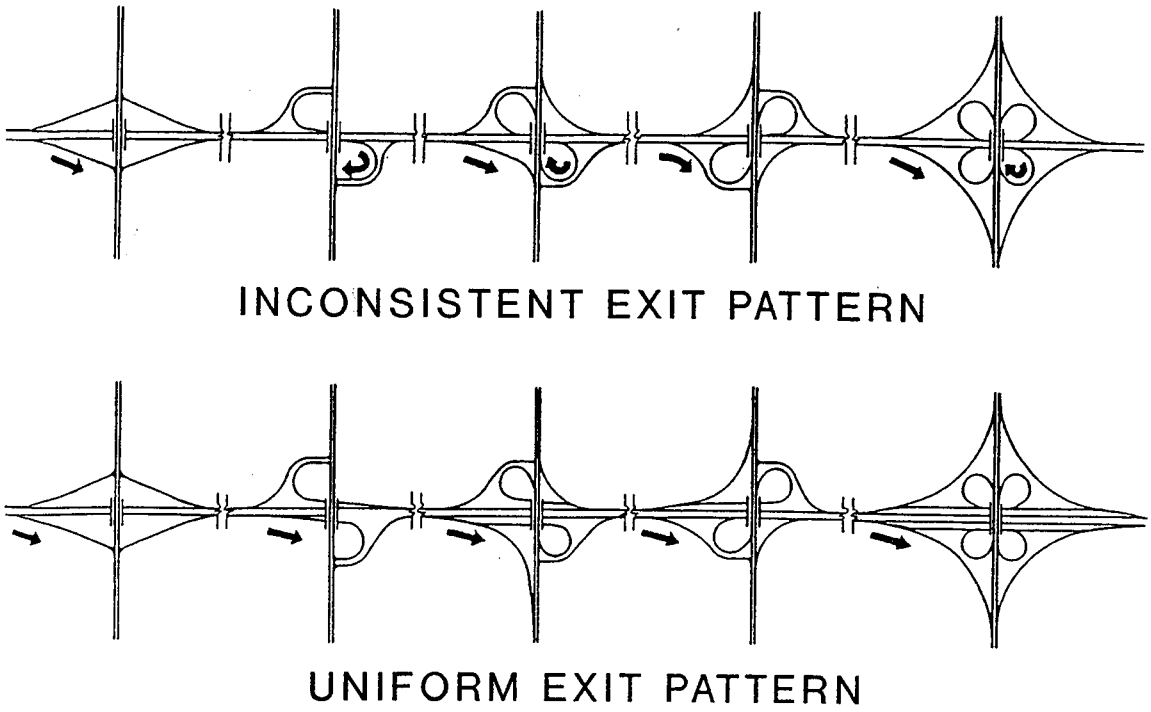

FIGURE 12 Operational Uniformity

Right Side Exits and Entrances (for countries that drive on the right)

Operational experience gained and research conducted on interchanges have shown conclusively that right exits and entrances for interchanges are significantly better than those on the left. Left side ramps (exits and entrances) create or experience several problems:

- Weaving across all lanes when right exits and when entrances also exits
- Driver visibility deficiency with left entrances
- Slower exiting and entering traffic in high speed left thru lane
- Does not satisfy driver expectancy

The resultant accident experience is significantly higher with left side ramps. Most countries have "generally" adopted this guideline.

Interchange Operational Uniformity - Single Exit in Advance of Cross Road

This guideline has become a critical one in simplifying the driver's task by providing only one decision point on the freeway and giving the driver a view of the exit ramp well in advance. **Operational Uniformity** can thus be achieved by implementing the above criteria. These produce a uniform arrangement of exits and entrances along a freeway providing for a uniform pattern of directional signing and allows a driver to exit in a consistent manner at all interchanges. A demonstration of this is seen in Figure 12.

The two freeway/interchange systems shown in the figure produce very different operational characteristics while the basic forms of the interchanges are identical. In the upper facility a difficult or what may be a confusing pattern of exits is illustrated. Each interchange produces different operational characteristics along the freeway. Some interchanges result in two exits, some with one exit. One interchange has one exit beyond the crossroad hidden from the driver's view and, of course, the cloverleaf not only has two exits with one beyond the crossroad but a weaving section between the entering and exit loop ramps.

The facility in the lower portion of the figure with similar interchange forms has a uniform pattern of distances between interchanges providing for an appropriate level of service (quality of traffic operation). It also allows for sufficient spacing of guide signs providing driver information reactive to exits at the interchanges. This guideline has been extensively adopted worldwide.

Lane Balance at Exits and Entrances

Capacity analyses sometimes indicate abrupt changes in number of lanes at points of entrance or exit. Whereas such changes may be logical in terms of volume-capacity relations, they are not always appropriate in achieving smooth operating characteristics. Through operational experience and recently with simulation to achieve efficient operation and to realize the indicated capacity potential where merging, diverging, and weaving take place, a certain balance of lanes must be maintained. Lane balance should comply with the relations outlined in Figure 13.

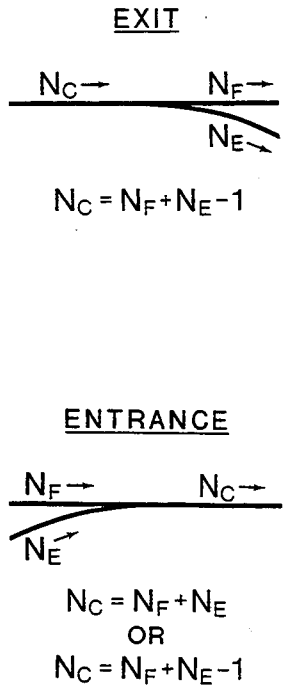

FIGURE 13 Lane Balance (Reduce Lane Changing)

The equations indicate that at exits the number of lanes approaching should be equal to one lane less than the combined number departing; and at entrances the combined number of lanes after the merge should either be equal to or one lane less than the total number of lanes approaching the merge. The principle of having an extra lane at the point of divergence (that is, " one more lane going away") is a form of "escape hatch," or a device which tends to "flush" traffic away from the point of divergence due to greater exit than approach capacity.

Lane balance could produce a lane drop at certain exits. This need not be so as long as the lane dropped is an auxiliary lane added to the freeway at a previous entrance ramp. Thus the basic lanes or established through lanes are maintained over the length of the freeway facility. These guidelines of lane balance, basic lanes, and application of auxiliary lanes to accommodate entering,

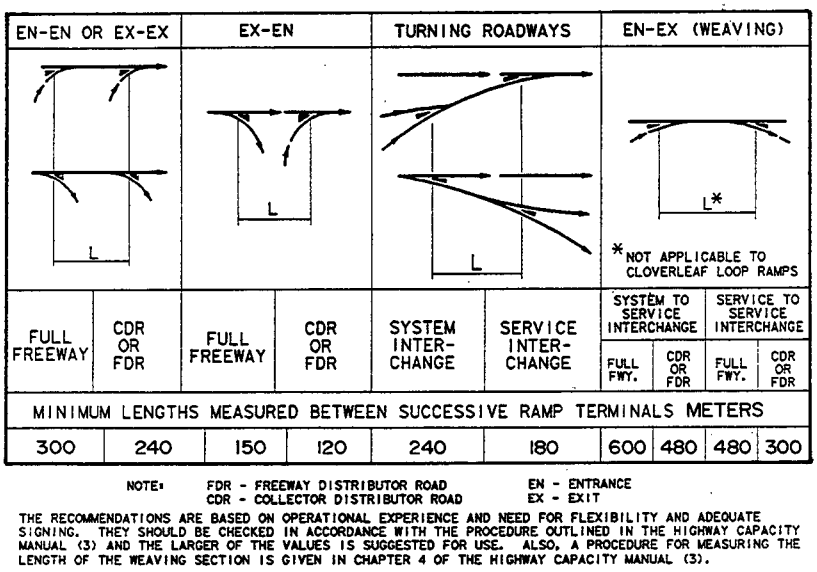

FIGURE 14 Recommended Minimum Ramp Terminal Spacing (Ref. 1994 AASHTO Policy)

exiting and weaving traffic between interchanges have proven to be important in reducing lane changing and achieving uniform operation.

Generally in North America this guideline has been adopted. Again, as with previous guidelines, this one has only been partially adopted worldwide.

Interchange and Ramp Spacing

Experience has shown that in urban areas interchanges should be at least 1.5 km apart and in rural areas 3 km apart. This spacing generally provides for sufficient weaving distances between interchanges, providing for an appropriate level of service (quality of traffic operation). It also allows for sufficient spacing of guide signs providing driver information reactive to exits at the interchanges.

Guidelines have been developed for spacing of ramps (exits and entrances) within and between interchanges. This spacing relates to geometrics and operations. These dimensions, as presented in Figure 14, are only guidelines and may need to be modified by actual traffic and geometric conditions of a specific freeway and its interchanges. This guideline, while adopted in North America, has been adopted in only a few other countries worldwide.

North America recognized the need for these guidelines by the early 1960's and generally has applied it in new interchange construction and in reconstruction. Some other countries have adopted these guidelines while others have not.

Simplified Signing

With the application of the previous guidelines, signing becomes not only simplified but also uniform along a freeway. This greatly simplifies the driver's task in negotiating freeways and interchanges.

SUMMARY AND RECOMMENDATIONS

There are design similarities and dissimilarities based on driver characteristics between countries. This, of course, is appropriate for today. The criteria used, however, in some countries reflect a lack of experience and research reflective of driver characteristics and that understanding in design translation. Certainly experience and research in one country can benefit another. Symposiums like this, encouraging communication and sharing of experience, can be of significant benefit.

Recommendations as a result of the symposium are the following:

1. Reduce or eliminate vehicle conflicts through application of the guidelines related to exit and entrance design and appropriate ramp spacing.

2. Simplify Driver Decision Making by:
   a. Spreading decision points
   b. Visually clarifying decision points
   c. Creating "operational uniformity"
   d. Simplifying signing

These recommendations are very much in the recognition of increased international travel and the need to simplify freeway and interchange operations to assure safe and efficient traffic operations throughout the world.

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