Grade-Separated Intersections

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"Grade-separated intersections" refers to the various means of significantly increasing the capacity or resolving physical constraints by grade-separating the through movements on two intersecting roadways and interconnecting the two with ramps or roadways that form one or more intersections. Concepts and designs are discussed that have been successful in resolving intersection capacity problems and geometric or physical constraints in a manner responsive to the various needs and requirements of individual locations. Guidance is provided to the planner, designer, or traffic engineer in selecting the appropriate forms for a given condition. The 1990 AASHTO *Policy* discusses interchanges in Chapter X, but does not discuss adaptation of interchange forms to arterial (nonfreeway) situations. The categories of interchanges discussed include compact diamond, partial cloverleaf, and rotary forms. Each interchange type is described, and operational and design characteristics are discussed and compared with the others. The characteristics described, though generalized, reflect experiences gained through operational and design observation. All the interchanges presented are good forms when implemented under the site conditions that fit the specific design.

The increase in traffic on arterials in metropolitan areas has, in many cases, dictated the need to develop and implement solutions with higher capacity than can be provided by at-grade intersections. Also, there are some situations where capacity does not control but physical constraints may dictate the configuration of an intersection requiring a grade separation or other solution.

"Grade-separated intersections" in this paper refers to the various means of significantly increasing the capacity or resolving physical constraints by grade-separating the through movements on two intersecting roadways and interconnecting the two with ramps or roadways that form one or more intersections. The concepts and designs discussed here relate to experiences throughout the United States that have been successful in resolving intersection capacity problems and geometric or physical constraints in a manner responsive to the various needs and requirements of individual locations.

The 1990 AASHTO *Policy* (1) discusses interchanges at great length in Chapter X. However, there is no discussion related to adaptation of interchange forms to arterial (nonfreeway) situations. This paper is intended to supplement the *Policy* and provide guidance to the planner, designer, or traffic engineer in selecting the appropriate forms for a given condition.

WARRANTS/GUIDELINES

There are three controls that may dictate the need for a grade separation between two intersecting highway facilities: traffic volumes/capacity, safety, and alignment and profile (terrain).

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Traffic Volumes

In urban areas, traffic volume usually dictates the need for a grade separation where in the past an at-grade intersection even with improvements accommodated the through and turning traffic movements on the intersecting facilities. In most situations, volumes that create delay per vehicle approaching or in excess of 60 sec (LOS E-F) may be candidates for a grade separation to increase capacity and raise level of service (decrease delay). Obviously, other factors may influence implementation of a grade separation, such as improvement priorities and funding, not to mention physical constraints and environmental considerations.

Safety

In urban or rural areas, safety considerations may influence the need for a grade separation where an at-grade intersection exists. Where right-angle collisions (which may be related to traffic signal or stop control violations) are common, a grade separation could lower accident experience. Similarly, where a particular turning movement (usually a left turn) has particularly high accident experience, a grade separation may be used as a means of reducing conflicts and improving safety. The types of accidents associated with turning movements are usually sideswipe, rear-end, right angle, and head-on.

Terrain

The physical environment could influence the need or desirability of grade separations. They are already common in cities, such as in San Francisco, and in rural areas where the terrain and highway/street network require such a solution. Often the significant profile differences between the two intersecting facilities may require a grade separation as an economical solution. Interconnecting the two facilities to provide for traffic movements is often accomplished through other elements of the highway/street network.

Other physical or man-made constraints, such as railroads, rivers, and so forth, may also dictate the need to grade-separate two facilities that under "normal" circumstances could intersect and accommodate the traffic volumes through signal or stop control.

GRADE-SEPARATED INTERSECTION (INTERCHANGE) FORMS

The different forms of grade-separated intersections (interchanges) can be categorized in the following way: compac diamond, partial cloverleaf (Parclo), and rotary. The forms are depicted in Figures 1, 2, and 3, respectively.

Diamond Forms

Diamond forms are generally of three types: the single-point diamond, the compressed diamond, and the three-level diamond (see Figure 1).

The single-point diamond has the following characteristics:

- It takes little ROW.
- It has moderate capacity.
- It is a single intersection with three-phase signal control. Four-phase signal control is required if ramp through traffic movements are provided.
- It is the second most costly to construct of all diamond forms.
- Access is eliminated for a minimum of 1,500 to 2,000 ft along the priority facility.

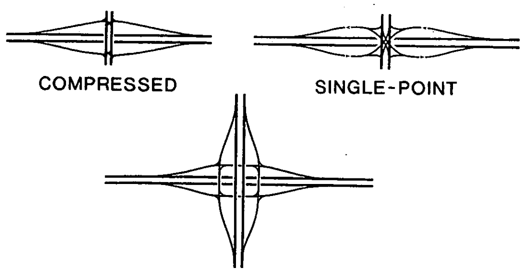

FIGURE 1 Diamond interchange forms.

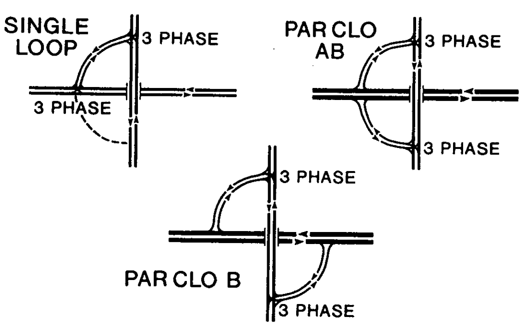

FIGURE 2 Partial cloverleaf forms.

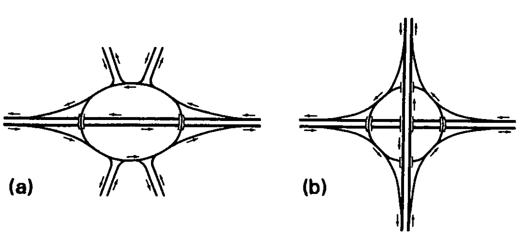

FIGURE 3 Rotary interchange forms.

- It is possible to have access on ramps if they are judiciously located.
- U-turn loops to interconnect ramps and reduce intersection traffic can be provided.
- Large left-turn radii can facilitate truck movements.

The compressed diamond with ramp terminal intersections 200 to 400 ft apart has some characteristics that are similar to and others that are much different from the single-point diamond:

- It takes a moderate amount of ROW.
- It has moderate capacity.
- It has two intersections with coordinated four-phase overlap signalization.
- It is less costly to construct than the single-point diamond (generally 10 to 20 percent).
- Access is eliminated for a minimum of 1,500 to 2,000 ft along the priority facility.
- It is possible to have access on ramps if they are judiciously located.
- U-turn loops to interconnect ramps and reduce intersection traffic can be provided, or U-turns through intersection are possible.

The three-level diamond has very different characteristics from the other diamond forms:

- It takes the most ROW.
- It has high capacity.
- It has four intersections, each with two-phase signal control.
- It is the most costly to construct—nearly double the compressed diamond.
- Access is eliminated for a minimum of 1,500 to 2,000 ft along both facilities.
- It is possible to have access on ramps if they are judiciously located.
- There is no need for U-turn loops.

The application and implementation of one of these diamond forms is obviously related to the site-specific requirements associated with traffic/capacity, ROW, other physical constraints, and access needs.

Partial Cloverleaf Forms

Partial cloverleaf forms are also of three general types, as shown in Figure 2. They include a single-loop and two two-loop varieties. Their characteristics are somewhat different from the diamond forms. Partial cloverleaf forms often have application in locations where physical requirements, ROW constraints, access needs, and highway/street network configurations govern.

The single-loop or "cutoff" roadway form can have many applications in situations where turning traffic movements are not high and when roadway network and access requirements are compatible. This form is often applied where terrain controls and the two-way cutoff roadway is sufficient to accommodate the turning movements between the intersecting roadways.

- It takes little ROW.
- It has low to moderate capacity.
- It has two intersections—one on each roadway with three-phase signal control or stop control.
- It is generally not as costly as the diamond forms.
- Access is easy to coordinate; access off loop is possible.
- Consideration of highway/street network is required and could be used.
- It is the lowest in cost of the partial cloverleaf forms.

The Parclo B, two-loop/opposite quadrant form, is somewhat higher in capacity and responds to different traffic pattern and highway network requirements.

- It takes more ROW than the single-loop form.
- It has moderate to high capacity.
- It has free flow on the priority street, with right in and right out at connecting roads. Crossroad has two three-phase signal-controlled or stop-controlled intersections.
- It has construction costs similar to those of the two-loop/opposite quadrant form.
- Access is easy to coordinate; access from both loops is possible.
- Consideration of highway/street network is required and could be used.

Rotary Interchange Forms

Rotary interchanges have limited application. There are two types of rotary interchanges, as shown in Figure 3.

The first configuration (A) may be fitting in suburban areas where a major arterial serves a residential or partly commercial area with multiple streets forming five or more intersection legs and where traffic volumes are of the order that can be accommodated on a series of short weaving sections. The characteristics of a rotary interchange are as follows:

- The ROW required is about the same as or slightly more than the three-level diamond.
- It has moderate capacity.
- It has multiple intersections that could operate with yield control and with weaving between them.
- Its construction cost is similar to that of the compressed diamond.

An application of the rotary interchange is shown in Figure 3B in which two arterial highways have all through movements separated, using five structures. Each left-turning movement weaves with the other left-turning movements in negotiating three of the four weaving sections. A rotary with a radius of 400 to 500 ft produces weaving sections about 300 to 400 ft in length. The latter occupy an area approximately equal to a cloverleaf with 150-ft radius loops. In terms of serviceability, each weaving section is limited to a weaving volume of 1,200 to 1,500 vph. Construction cost approaches that of a three-level diamond.

SUMMARY

The interchange (grade-separated intersections) forms that have been presented in this paper have been implemented under varying traffic and physical conditions in urban, suburban, and rural areas where two or possibly more streets/highways intersect. The characteristics described, though generalized, reflect experiences gained through operational and design observation. All the interchanges presented here are good forms when implemented under the site conditions that most appropriately fit the specific design.

REFERENCE

1. *A Policy on Geometric Design of Highways and Streets*. AASHTO, Washington, D.C., 1990.

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