

Hybrid Interchanges: Developing the Arterial of the Future

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ABSTRACT

Urban arterial roadways are one of the most important facilities provided for the public. To be beneficial, they should be designed to move high volumes of traffic safely at reasonable speeds and provide needed access to businesses and residences. This is the challenge roadway designers have before them. The ultimate goal of arterial design has been to develop a facility that will do all those things, do them well, and do them at a reasonable cost. The ideas presented in this paper suggest that this goal may be nearing fulfillment.

The weak point of arterial design (or the linchpin, depending on the perspective) has been the arterial/arterial intersection. Extremely high volumes, both through and turning, come together at the same point at the same time, and all of these substantial traffic demands need to be served in the best manner we know how. Because of these conflicting needs, intersections have served as bottlenecks to the flow on arterial roadways, providing only 30–50% of the capacity available on the arterial itself. To improve arterial intersections, a widened intersection with turn lanes has typically been provided, controlled by a traffic signal. The alternative to this has been the consideration of a grade-separated interchange. For a congested arterial/arterial intersection, the at-grade solution has typically been too little, while the grade-separated solution has typically been too much. What follows is a concept that the authors hope practitioners see as a method for improving operational efficiency and utilizing untapped capacity on arterials.

Key words: arterials—arterial intersections—hybrid interchanges

BACKGROUND

Intersection and interchange designers are commonly faced with the issue of comparing alternatives to improve congested intersections. The alternatives commonly involve the comparison of widening the intersection vs. creating a grade-separated interchange. Both alternatives are likely to involve a major widening of the project's footprint. That commonly means acquiring additional right-of-way, which adds to the project's cost and impacts.

The hybrid interchange is a concept that utilizes aspects of both at-grade intersections and grade-separated interchanges. The following is a verbal description of a hybrid interchange:

- A hybrid interchange uses grade separation to modify a single at-grade intersection and create two separate intersections, one above the other.
- Each of these two intersections involves the pairing of two of the four approaches to create two separate intersections.
- Each of these two separate intersections proximate the intersection of two one-way streets.
- Drivers at hybrid interchanges are not required to do anything unusual or unexpected.

This particular intersection geometry creates several opportunities, including the following:

- Two-phase signal operation
- Pairing approaches to take advantage of peak and off-peak directions
- Modifying signal splits to take advantage of the traffic flows at the intersection

Although not a solution for every problem, the hybrid interchange shows significant promise regarding substantial improvements in operational efficiency vs. moderate construction costs (less than the cost of typical grade-separated interchanges). Environmental impacts need to be evaluated on a case by case basis, but the preliminary estimates of impacts caused by the hybrid interchange are very encouraging. It is also recommended that a cost-benefit analysis be conducted to determine the relative value of any alternative studied, including the hybrid interchange.

EXAMPLE PROBLEM INTERSECTION IN RENO, NV

The Regional Transportation Commission (RTC) in Reno, Nevada, has an arterial ring-road network named McCarran Boulevard, which surrounds and serves the greater Reno community. The first of 13 congested intersections selected for improvement and testing of various alternatives is the intersection of McCarran Boulevard and Pyramid Way. It was felt appropriate to test a few alternatives to improve this intersection against the hybrid interchange concept to see whether this alternative deserves any additional consideration.

The design year is 2012, and the following are the design hour turning traffic volumes:

	Eastbound	Westbound	Northbound	Southbound
AM Left turns	483	147	200	198
AM Thru	761	654	1064	1998
AM Right turns	124	217	56	1289
PM Left turns	707	91	200	157
PM Thru	905	827	2015	1259
PM Right turns	70	334	153	785

The current design for all legs is essentially a five-lane divided roadway, with dedicated left-turn lanes in all directions, and dedicated right-turn lanes in a few directions. The intersection currently runs at level of service (LOS) F (2004 conditions).

Alternative Solutions

The proposed alternatives for this intersection are as follows:

- A. Widened intersection
 - 1. Thru lanes/direction = 3
 - 2. Left turn lanes/direction = 2
 - 3. Right turn lanes/direction = 1 (2 RTL's, SB)
 - 4. Roadway footprint = 130 ft (approx.)
- B. Overpass
 - 1. Single point urban interchange (SPUI)
 - 2. East/West thru traffic (McCarran Blvd) = 3 lanes/direction, w/ramps
 - 3. North/South traffic (Pyramid) same as Alternative A (2 right turn lanes, SB)
 - 4. Roadway footprint = 160 ft (approx)
- C. Hybrid interchange
 - 1. Thru lanes/direction = 2
 - 2. Left turn lanes/direction = 1
 - 3. Right turn lanes/direction = 1
 - 4. Roadway footprint = 90 ft (approx)

Level of Service Analysis for Alternatives

The LOS analyses for the alternative are as follows:

- A. Widened intersection
 - 1. AM Condition
 - a. AM LOS = E (Almost F)
 - 2. PM Condition
 - a. PM LOS = E (Almost F)
- B. Overpass
 - 1. Flyover LOS (East/West)
 - a. AM LOS = A
 - b. PM LOS = A
 - 2. SPUI Intersection LOS
 - a. AM LOS = D
 - b. PM LOS = D
- C. Hybrid interchange
 - 1. Upper intersection LOS (Eastbound/Southbound)
 - a. AM LOS = D
 - b. PM LOS = C
 - 2. Lower intersection LOS (Westbound/Northbound)
 - a. AM LOS = C
 - b. PM LOS = D

COST, RIGHT-OF-WAY, NEIGHBORHOOD, ENVIRONMENTAL, AND OTHER IMPACTS

The cost, right-of-way, and environmental impacts are going to vary substantially from location to location, as well as impacts to neighborhoods or businesses. Any preferred alternative needs to be reviewed carefully in an isolated manner, taking into consideration all potential costs and impacts.

Also, the system costs and impacts need to be identified and compared, and will be affected based on the intersection/interchange that is selected to solve a given problem. The implications of choosing an intersection/interchange improvement that requires a six-lane divided in lieu of a four-lane divided facility should be examined carefully.

For instance, the following possible choices are likely, and system decisions need to follow:

- A. Choice = Widened intersection (six-lane, divided)
Implication = Widened arterial (six-lane, divided)
- B. Choice = Overpass with SPUI
 - (1) Implication = Widened arterial (six-lane, divided)
 - (2) Implication = Non-widened arterial (four-lane, divided)
- C. Choice = Hybrid interchange
Implication = Non-widened arterial (four-lane, divided)

The implications are obvious, and making the decision for the preferred alternative at a selected intersection affects other system-wide decisions (which may be more far reaching). The city may save money because an at-grade widened intersection was selected over the cost of a grade-separated interchange or a hybrid interchange, but the city may need to face the implications (cost, right-of-way, neighborhood and business impacts, and environmental impacts) of the broader scale decisions to widen the arterial from four lanes to a six-lane divided facility.

Other implications may be equally obvious. If a city faces a similar situation to that confronting the RTC in Reno, NV, the alternatives should be considered on both an isolated and system-wide basis. The impacts at the intersection/interchange being studied and the impacts on the arterial away from the affected intersection/interchange have been discussed. In addition, the RTC is looking at this location to set the stage for improvements to 13 similar intersections along McCarran Boulevard. It would be appropriate to test not only various treatments to the affected intersection/interchange, but to the arterial and the 13 other similar intersections as well. Only when the system implications are examined does it become possible to understand the impacts and implications of selecting any one treatment over another.

Anticipated Benefits

A ballpark estimate of benefits for the intersection described above, when converted to a hybrid interchange, is as follows:

Annual time and fuel savings = \$6.3M/year

Annual air quality impacts = 450,000 lbs reduction in CO/year
= 50,000 lbs reduction in HC/year
= 36,500 lbs increase in NOX/year (idling decrease)

According to these figures, it would require one to two years of benefits to pay back the cost of construction.

System Implications on the Arterial and Freeway Network

As mentioned above, making decisions for individual intersections can have system implications, whether they involve arterial corridors, arterial systems, freeways, or transportation within urban areas. If building hybrid interchanges eliminated the need for expanding arterials, and if the added capacity on the arterials resulted in a reduced need to expand freeways, the financial impacts of widening those facilities is significant. The costs of converting intersections to hybrid interchanges should be weighed against the costs of not widening corridor facilities that are in place (because the arterial per-lane efficiencies are anticipated to increase 50–100%). After testing the impacts of hybrids (using traffic simulation), the current arterial roadways may not need to be widened. Since much of projected travel volume diverts from congested arterials to freeway corridors, the impacts on freeways also need to be tested (again, by traffic simulation). So, it may be possible that substantial construction might not be required on either arterials or freeways if hybrid interchanges were implemented in a systematic way. The following are hypothetical (theoretical) construction cost savings, which can illustrate these implications:

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|----|--------------------------------------|---|-------------------|
| A. | Arterial corridors (not widening) | = | \$10-20M/mile |
| B. | Arterial systems (not widening) | = | \$20-40M/sq. mile |
| C. | Freeway systems (not widening) | = | \$50-100M/mile |
| D. | Urban areas (arterials and freeways) | = | \$30-60M/sq. mile |

Another way of looking at this is for every 10 lanes of arterials for which capacity is increased by converting to hybrid control, the equivalent of 3 additional lanes of freeway capacity are created.

HYBRID INTERCHANGES: A NEW GEOMETRIC FAMILY?

In performing this analysis, it became evident that hybrid interchanges are likely not something new. In looking around the United States, there are several examples of hybrid interchanges (in multiple geometric forms). These were created to respond to the conditions at a specific location and were designed to perform a specific function. The keys to being a hybrid are to use vertical separation (grade-separation) and still use at-grade signals (or other treatments as may be appropriate) to help resolve various transportation problems. It is possible that hybrids may become a preferred option to resolve various problems, rather than a make-do option, because nothing else can be constructed to resolve a problem within given cost and right-of-way restrictions.

CONCLUSION

When brainstorming alternatives for improvements to arterials operating at very congested levels, it may be valuable to “think outside the box” and develop alternatives that are not depicted in standard manuals. Many of these ideas sound outlandish initially, but can eventually be accepted once they are constructed and proven. We sometimes forget that everything that is in current manuals and standards was originally developed as a new idea. All new ideas are met with skepticism and doubt, which is normal, but an idea’s time has come, practitioners will recognize it for what it is, and can weigh the advantages/disadvantages for themselves. Two relatively new concepts were seen in that light recently, but are rapidly gaining acceptance: the SPUI and the roundabout. Perhaps it is time for another concept: the hybrid interchange.