Design Considerations for US 50 / SR28 Trumpet Interchange

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Abstract

In our paper entitled "Are US 50 Roundabouts Justified based on FHWA Thresholds?"[1] we conclude that the 3-leg roundabout at the US 50 / SR28 intersection near Spooner Summit, proposed by the Nevada Department of Transportation (NDOT) in the most recent version of the "US 50 East Shore Corridor Management Plan (CMP),"[2] would satisfy Federal Highway Administration (FHWA) criteria, provided additional bypass lanes and lane-reconfiguration provisions are included in the road design to accommodate wildfire evacuation. However, we suggest that a "trumpet" interchange, with SR20 passing under US 50, is likely to be a better alternative, as it improves left-turn movements, maintains free-flow capacity, and does not require emergency lane reconfigurations for evacuation operations.

In this supplement, we address design considerations associated with the proposed trumpet interchange. Based on this analysis, we conclude that such an intersection control configuration is technically feasible, based on established geometric highway design criteria. Because of the grade separation, bridge, and stormwater runoff design elements, a trumpet interchange will be more expensive to design and construct than a comparable roundabout intersection. Therefore, we recommend that NDOT conduct a detailed cost-benefit analysis as part of its formal Intersection Control Evaluation (ICE).

Since the trumpet design will substantially improve safety by eliminating weaving movements required in a roundabout and provide improved bicycle safety for crossing and left-turn movements, we further recommend seeking federal funding to help offset the additional cost.

Single-Trumpet Interchange Description

The canonical single-trumpet interchange shown in Figure 1 is a 3-leg intersection that uses "grade separation" to allow continuous traffic flow and turn movements in all directions. Two of the legs are directional interchange ramps. The third uses a combination of semi-directional and indirect (loop) interchange ramps. The term "trumpet" refers to the resemblance of this intersection's geometrical design to the musical instrument of the same name. This intersection may also be called a "jug handle."

Advantages of the trumpet interchange are: (1) improved operational performance for automobile and truck left-turn movements, (2) unimpeded free-flow capacity for US 50 under normal traffic conditions, (3) no weaving movements and associated accidents, (4) improved bicycle safety by eliminating crossing movements, and (5) enhanced wildfire evacuation capacity, allowing for three egress lanes and one ingress lane, without the need for emergency reconfigurations.

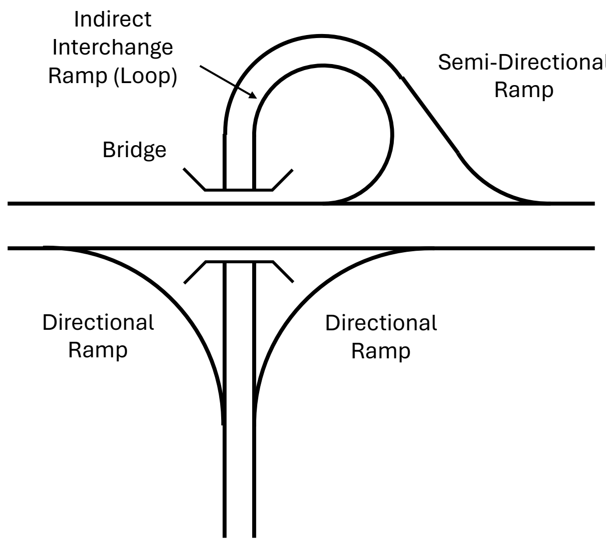

Figure 1. Single-Trumpet Interchange Configuration

A relevant example of single-trumpet interchanges can be found on the Carson Valley side of Spooner Summit where Golf Club Road terminates onto US 50, as shown in Figure 2. The major tradeoff of the trumpet interchange is readily apparent in this view, the radius of the loop portion must be large enough to minimize accidents and accommodate anticipated truck sizes yet small enough to satisfy topographical constraints, as well as meet budget.

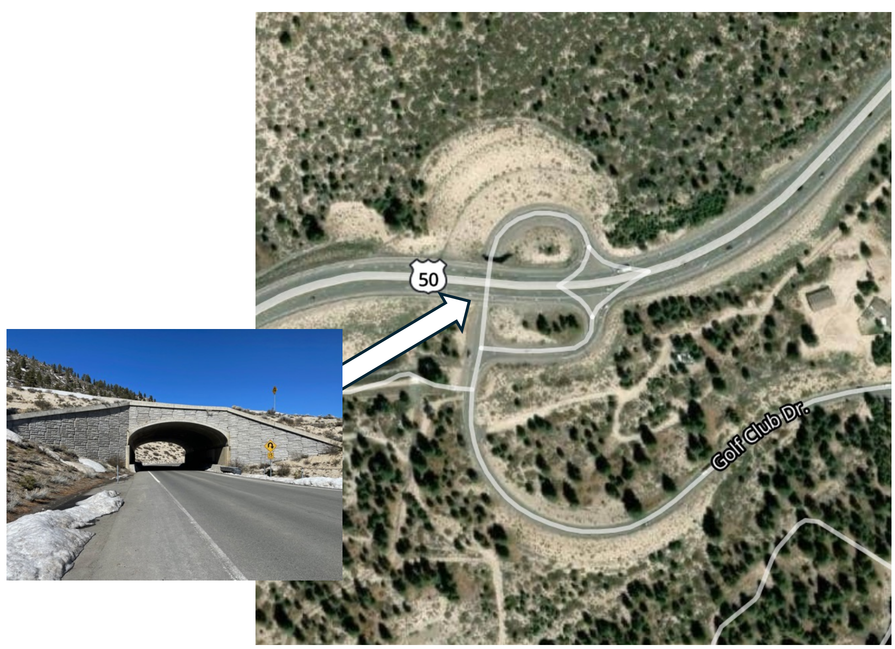

Figure 2. Trumpet Interchange at US 50 and Golf Club Road Intersection (MapQuest Satellite Imagery)

The indirect interchange ramp (loop on-ramp at North side of US 50) has a minimum inner radius of approximately 120 feet with minimal superelevation. This does not meet the American Association of State Highway and Transportation Officials (AASHTO) standard for a non-urban road horizontal alignment (discussed later). However, since Golf Club Drive is limited to Clear Creek Tahoe access and local traffic, the topographically-constrained radius is reasonable for truck speeds below 15 mph. Also, the arched bridge requires a greater grade separation than a comparable voided-slab bridge deck design.

Spooner Single-Trumpet Interchange Design Considerations

Figure 3 shows our suggested single-trumpet interchange design for the UD 50 and SR28 intersection near Spooner Summit. As with the Golf Club Drive interchange, SR28 (the minor road) would under pass US 50 (the major road) and join the eastbound flow via a loop on-ramp. This configuration allows US 50 traffic to flow unimpeded during both normal operation and wildfire evacuation, with no additional lane reconfiguration. Because many wide-load tractor trailers containing bull dozers and other large earth-moving equipment must ingress along westbound US 50 during firefighting operations, the trumpet interchange avoids issues with tight horizontal curves that would be imposed by a roundabout design. The trumpet also significantly reduces wait time for all turn movements.

Figure 3. Suggested Trumpet Interchange Design at US 50 and SR20 Intersection near Spooner Summit (OpenStreetMap[3])

Topography

Figure 4 shows the existing topography of the land near the existing US 50 to SR28 intersection. This area is relatively flat with an average grade along the roadway of approximately 3% near the intersection. To achieve required grade separation, both US 50 overpass and SR28 underpass will need further grading. Some stormwater piping under US 50 may be required to drain the underpass to avoid flooding. Also, the underpass portion of SR28 would need to be displaced toward the south to avoid the steep uphill grade to the northeast. This will allow the underpass portion of SR28 to intersect US 50 at a more oblique angle, minimizing excavation of the steeper hillside to the northeast.

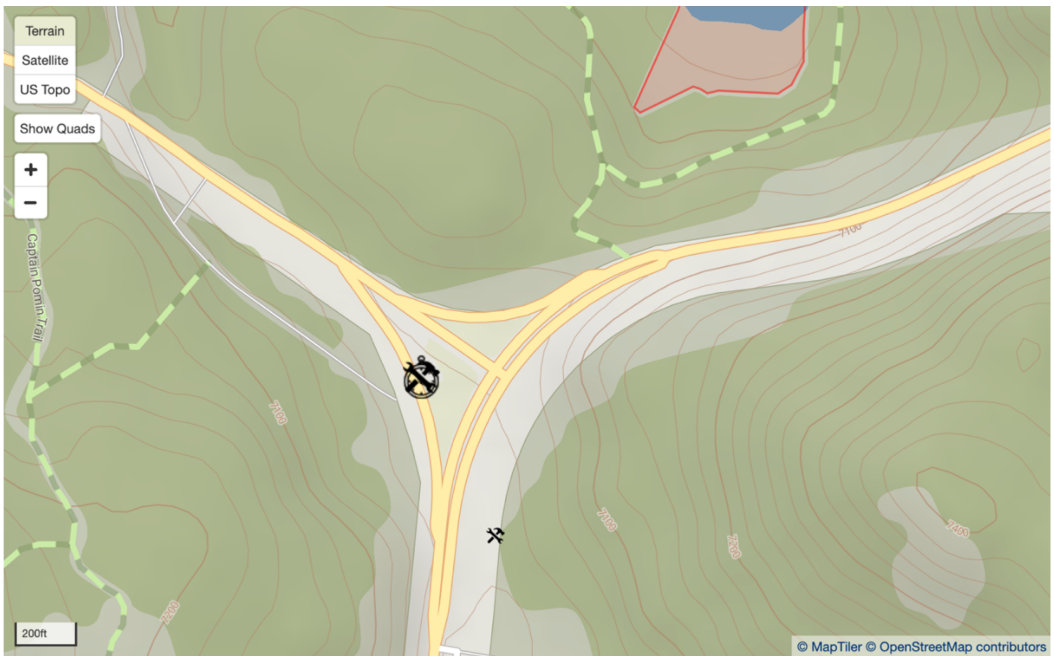

Figure 4. Topographic Map of Area Around Existing Spooner Trumpet Interchange.

Horizontal Alignment (US 50 Overpass)

The existing horizontal turn radius for US 50 at the SR20 intersection is approximately 1100 feet. Table 1 shows the required turn radius as a function of superelevation rate (bank angle in %) from AASHTO's *The Green Book*[4]. The posted speed limit is 50 mph, which is 10 mph below the design speed of 60 mph. Clearly, the existing turn radius is less than the minimum, even for a 6% superelevation (1,330 ft). Therefore, we will not further reduce this radius.

Table 1. Radii and Superelevation Rates for Non-Urban Roads

Superelevation Rate (%)	Minimum Radius -- Inside Edge (ft)			
	Design Speed			
	50 mph	55 mph	60 mph	65 mph
Normal Crown	7,870	9,410	11,100	12,600
Reverse Crown	5,700	6,820	8,060	9,130
2.2	5,100	6,110	7,230	8,200
3.0	3,480	4,200	4,990	5,710
4.0	2,300	2,810	3,390	3,950
5.0	1,510	1,890	2,330	2,800
6.0	833	1,060	1,330	1,660
Based on Superelevation Diatribution Method 5, AASHTO's The Green Book				
Max Superelevation < 6%				

Horizontal Alignment (Loop)

Table 2 shows the required horizontal turn radius as a function of superelevation rate for a loop on-ramp. We assume a design speed of 30 mph, again 10 mph above a posted ramp speed of 20 mph, which can accommodate larger trucks that might travel on SR28 (e.g., logging transports, construction and maintenance vehicles, and fire trucks)[4]. We select a nominal horizontal curve radius of 231 ft with 6% superelevation. These parameters can be accommodated within with the topography described above. This horizontal curve radius should be sufficient to allow a lane width of 14' (TBD).

Table 2. Radii and Superelevation Rates for Non-Urban Roads

Superelevation Rate (%)	Minimum Radius -- Inside Edge (ft)			
	Design Speed			
	25 mph	30 mph	35 mph	40 mph
2.2	1,450	2,000	2,630	3,370
3.0	944	1,320	1,760	2,270
4.0	511	766	1,070	1,440
5.0	292	456	654	911
6.0	144	231	340	485
Based on Superelevation Diatribution Method 5, AASHTO's The Green Book				
Max Superelevation < 6%				

Vertical Alignment

Vertical alignment is an important parameter in achieving a safe line-of-sight distance. Figure 5 shows the vertical alignment of US 50 near the bridge crest for the trumpet interchange. The tangent grades for this crest are 4.8% and 2%, both in the same direction (hence Type II alignment). The algebraic difference in grades is 4.8% - 2% = 2.8%. Figure 5 shows the required length of a crest vertical curve as a function of the design speed (V) and the algebraic difference in grades (A) to achieve the required line-of-sight distance[4]. For a design speed of 60 mph, the minimum length between vertical point of curvature (VPC) and vertical point of tangency (VPT) is approximately 400 ft. We choose to relax the design by doubling the length of the crest to 800 ft, which is still well within the ~3,000 ft available.

The vertical offset (E) at the vertical point of intersection (VPI), which corresponds to the location of the bridge, is given within the AASHTO *The Green Book* as:

$$E = \frac{AL}{800} = \frac{(2.8\%)(800\,ft)}{800} = 2.8\,ft$$

The height of the US 50 roadway over the bridge is 10 ft - 2.8 ft = 7.2 ft above the existing grade level. Allowing for 2 ft bridge thickness and 15 ft bridge clearance, this sets the level of the SR28 roadway at the base of the bridge at 9.8 ft below the existing grade. These parameters help equalize the volume of fill dirt from underpass excavation to overpass fill.

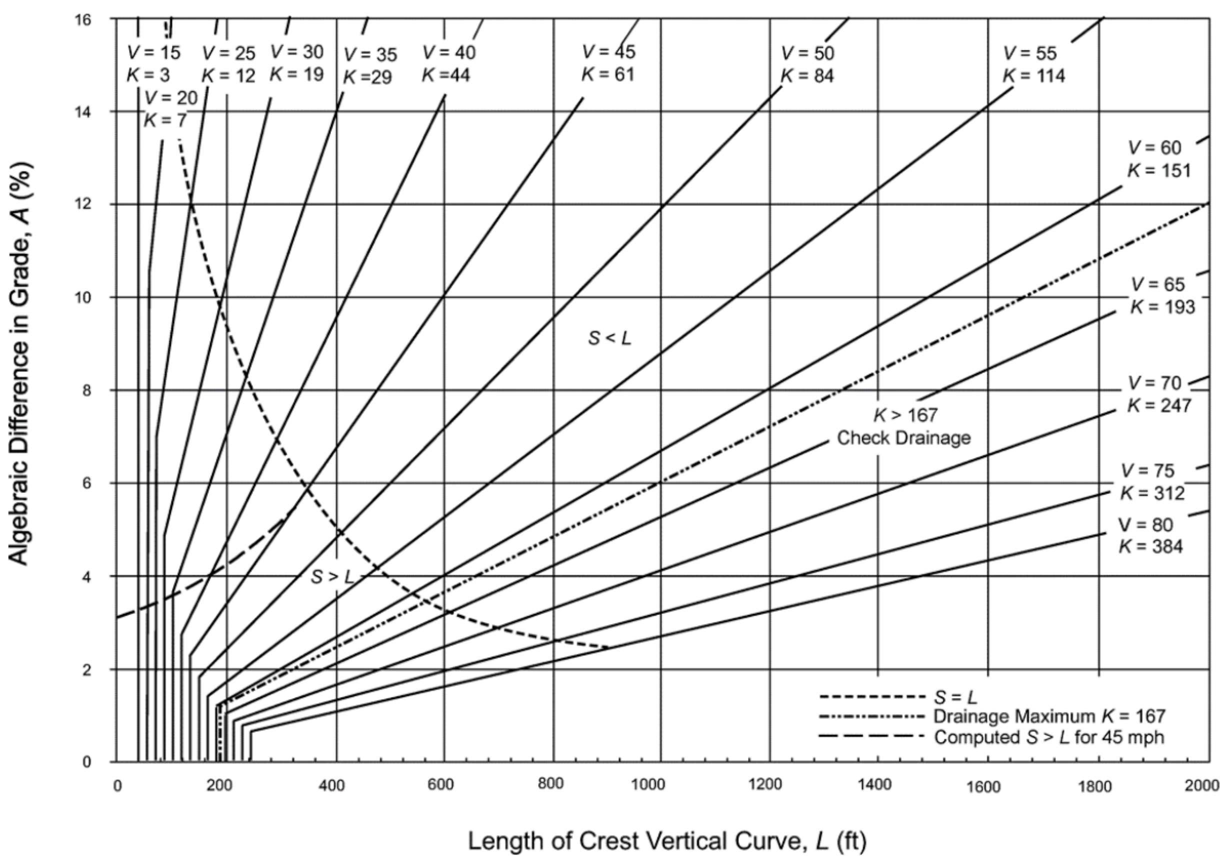

Figure 5. Design Controls for Crest Vertical Curves

Figure 6 shows the crest vertical alignment design along the US 50 centerline, exaggerated in the vertical dimension. The grades are shown as averages, an actual design would smooth these over the span. Ramps for both indirect (loop) and semi-directional are shown with opposite 1% grades.

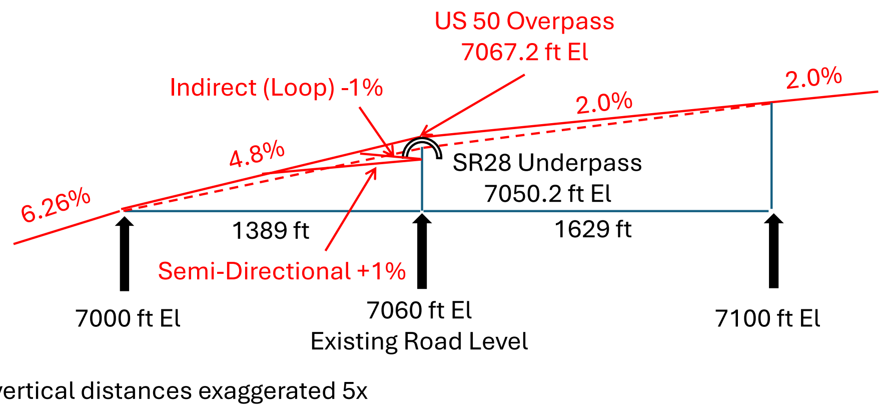

Figure 6. Vertical Alignment of US 50 Roadway with Trumpet

Bicycle Lanes

The unimpeded traffic lanes afforded by the trumpet interchange configuration also allows for the implementation of bicycle lanes that would not cross the roadway for all through and turn movements. This will substantially enhance bicycle safety and avoid frustration for both cyclist and driver. Adding a bicycle lane to the inner circle of the loop on-ramp will not change the horizontal alignment calculation as the bicycle lane can be safely designed to have a much tighter radius.

Conclusions:

A trumpet-type interchange is technically feasible at the US 50 and SR20 intersection near Spooner Summit and provides several advantages over the 3-leg large-scale roundabout proposed in the CMP:

- Free-flow of traffic on US 50
- Improved automobile and truck turn movements in all directions, minimizing wait time
- No weaving (lane change) movements, thus avoiding certain accident types
- Improved bicycle safety by eliminating crossing movements
- Improved evacuation operations with no roadway reconfiguration

These advantages are offset by an increase in design and construction costs, and an increase in construction time. The re-grading and rainwater drainage designs may require a more extensive environmental impact analysis and permitting.

Recommendations:

Tahoe East Shore Alliance (TESA) recommends that NDOT take the following actions before implementing the proposed roundabout at the SR28 intersection of US 50 near Spooner Summit:

1. Conduct a formal Intersection Control Evaluation (ICE) documenting the alternative configurations and rationale for the preferred selection, per FHWA guidelines. The ICE should include a trumpet-type interchange, as described above.

2. Make the ICE report available to the general public and accept verbal and written comment.

3. If NDOT concludes that a roundabout should be considered and would not exacerbate the traffic congestion relative to the existing control mode, design a reconfigurable roundabout able to accommodate three lanes of egress (evacuation traffic) and one lane of ingress (firefighting and service vehicle traffic) during probable worst-case wildfire evacuation scenarios.

4. Involve community members in every phase of the design.

References:

1. R. Byren, " Are US 50 Roundabouts Justified based on FHWA Thresholds?," Tahoe East Shore Alliance, https://eastshorealliance.com/wp-content/uploads/Roundabout-Paper-Jan-31-2024.pdf, Jan. 2024.

2. M. Chandler, et al, "Draft US 50 East Shore Corridor Management Plan (CMP)," Nevada Department of Transportation, https://us50eastshore.com/uploads/US_50_East_Shore_CMP_Feb2024_DRAFT.pdf?v=2, February 2024.

3. Topographic Map of Spooner Lake NV, OpenStreetMap contributors, https://www.anyplaceamerica.com/directory/nv/douglas-county-32005/reservoirs/spooner-lake-861535/, downloaded March 2024.

4. "A Geometric Policy on the Design of Highways and Streets (The Green Book)," 7th Edition, American Association of State Highway and Transportation Officials, Sep. 2018. (see http://onlinemanuals.txdot.gov/TxDOTOnlineManuals/txdotmanuals/rdw/vertical_alignment.htm)

Author Biography

Robert Byren: Mr. Byren is a retired electrical engineer with over 40 years professional experience in military lasers, laser radar, beam control, adaptive optics, thermal imaging, and optical metamaterials. Prior to retirement, he served as Chief Technologist for Raytheon's Space and Airborne Systems business unit with responsibility for the senior technical staff, intellectual property, innovation, and university relations. Post retirement, he led a small consulting firm in the field of high energy laser systems. Mr. Byren holds 43 US Patents and has co-authored 55 books and technical papers. He received his MSEE degree from Stanford University in 1975 and his BSEE degree from Lehigh University in 1974.