Review of Highway-Rail Grade Crossing Alternatives

Prepared by CTC, Inc., for

The City of Richland, Washington

January 17, 2017

WA, Richland
Steptoe Street
DOT # 310397T, MP 46.10
B Line (Richland Industrial Lead)

Review of Highway-Rail
Grade Crossing Alternatives

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Tri-City Railroad
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Prepared by:

I hereby certify that this Report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Washington. This report represents an electronic version of the original hard copy report, sealed, signed and dated by Nicole L. Jackson, PE, PTOE. The content of the electronically transmitted report can be confirmed by referring to the original hard copy which will be kept on file with CTC, Inc.

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Introduction

Nestled in the southeastern part of the State of Washington, where the Yakima and Columbia Rivers meet, is the City of Richland. Originally a community of 300 and about half the size of Rhode Island, Richland now boasts more than 53,000 inhabitants and 39.11 square miles. The City, together with neighboring communities Pasco and Kennewick, make up the vibrant Tri Cities metropolitan area, a thriving community more than 250,000 people call home.

Over the last several years, Richland and its neighbors have experienced tremendous residential growth and commercial development. Part of this rapid expansion can be traced to Richland's easy access to major highways from State Route 240 and up into Interstate Highway 182. The metro boasts an active regional rail system owned by the Port of Benton and operated by the Tri-City Railroad (TCRY).

Photo 1 - Steptoe Street Region, 1996

Photo 2 - Steptoe Street Region, 2015

While the railroads are important to the region, existing tracks can pose challenges for city planning, especially when opportunities for new developments arise. The City's focus on expansion is inclusive, as indicated in its 10-Year Comprehensive Plan, and includes attention to the railroad crossings established long before commercial and residential growth occurred. One such crossing on the northern area of Steptoe Street is soon to intersect with a busy commercial property. Studies conducted around this region predict an increase in traffic and pedestrian volume with the introduction of the Tapteal Lifestyle Center, which will be constructed on the west side of Steptoe Street just south of the highway-rail grade crossing.

The City's 10-Year Plan also includes details on land use designation, and indicates that the region east of the crossing along Tapteal Drive will consist primarily of commercial land use in addition to the lot west of Steptoe Street. The increase of overall traffic in the area will need to be taken into careful consideration when designing the traffic signal due to the close proximity of the highway-rail grade crossing.

CTC was approached by the City in the Fall of 2014 to review the Steptoe Street highway-rail grade crossing and provide appropriate preemption recommendations to support expected commercial growth. The following report provides fact-based analysis and assessment of the proposed alternatives for the highway-rail grade crossing, highlighting the importance of safety in the design decision making process, and offers recommendations for consideration by the City of Richland, City of Kennewick, Port of Benton, Tri-City Railroad, and other operating railroads.

The primary goal is to ensure safety at the crossing while maintaining efficient traffic flow over the crossing with the installation of traffic signals interconnected to the grade crossing active warning system at Steptoe Street.

1.0 General Information

The Tri-City Railroad (TCRY) is a common carrier Class III railroad operating freight services under a long-term lease arrangement with the Port of Benton. The railroad system encircles Richland's city center and connects the upper east sector of Washington State with regions across the United States. In addition to TCRY, BNSF Railway (BNSF) and Union Pacific Railroad (UPRR) transport freight shipments along these tracks, to areas throughout the City of Richland.

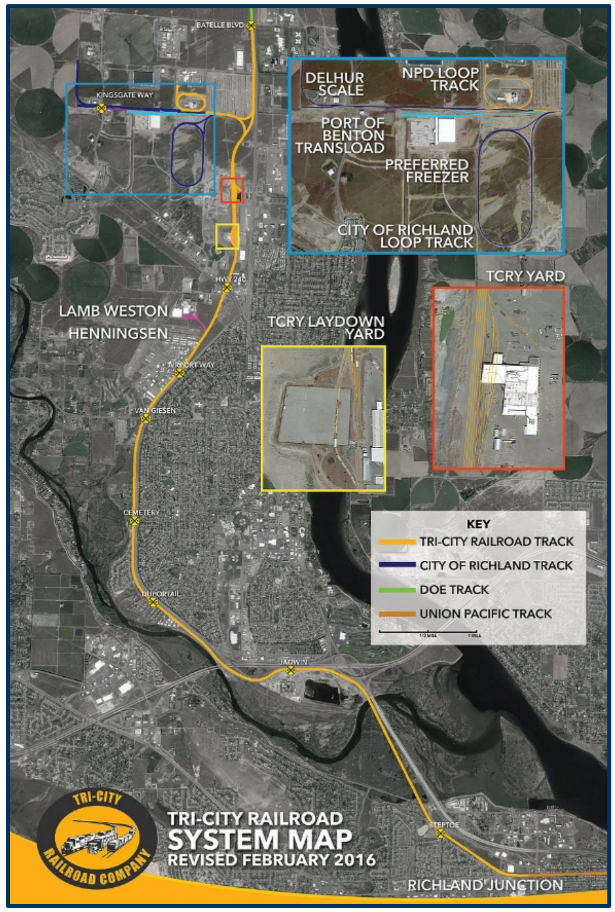


Figure 1 – Tri-City Railroad System Map

CTC, Inc. (CTC) was tasked by the City of Richland (City) to review the highway-rail grade crossing, DOT# 310397T, located jointly in Kennewick and Richland, Washington on Steptoe Street between the intersections of Tapteal Drive and Canyon Street. This crossing is located approximately one quarter-mile south of a roundabout ramp egress from State Route 240.

From inception of this project, it was recognized that involvement from the two additional operating railroads, BNSF and UPRR, would be essential in providing a thorough analysis of the current rail operations.

This report serves three functions:

1. Study existing data at the Steptoe Street highway-rail grade crossing including crash history, existing and projected traffic data and train volumes, speeds, and operations.
2. Analyze and provide recommendations concerning the City's proposed split-t intersection or four-leg intersection design options to determine a cost effective and safe solution for railroad personnel and the traveling public.
3. Provide recommendations for modifications and enhancements concerning the final design and operation of the railroad active warning system and traffic signal system.

CTC inc

2.0 Area Characteristics

2.1 Tri-City Railroad Operations

The Richland Industrial Lead is an important junction for the Tri-Cities Region of Washington. The railroad line was acquired by the Port of Benton from the Department of Energy in 1998. The Port entered into a long-term lease with TCRY in 1999 to operate and maintain the facility. This segment of the rail allows for their continued freight transport, along with BNSF and UPRR, to north of the city. Combined, TCRY, BNSF and UPRR operate approximately four daily trains through the grade crossing at Steptoe Street Monday through Friday.

2.2 Land Development

The City of Richland has specific goals in mind regarding land development. Published in the City's Comprehensive Plan, Land Use Goal 3 is aimed at the promotion of commercial expansion to improve the economic trajectory of the city. As part of this initiative, properties near the northern part of Steptoe Street are planned for future commercial and residential development. Steptoe Street also serves equally growing residential and commercial areas of Kennewick, a neighboring city to the southeast of Richland.

Existing rail lines must also be taken into account during land development. Steptoe Street crosses the Richland Industrial Lead at milepost 19.63, granting commuters easy access to State Route 240. Since the city plans to develop areas near the tracks, the proper intersection design and grade crossing warning system must be implemented to accommodate for the increased activity in the region.

2.3 Access North of the Highway-Rail Grade Crossing

While improved access through the installation of a highway rail-grade crossing aids economic expansion, it also creates the probability of a vehicular-train collision. Alternate routes were evaluated by navigating major roadways throughout the cities of Richland and Kennewick for a possible closure of the Steptoe Crossing. If this crossing was to be closed, alternate routes to areas north of the Steptoe Street crossing would include either a route west to Leslie Road or a route east to North Columbia Center Boulevard.

The grade separated crossing under the TCRY tracks at Columbia Park Trail is approximately 0.3 miles northwest of the Steptoe Street crossing. Traffic would be required to commute along Steptoe Street, Gage Boulevard, Leslie Road, and Columbia Park Trail for a total of 3.3 miles in order to pass the Columbia Park Trail crossing at DOT# 808937S.

Figure 2 - Alternate route west of Steptoe Street

Figure 3 - Alternate route east of Steptoe Street

The second alternate crossing is approximately 1 mile east of Steptoe Street crossing at North Columbia Center Boulevard. Traffic would be required to commute along Steptoe Street, Gage Boulevard, Center Parkway, Quinault Avenue, and Columbia Center Boulevard for a total of 3.75 miles in order to pass the North Columbia Center Boulevard crossing at DOT# 808969X.

While a closed crossing is the safest alternative, the Steptoe Street crossing provides the developing commercial and residential areas with convenient access to State Route 240 and areas north of the highway. Alternate access and routes would require excessive adverse travel, as well as, additional emergency response times. Therefore, an upgrade of the crossing and proper engineering design is necessary to achieve safety for the motoring public.

3.0 Project Characteristics

3.1 Highway-Rail Grade Crossing

Steptoe Street is currently a four-lane, two-way road crossing the railroad. There is an existing stop controlled intersection approximately 180 feet north of the crossing at Tapteal Drive. The roadway over the crossing, which is separated by a 12-foot painted exclusion zone, is approximately 24-feet wide for the eastbound lanes and 24-feet wide for the westbound lanes with 4-foot shoulders on each side and sidewalks. There is a positive grade approaching the crossing southbound of 4.4%, while the grade approaching the crossing northbound is -7.4%.

Location map of subject crossing:

Photo 3 – Steptoe Street Grade Crossing

The railroad currently operates on one main line track crossing Steptoe Street at an approximate 45-degree angle with a current timetable maximum allowable speed of 20 miles per hour. The active warning system[1] train detection is provided by a phase motion detector[2] for the main

[1] **Active Warning System** – A system of devices used to inform road users of the approach or presence of rail traffic at grade crossings. These systems include flashing-light signals (both mast-mounted and cantilevered), bells, automatic gates, active advance warning devices, and highway traffic control signals. (FHWA Railroad-Highway Grade Crossing Handbook, Part IV, Section I)

[2] **Phase Motion Detector** - A motion sensitive device capable of detecting the movement of a train toward a crossing over a fixed distance. The actual warning time provided for a crossing varies as a function of the speed of the train. (AREMA, Part 1.1.1)

track. There is currently 30 seconds of warning time provided at a design speed of 25 miles per hour for the grade crossing. The active warning system includes two electro-mechanical bells[3], railroad flashing-light signals[4] and automatic gates[5] for north and south vehicular and pedestrian sidewalk approaches. Grade crossing advance warning signs (W10-1) are provided for northbound and southbound on Steptoe Street.

This crossing is located a quarter-mile southeast of a roundabout leading onto State Route 240 and up to Interstate Highway 182. Traveling south, Steptoe Street provides a connection to Interstate Highway 82 via Clearwater Avenue and continues south via Bob Olson Parkway and Hildebrand Boulevard to connect with US Highway 395 in Kennewick. As the principal arterial with a direct connection to State Route 240, Steptoe Street provides numerous businesses, residential areas and schools with access to State Route 240. According to Richland's comprehensive plan, areas south of Tapteal Drive and north of the tracks east of the crossing will also be developed for commercial land use.

Photo 4 – Access to Major Highways

[3] **Electro-Mechanical Bell** – An audible warning device typically operated in conjunction with railroad flashing-light signals to provide additional warning for pedestrians, bicyclist and/or other non-motorized road users. (MUTCD Chapter 8C, Section 8C.02); A repeating bell, operated by direct current, as an adjunct to highway-rail grade crossing warning systems. (AREMA, Part 3.2.60)

[4] **Flashing-Light Signals** - A warning device consisting of two red signal indications arranged horizontally that are activated to flash alternately when rail traffic is approaching or present at a grade crossing. (MUTCD Chapter 1A, Section 1A.13)

[5] **Automatic Gates** – A traffic control device used in conjunction with flashing-light signals to prohibit vehicle movement onto the tracks. (MUTCD Chapter 8C, Section 8C.04)

3.2 Alternative Design Options

With future development of surrounding areas and the City's need for improvements in traffic control near the Steptoe crossing, three intersection design alternatives were proposed:

1. Split-T Intersection
2. Four-Leg Intersection
3. Roundabout

These concepts were explored by the City's traffic engineers, as well as JUB Engineers (City consultant) who evaluated the volume of traffic in this region and the serviceability of each proposed alternative.

The split-t intersection design maintains the existing intersection of Tapteal Drive to the north of the crossing and creates new access from the west of Steptoe Street approximately 170 feet south of the crossing. This option would require the installation of traffic signals at both intersections that would each require interconnection to the grade crossing active warning system.

Figure 4 - Alternative 1: Split-T Intersection

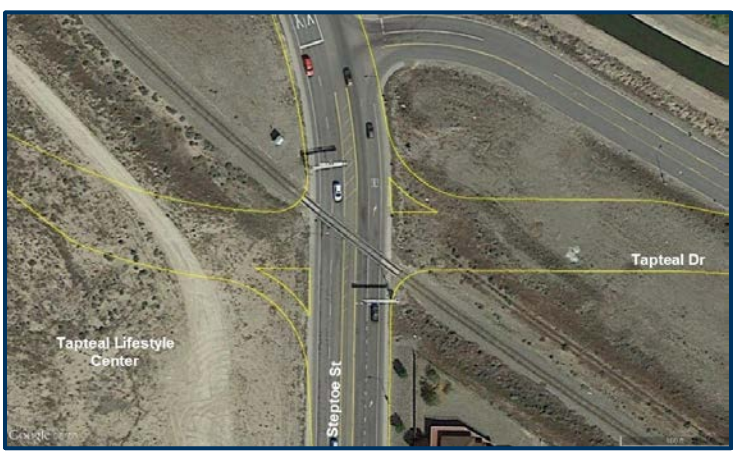


Figure 5 - Alternative 2: Four-Leg Intersection

The four-leg intersection would realign Tapteal Drive further south of its existing location and cross Steptoe Street at the highway-rail grade crossing. The eastbound approach from the Tapteal Lifestyle Center commercial development would join as one of the legs of the intersection. The railroad tracks would pass diagonally through the intersection.

The third alternative was a roundabout intersection over the Steptoe Street crossing.

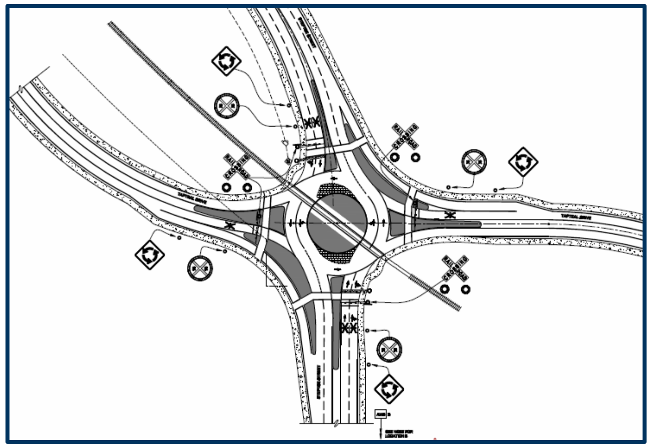


Figure 6 – Alternative 3: Roundabout conceptual design

Traffic signals are imperative components of an intersection near a railroad crossing, and must distribute right-of-way ruling to designated vehicles in order to allow clearance of the railroad tracks. For a roundabout intersection, traffic signals would need to be installed from all four approaches. These traffic signals would remain green in absence of a train, achieving the junction's improvement in traffic flow. However, in the event of a railroad preemption call, there must be enough time included in the design for the design vehicles to clear the roundabout prior to train arrival. While this does create a more controlled intersection, alterations to the common roundabout will interrupt driver expectations. Such effects would be more apparent due to the presence of a typically functioning roundabout north of the studied crossing at the intersection of Steptoe Street and Columbus Park Trail. The City determined that a roundabout would be excluded from this study due to the inherent safety concerns and rejection of the roundabout concept by the operating railroads.

4.0 Design Elements

4.1 Alternative 1: Split-T Intersection

Alternative 1 proposes that Tapteal Drive remain in its existing location 190 feet north of the grade crossing. The roadway exiting from the Tapteal Lifestyle Center will intersect Steptoe Street approximately 170 feet south of the crossing, creating a split-t intersection.

Steptoe Street would remain a four-lane, two-way road crossing the railroad as it exists today. Two lanes will run northbound from the Tapteal Lifestyle Center intersection, crossing the railroad and continuing north of Tapteal Drive. Prior to the Tapteal Lifestyle Center intersection, the City would convert the existing striped median into a northbound left turn only lane on Steptoe Street. Southbound Steptoe Street will consist of two lanes beginning from the Tapteal Drive intersection, crossing the railroad and continuing south of the Tapteal Lifestyle Center intersection. Prior to the Tapteal Drive, southbound Steptoe Street will taper into a third left turn only lane.

Traffic signals would be installed for northbound and southbound Steptoe Street at both intersections. Although these are separate intersections, they will be operated by a single traffic signal controller to maintain improved traffic flow. The existing railroad flashing-light signals and automatic gates would remain for the grade crossing.

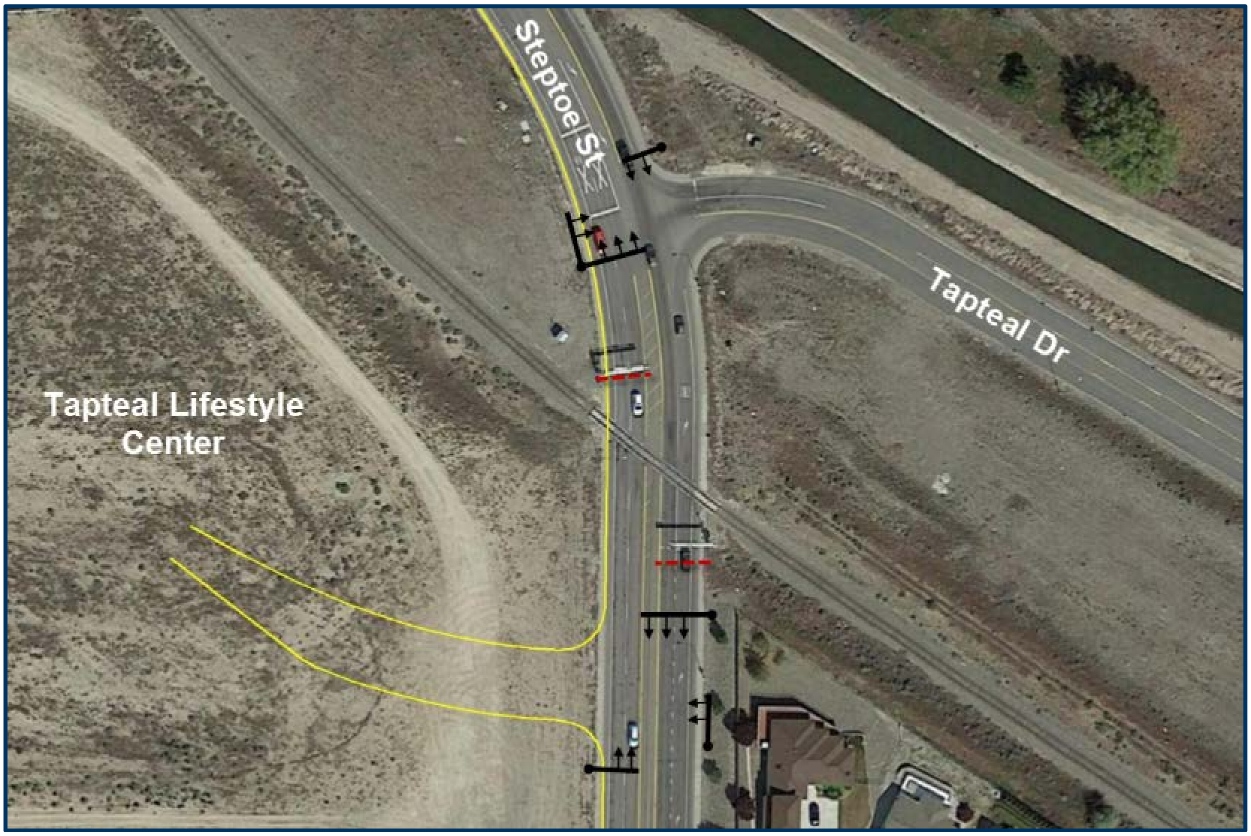


Figure 7 - Split-T: Conceptual Traffic Signal and Automatic Gates Layout

The signalized intersections would be within 200 feet of the crossing from both the north and south, requiring the Steptoe Street crossing to be interconnected to the grade crossing warning system in accordance with the *Manual on Uniform Traffic Control Devices* (MUTCD). Based on the general layout of the split-t intersection, a clear storage distance[6] (CSD) of 134 feet was determined for the southbound approach. The minimum track clearance distance[7] (MTCD) for

[6] **Clear Storage Distance** - The distance available for vehicle storage measured between 6 feet from the rail nearest the intersection to the intersection stop line or the normal stopping point on the highway. (MUTCD, Chapter 1A, Section 1A.13)
[7] **Minimum Track Clearance Distance** – For standard two-quadrant warning devices, the minimum track clearance distance is the length along a highway at one or more railroad or light rail transit tracks, measured from the highway stop line, warning device, or 12 feet perpendicular to the track center line, to 6 feet beyond the track(s) measured perpendicular to the far rail, along the centerline or edge line of the highway, as appropriate, to obtain the longer distance. (MUTCD, Chapter 1A, Section 1A.13)

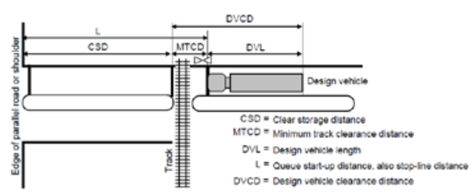
the grade crossing was determined to be 58 feet. Since the design must consider the conflicting pedestrian movement, the pedestrian clearance time during right-of-way transfer is calculated for a crosswalk that is approximately 63 feet long. Based on the intersection layout and City's proposed traffic signal operation, the proposed right-of-way transfer time[8] for the split-t intersection design is as follows:

	Proposed Values (Seconds)
Controller Preemption Delay Time[9]	0.0
Controller Preemption Response Time[10]	0.0
Minimum Green before Track Clearance	5
Walk before Track Clearance	0
Pedestrian Change before Track Clearance*	18
Yellow Change before Track Clearance	0
Red Clearance before Track Clearance	1.0
Maximum Right-of-Way Transfer Time	**19**

Table 1 – Split-T: Proposed Right-of-Way Transfer Time

* *Pedestrian Intervals time concurrently with minimum green time.*

In addition to required allowance of pedestrian change during the right-of-way transfer time, the split-t intersection must also incorporate the time needed to clear the tracks. As a result, the advance preemption time[11] (APT) required for this alternative is 34 seconds (see Appendix B for preemption calculations supporting document).



[8] **Right-of-Way Transfer Time** – The maximum amount of time needed for the worst case condition, prior to the display of the track clearance green interval. This includes any railroad or light rail transit or highway traffic signal control equipment time to react to a preemption call, and any traffic control signal green, pedestrian walk and clearance, yellow change, and red clearance intervals for conflicting traffic. (MUTCD, Chapter 1A, Section 1A.13)

[9] **Controller Preemption Delay Time** – The traffic signal controller programmed time between receipt of the preemption call and initialization of the preemption sequence.

[10] **Controller Preemption Response Time** – Time provided by the traffic signal controller application designer to account for controller reaction time of individual components prior to initiating activation of the preemption sequence.

[11] **Advance Preemption Time (APT)** - The period of time that is the difference between the required maximum highway traffic signal preemption time and the activation of the railroad or light rail transit warning devices. (MUTCD, Chapter 1A, Section 1A.13)

4.2 Alternative 2: 4-Leg Intersection

Alternative 2 proposes realigning Tapteal Drive to the south, veering away from the nearby canal and intersecting perpendicular to Steptoe Street at the highway-rail grade crossing. The proposed roadway exiting from the Tapteal Lifestyle Center will intersect Steptoe Street as a continuation of Tapteal Drive, creating a four-leg intersection. Channelized right turns will also be installed for both the eastbound and westbound approaches. Steptoe Street would maintain four 12-foot through lanes; however, an additional 12-foot left turn only lane would be installed for the northbound left turn and southbound left turn lanes on Steptoe Street.

Traffic signal indications will be installed for each approach at the four-leg intersection. Railroad flashing-light signals and automatic gates would be installed after the crosswalks, preventing pedestrians from encroaching into the intersection and near the tracks. The gate performs as a barrier between the train movement and pedestrian movement and allows for the completion of pedestrian movements during train movements.

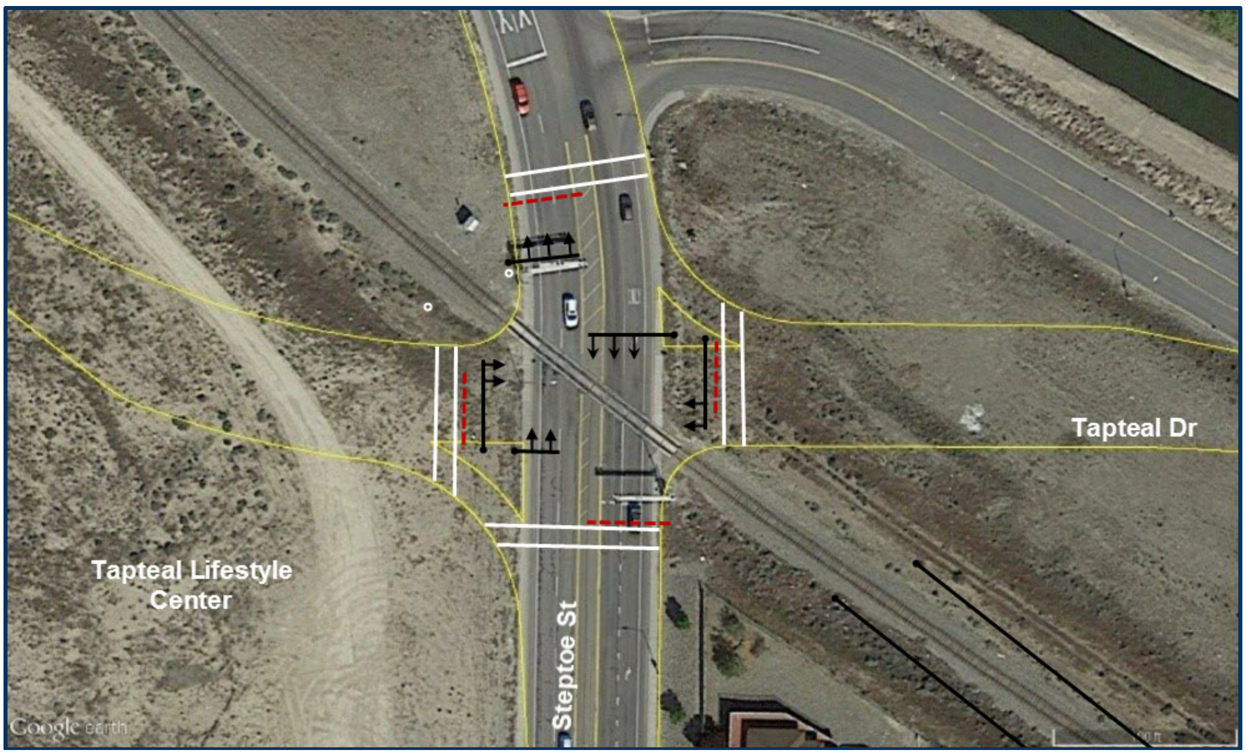


Figure 8 – Four-Leg: Conceptual Traffic Signal and Automatic Gates Layout

Since the grade crossing would be located within the intersection, this design would result in no vehicles queuing over the tracks. As such, there is no queue clearance time[12] and the advance preemption time needed for the intersection will only need to be sufficient in transitioning the intersection to an all-red state:

	Proposed Values (Seconds)
Controller Preemption Delay Time	0.0
Controller Preemption Response Time	0.0
Minimum Green before Track Clearance	5
Walk before Track Clearance	0
Pedestrian Change before Track Clearance	0
Yellow Change before Track Clearance	4.6
Red Clearance before Track Clearance	0
Maximum Right-of-Way Transfer Time	**9.6**

Table 2 - Four-Leg: Proposed Right-of-Way Transfer Time

Due to the unique design of the crossing, the pedestrian movements will not impact clearance of the tracks and therefore do not need to be honored during the right-of-way transfer.

With the tracks located within the intersection of the two main roadways, a track clearance movement will not be necessary and the grade crossing will begin flashing-light signals activation after the traffic signal has completed its right-of-way transfer time (minimum green and yellow change only). As a result, the advance preemption time required for this alternative is 10 seconds (see Appendix C for preemption calculations supporting document).

UPRR has expressed concerns regarding the layout of the four-leg intersection and its impact on the safety of motorcyclists. They are apprehensive of the possibility that motorcyclists could lodge their wheels between the flanges of the railroad tracks due to the skewed angle of the tracks. However, the four-leg intersection reduces the likelihood of this type of event and furthermore eliminates the 45-degree skewed angle for the eastbound and westbound left turn

[12] **Queue Clearance Time** - The time required for the design vehicle of maximum length stopped just inside the MTCD to start up and move through and clear the entire MTCD. If pre-signals are present, this time shall be long enough to allow the vehicle to move through the intersection, or to clear the tracks if there is sufficient CSD. If a four-quadrant gate system is present, this time shall be long enough to permit the exit gate arm to lower after the design vehicle is clear of the MTCD. (MUTCD, Chapter 1A, Section 1A.13)

movements. With proper marking, this intersection layout guides left turning vehicles, including motorcyclists, to cross the railroad tracks at a 90-degree angle:

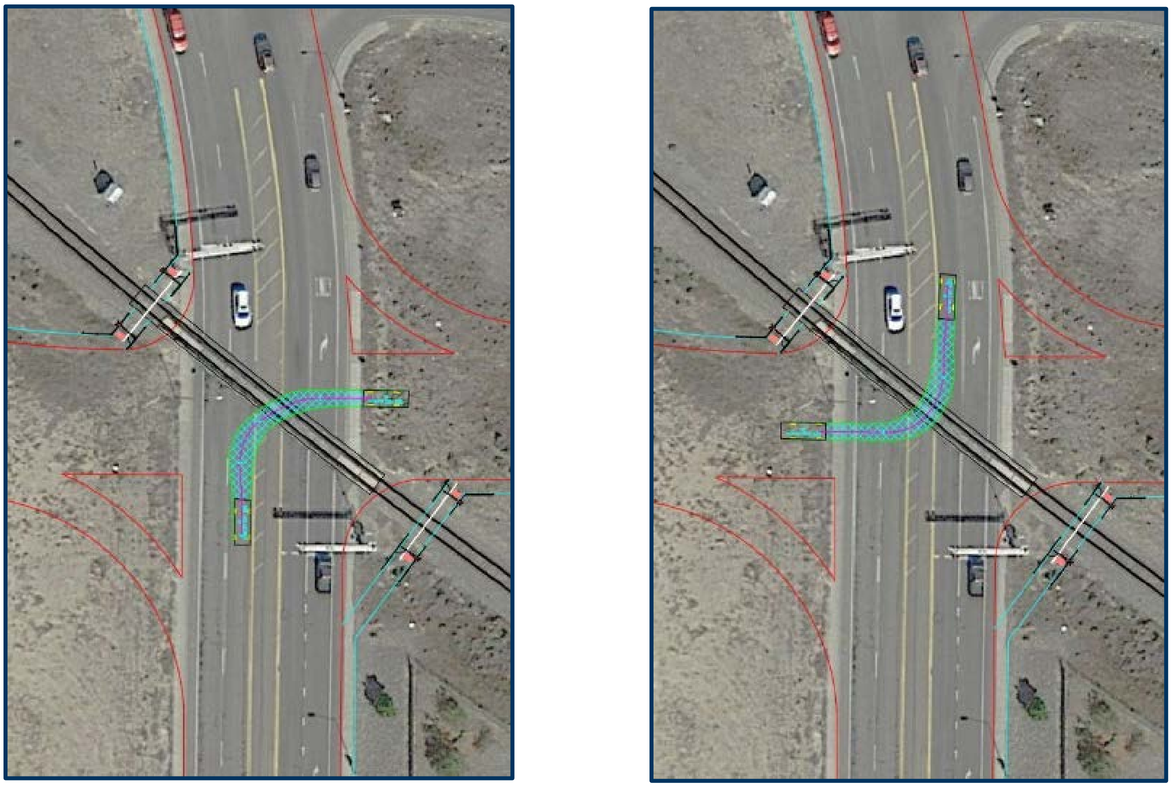


Figure 9 – 90-degree angle crossing eastbound and westbound left turns

4.3 Alternative Comparisons

Safety of the grade crossing is the most important aspect in deciding the final recommended alternative for the project. One way to avoid collisions at railroad crossings is by keeping the tracks cleared as much as possible.

As part of a preliminary study, the City consultant provided projected traffic queue lengths for each alternative. The southbound through queue length for the split-t intersection, prior to the Tapteal Drive intersection is 968 feet. However, the city consultant's study allows 292 feet of additional queue length to remain on the tracks and even extending back into the intersection. As for the northbound through movement prior to the Tapteal Lifestyle Center intersection, the queue length is 664 feet, and 242 feet of additional northbound queue length is on the tracks as well. The southbound through movement for the four-leg intersection has a queue length of 1,297 feet. The northbound through movement for the four-leg intersection has a queue length of 815 feet.

The split-t intersection's layout allows the queue to consistently back up over the tracks due to the inherent nature of the traffic signal operations. To avoid such predicaments, additional time will be needed for each phase that passes over the tracks in order to clear vehicles that have entered the clearance storage distance. With such high volumes predicted in the given region, the probability of traffic being backed up over the tracks is a guarantee during peak hours of the day.

Advance preemption time can also be a substantial factor in comparing alternative designs. While warning devices at railroad crossings can improve them substantially, APT is needed to sequentially clear the tracks prior to train arrival. As a result of the design and preemption calculation review, the following table offers a comparison of the proposed railroad preemption values and APT required for each of the alternatives:

	Advanced Preemption Time (Seconds)	
	Alternative 1	Alternative 2
Minimum Time (MT)[13]	20	20
Clearance Time (CT)[14] *	3	12
Prescribed Warning Time or Minimum Warning Time[15] (MT + CT + CT other)	23	32
Buffer Time (BT)[16] *	5	5
Total Warning Time (TWT) (MT + CT + CT other + BT)	28	37
Equipment Response Time (ERT)[17] *	5	5
Advance Preemption Time (APT)	34	10
Total Approach Time (TAT)* (MT + CT + CT other + BT + ERT + APT)	**67**	**52**
***Railroad to verify time needed**		

Table 3 – Comparison of Advance Preemption Times

13 **Minimum Time (MT)** – Highway-rail grade crossing warning devices shall operate for a minimum of 20 seconds for nominal operation of through trains prior to the arrival at a grade crossing in accordance with MUTCD and 49 CFR §234.225.

14 **Clearance Time (CT)** - If the MTCD exceeds 35 feet, clearance time is one second for each additional 10 feet, or portion thereof, over 35 feet. (AREMA, Part 3.3.10, B. 2a.)

15 **Prescribed Warning Time or Minimum Warning Time** - For through train movements, prescribed warning time or minimum warning time is the least amount of time active warning devices shall operate prior to the arrival of a train at a highway-rail grade crossing. For two quadrant gates, this time is the sum of MT plus CT. For four quadrant gates, this time is the sum of MT plus CT plus (Exit gate clearance time [EGCT] – CT – 5 [but not less than zero]). (AREMA, Part 3.3.10, B. 4.)

16 **Buffer Time (BT)** - Buffer Time is discretionary and may be provided to accommodate for minor variations in train handling, track circuit variability and allowable tolerances within locomotive speed measurement apparatus. Buffer time may be lost under certain conditions and shall not be considered for Prescribed Warning Time or Advance Preemption Time. (AREMA, Part 3.3.10, B. 5.)

17 **Equipment Response Time (ERT)** – Time provided by the system application designer to account for system reaction time of individual components prior to initiating activation of warning device control equipment. (AREMA, Part 3.3.10, B. 6. [A, B and C])

The maintenance of proper traffic flow is important in preserving compliant driver behavior and keeping the motoring public content. The four-leg intersection alternative permits more fluid transitions between traffic movements. The phase timing and phase change for this intersection would behave similarly to a four-leg intersection without a railroad crossing, in regards to the intersections phase timing and phase changes. Due to the close proximity of each t-intersection to one another, the split-t intersection design is extremely inefficient. Each phase that involves crossing the railroad requires additional time during these cycles to maintain clearance of the tracks.

Highway-rail grade crossings ideally should have a 90-degree angle at their point of intersection. This angle not only allows vehicles, particularly buses and trucks, to maintain proper visuals down the track, but it also ensures that bicyclists and motorcyclists will navigate across the tracks safely. Currently, the railroad tracks are at a 45-degree angle with the intersecting Steptoe Street. With a design based on the split-t intersection, the northbound and southbound left turn movements would occur prior to the crossing and remain unaffected. Similar to the existing crossing, however, the split-t intersection requires all Steptoe Street through traffic to traverse the tracks at a 45-degree angle. This traffic includes northbound and southbound through movements, eastbound and westbound left turn movements onto Steptoe Street, as well as northbound and southbound right turn movements onto Tapteal Drive. In contrast, the four-leg intersection allows the eastbound and westbound left turn movements to cross the tracks at the preferred 90-degree angle, lessening the number of vehicles that would otherwise pass at a 45-degree angle in the split-t intersection. This characteristic also applies to the northbound and southbound right turn movements.

According to the estimated magnitude of cost conducted by CTC, the four-leg intersection will require slightly more funding in comparison to the split-t intersection. In addition to the cost of a complete crossing upgrade, pedestrian gates, and shunt relocation - all services required for both alternatives - the four-leg intersection will require two additional vehicle gates. The split-t intersection has a total preliminary estimated cost of $340,000 while the four-leg intersection has a total preliminary estimated cost of $400,000 (see appendix D for cost breakdowns).

5.0 Recommendations

As a result of the review, CTC proposes the following recommendations for the City of Richland's consideration for highway-rail grade crossing design and operation of the preemption system. The City of Richland is the authority regarding the design and operation of the preemption system in accordance with the MUTCD Chapter 8C, Section 8C.09.

2009 MUTCD Chapter 8C, Section 8C.09 Paragraph 6

"The highway agency or authority with jurisdiction and the regulatory agency with statutory authority, if applicable, should jointly determine the preemption operation and the timing of traffic control signals interconnected with highway-rail grade crossings adjacent to signalized highway intersections."

Note: Should the City of Richland decide to pursue the following recommendations, the Agency should be aware that multiple solutions exist for any recommendation. The City of Richland should perform due diligence to determine the solution(s) or product(s) that best meet site-specific conditions for the highway-rail grade crossing.

5.1 Intersection Design

According to the individual alternative analyses and comparisons conducted by CTC, the four-leg intersection crossing is the safest and recommended crossing configuration. This alternative was chosen as the recommended crossing alternative based on the following reasons:

- The traffic queue for this intersection design will remain behind the stop line of each approaching leg of the intersection. A preemption event at this crossing will appear as a fluid movement with the intersection, holding vehicles at a red-light with railroad flashing-light signals and automatic gates to allow the train to pass.
- The four-leg intersection will require a significantly less amount of advance preemption time.
- Due to the location of the railroad tracks, this intersection design will increase operational efficiency and provide more fluid traffic flow for the area.
- This intersection layout reduces the overall number of vehicles that will traverse the crossing at a skewed (45-degree) angle, thereby improving safety over the crossing.

The remaining recommendations apply to the selected preferred alternative 2, the four-leg intersection.

5.2 Railroad Preemption

The city must interconnect the railroad active warning system to the traffic signal located at the intersection of Steptoe Street and Tapteal Drive to provide time to allow vehicles entering the intersection a minimum green and yellow change time to clear the intersection during a preemption event. At a minimum, the following items should be considered as part of the railroad preemption design:

- **Ensure that the actual right-of-way transfer time during railroad preemption does not exceed the design value of 9.6 seconds (see the preemption calculations in Appendix C).** If the right-of-way transfer time is programmed to exceed this value, then additional APT would need to be requested by the Agency.

- **Review the traffic signal controller hardware and firmware capabilities for railroad preemption.** The traffic signal controller is an integral part of the operation of the preemption system and understanding the traffic signal controller functionality during railroad preemption is critical to the safety of the preemption operation. Many conditions such as, but not limited to, coordinated operation, train restart or second train events, emergency vehicle preemption, transit priority, or manual control will alter the operation of the traffic signal controller when those conditions are in effect. The Agency must thoroughly inspect and test the functionality of the traffic signal controller and firmware to ensure the recommended railroad preemption features can be provided. Periodic updates or revisions to the controller unit firmware or hardware may negatively affect the operation and/or programming parameters of the traffic signal controller. Any change in the firmware or hardware should be followed by a performance test in order to assure that the traffic signal controller is functioning in accordance with the design plans. At a minimum, an annual inspection should be completed to comply with Safety Advisory 2010-02 (FRA, Federal Register Volume 75, Issue 190 - Safety Advisory 2010-02).

- **Install a back-up power supply for the traffic signal equipment.** When local power outages occur, a dark traffic signal loses its ability to provide a track clearance interval. Railroad warning devices are required to be equipped with a back-up power supply to provide continuous operation for a number of hours. With the advent of LED technology, back-up power for traffic signals is now a realistic option. A back-up power supply maintains the operation of the traffic signal and its ability to display a track clearance interval. The MUTCD recommends the use of back-up power for interconnected signals in Chapter 4D, Section 4D.27.

- **Implement a Preemption Operation and Maintenance Program.** In accordance with the FRA Safety Advisory 2010-02 and FRA Technical Bulletin S-12-01, a comprehensive joint inspection program should be established between the Agency and the Railroad to provide, at a minimum, an annual operational test of the preemption system. Operational tests should also be conducted when traffic signal controller changes are made, including firmware updates.

  The Agency should develop a notification plan to contact the Railroad in the event the traffic control signal fails to operate as intended. The Agency should also develop a traffic management plan for special events or construction to help prevent motorists from stopping on the tracks as a result of the downstream traffic queues.

- **Install a warning label as recommended by the United States Department of Transportation Highway-Rail Grade Crossing Technical Working Group (USDOT TWG) in the traffic signal cabinet to alert traffic signal technicians to the presence of the interconnection with the railroad control equipment.**

5.3 Enhanced Preemption Circuitry

In order to maintain proper communication between the railroad warning system and the traffic signal, the city should provide interconnection circuits between the traffic signal controller and the railroad warning system and ensure the interconnection cable has an adequate number of conductors for the circuits requested. The interconnection between the traffic signal controller and the railroad warning system requires careful consideration as to the types of circuits to be utilized. Experience and extensive research on railroad preemption operation has revealed that the recommended interconnection circuits are necessary in order to assure that the highway-rail grade crossing and highway-highway intersection are operating together as one system. Intersection geometry, phasing, pedestrian considerations, type of controller unit, train volumes, and train speeds are all factors which must be considered in order to determine which circuits are necessary.

The following list identifies the recommended interconnection circuits:

- **Advance Preemption Circuit** - This circuit begins the preemption sequence when the railroad warning system first notifies the traffic signal controller of the approaching train (ITE, 2006).

- **Supervised Circuit** - This circuit provides a means to verify the integrity of the interconnection cable between the traffic signal controller and the railroad warning system. The purpose is to provide notification to the traffic signal controller in the event there is a failure (open or short) in the cable or associated circuitry (FHWA – MUTCD, 2009 – Section 8C.09, Paragraph 10).

- **Crossing Active Circuit** - This circuit will notify the traffic signal controller of an approaching train at the point the active warning devices (railroad flashing-lights) begin their operation. It is the circuit typically used for “Simultaneous Preemption.” (ITE, 2006).

- **Traffic Signal Health Circuit** - Where there is an advance preemption circuit, the traffic signal health circuit may be used to notify the railroad warning system if the traffic signal has an operational failure where the traffic signals are flashing or dark. When the traffic signal health circuit has de-energized, the railroad warning system devices may be activated early. The amount of additional time the railroad warning devices will be active can be extended up to the advance preemption time provided by the train detection equipment. By activating the systems early, the automatic gates will be lowered, preventing additional traffic from queuing onto the tracks and affording a longer period of time for stopped vehicles to start up and move clear of the tracks (ITE, 2006).

Note: The Agency must notify the Railroad which circuits are being requested at each location.

Another item to be addressed as a part of the interconnection determination is the electrical arrangement of the circuits. There are three possible interconnection options:

- **Single Break with Supervision** – This option provides a means to open a single energy source conductor through the railroad circuitry. In order to provide a means to verify the integrity of the interconnection cable between the traffic signal controller and the railroad warning system, an additional conductor is provided that closes upon the approach of a train. This is known as a supervised circuit.

- **Double Break** – This option provides a means to open both the positive and negative or line and neutral energy source leads through the railroad circuitry. By opening both conductors of the circuit, a level of reliability equal to single break with supervision is achieved.

- **Double Break with Supervision** - This option makes use of number 1 and number 2 where both conductors are opened through the railroad circuitry and a supervision circuit is included. By opening both conductors of the circuit and providing a supervision circuit, a higher level of reliability is achieved.

5.4 Roadway, Pavement, and Signage Improvements

In order to better guide the motoring public, it is important to notify the motoring public in accordance with the highway-rail grade crossing complexities. The following roadway recommendations have been made with regards to the safety of vehicles traversing the crossing:

- **Implement tubular markers along edge of pavement around the radii of the intersection to help guide motorists through the area and prevent turns onto the railroad right-of-way.** These devices assist in indicating the pathway for vehicles in close proximity to the intersection radii and left turning vehicles. Tubular markers preclude vehicles from premature turns at the intersection that may lead onto the tracks.

- **Extend edge lines around the intersection radii to help guide motorists through the area and prevent turns onto the railroad right-of-way.**

- **Install skewed crossing signs (W10-12) with a motorcycle plaque (W8-15P) on all intersection approaches as shown below.** This installment would warn bikes and motorcyclists that their wheel has the possibility of entrapment in the flange of the tracks. The symbol should make apparent the crossing's 45-degree angle (Cornell Local Roads Program, 2014).

**Figure 10 - Skewed Crossing Sign (W10-12)
with Motorcycle Plaque (W8-15P)**

5.5 Pedestrians

Convene a diagnostic team, including knowledgeable representatives of all interested parties in a highway-rail grade crossing to further evaluate the pedestrian treatments at the crossing and make appropriate modifications. At a minimum, the following should be considered:

- **Implement automatic pedestrian gates for the grade crossing along with pedestrian emergency exit routes behind the gates to allow pedestrians to escape the tracks without resorting to entering the traveled roadway or lifting the gate.** The following figure depicts the proposed recommendation for typical pedestrian treatments for sidewalks with pedestrian gates:

Figure 11 - Example pedestrian emergency exit gates

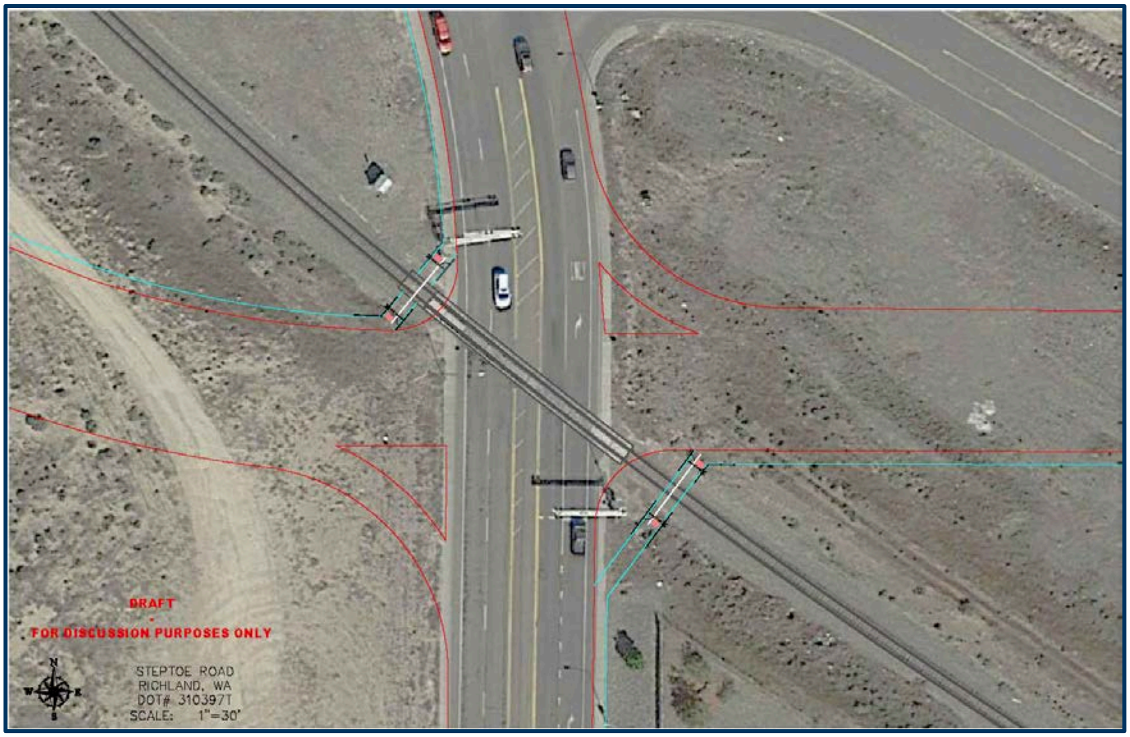


Figure 12 - Example placement of ped gates for intersection design

6.0 Conclusions

In addition to the operational improvements and recommendations in this report, the City of Richland, Tri-City Railroad, Union Pacific Railroad, BNSF Railway, and the Washington Utilities and Transportation Commission (WUTC) should assemble a diagnostic team to thoroughly review and analyze all elements pertaining to the highway-rail grade crossing as part of this new development. The points covered in this report provide an initial road map for items of note that the diagnostic team should consider, as well as, any other safety-sensitive and operational specifics to enhance the overall operation. Once the diagnostic team determines the recommended modifications, an action plan should be developed to implement the improvements.

APPENDIX A – References

CTC utilized the following supporting documents and recommended operational practices in evaluating the preemption operation and design:

- AREMA (2014). *Manual for Communications and Signals (C&S Manual)*. Landover, MD: American Railway Engineering and Maintenance-of-Way Association (AREMA).
- City of Richland (2008). *City of Richland Comprehensive Land Use Plan*. Richland, Washington
- CLRP (September 30, 2014). *Cornell Local Raods Program: Technical Assistance – Quick Answers*. Cornell Local Road Program (CLRP).
- FHWA (2007). *Railroad-Highway Grade Crossing Handbook - Revised Second Edition*. Federal Highway Administration (FHWA).
- FRA (July 25, 2012). *Technical Bulletin S-12-0, Guidance Regarding the Appropriate Processes for the Inspection of Highway-Rail Grade Crossing Warning System Pre-emption Interconnections with Highway Traffic Signals*. Federal Railroad Administration (FRA).
- FRA (October 1, 2010). *Federal Register Volume 75, Issue 190 - Safety Advisory 2010-02, Signal Recording Devices for Highway-Rail Grade Crossing Active Warning Systems that are Interconnected with Highway Traffic Signal Systems*. Federal Railroad Administration (FRA).
- ITE (2006). *Preemption of Traffic Signals Near Railroad Crossings, An ITE Recommended Practice*. Washington, DC: Institute of Transportation Engineers (ITE).
- TXDOT (March 2009). *Form 2304 Instructions, Instructions for the Guide for Determining Time Requirements for Traffic Signal Preemption at Highway Grade Crossings*. Texas Department of Transportation (TXDOT).
- TXDOT (March 2009). *Form 2304, Guide for Determining Time Requirements for Traffic Signal Preemption at Highway Grade Crossings*. Texas Department of Transportation (TXDOT).
- WSDOT (December 2011). *Washington Modifications to the Federal Manual on Uniform Traffic Control Devices.* Washington Department of Transportation (WSDOT).

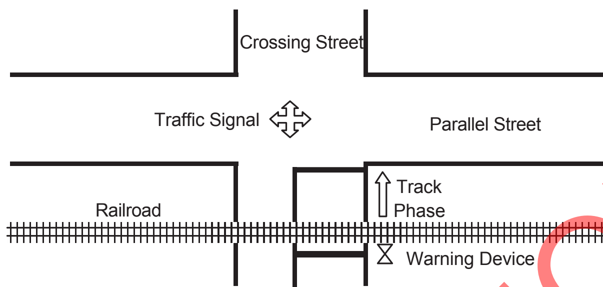
APPENDIX B – Preemption Calculation Form – Split-T Intersection

GUIDE FOR DETERMINING TIME REQUIREMENTS FOR TRAFFIC SIGNAL PREEMPTION AT HIGHWAY RAIL GRADE CROSSINGS

City: Richland, WA
County:
District:

Date: 09/09/16
Completed by: CTC
District Approval:

Show North Arrow



Parallel Street Name: Tapteal Dr.

Crossing Street Name: Steptoe St. SB

Railroad: Tri-Cities Railway
Crossing DOT#: 310397T

Railroad Contact: Rhett Peterson
Phone:

SECTION 1: RIGHT-OF-WAY TRANSFER TIME CALCULATION

Preempt verification and response time

Remarks

1. Preempt delay time (seconds) 1. 0.0
2. Controller response time to preempt (seconds) 2. 0.0

Controller type: ASC Cobalt

3. Preempt verification and response time (seconds): add lines 1 and 2 ....3. 0.0

Worst-case conflicting vehicle time

Remarks

4. Worst-case conflicting vehicle phase number ....4.
5. Minimum green time during right-of-way transfer (seconds) 5. 5.00
6. Other green time during right-of-way transfer (seconds) 6. 0.00
7. Yellow change time (seconds) 7. 4.90
8. Red clearance time (seconds) 8. 1.00
9. Worst-case conflicting vehicle time (seconds): add lines 5 through 8 ....9. 10.9

Worst-case conflicting pedestrian time

Remarks

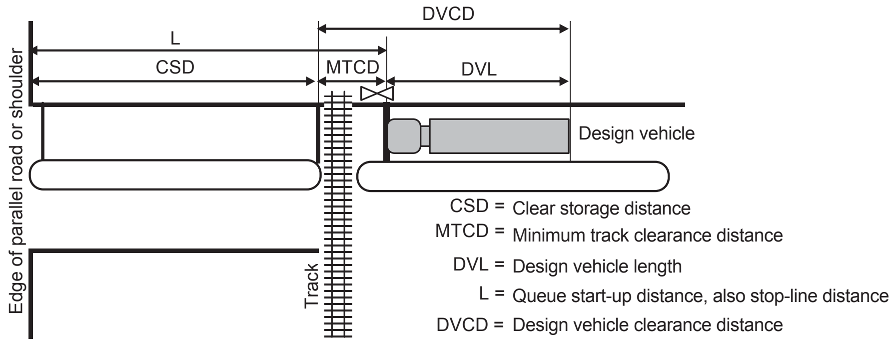
10. Worst-case conflicting pedestrian phase number....................10.
11. Minimum walk time during right-of-way transfer (seconds) 11. 0.0
12. Pedestrian clearance time during right-of-way transfer (seconds) 12. 18.0
13. Vehicle yellow change time, if not included on line 12 (seconds) 13. 0.0
14. Vehicle red clearance time, if not included on line 12 (seconds) 14. 1.0
15. Worst-case conflicting pedestrian time (seconds): add lines 11 through 14 ....15. 19.0

Worst-case conflicting vehicle or pedestrian time

16. Worst-case conflicting vehicle or pedestrian time (seconds): maximum of lines 9 and 15....................16. 19.0

17. **Right-of-way transfer time (seconds): add lines 3 and 16** 17. 19.0

SECTION 2: QUEUE CLEARANCE TIME CALCULATION



			Remarks
18.	Clear storage distance (CSD, feet)	134	
19.	Minimum track clearance distance (MTCD, feet)	58	
20.	Design vehicle length (DVL, feet)	75	Design vehicle type: WB-65
21.	Queue start-up distance, L (feet): add lines 18 and 19	192	
22.	Time required for design vehicle to start moving (seconds): calculate as 2+(L÷20)	11.6	
23.	Design vehicle clearance distance, DVCD (feet): add lines 19 and 20	133	
24.	Time for design vehicle to accelerate through the DVCD (seconds)	21.5	Read from Figure 2 in Instructions.
25.	**Queue clearance time (seconds): add lines 22 and 24**	33.1	

SECTION 3: MAXIMUM PREEMPTION TIME CALCULATION

			Remarks
26.	Right-of-way transfer time (seconds): line 17	19.0	
27.	Queue clearance time (seconds): line 25	33.1	
28.	Desired minimum separation time (seconds)	4.0	
29.	**Maximum preemption time (seconds): add lines 26 through 28**	56.1	

SECTION 4: SUFFICIENT WARNING TIME CHECK

			Remarks
30.	Required minimum time, MT (seconds): per regulations	20.0	
31.	Clearance time, CT (seconds): get from railroad	3.0	
32.	Minimum warning time, MWT (seconds): add lines	23.0	Excludes buffer time (BT)
33.	Advance preemption time, APT, if provided (seconds): get from railroad		
34.	Warning time provided by the railroad (seconds): add lines 32 and 33	23.0	
35.	**Additional warning time required from railroad (seconds): subtract line 34 from line 29, round up to nearest full second, enter 0 if less than 0**	34	

If the additional warning time required (line 35) is greater than zero, additional warning time has to be requested from the railroad. Alternatively, the maximum preemption time (line 29) may be decreased after performing an engineering study to investigate the possibility of reducing the values on lines 1, 5, 6, 7, 8, 11, 12, 13 and 14.

Remarks: Approach Grade: 4.4%

APPENDIX C – Supporting Preemption Calculations – 4-Leg Intersection

Alternate 2 – Realignment of Tapteal Drive

WA, Richland – Steptoe St and Tapteal Dr – DOT# 310397T

Yellow / All-Red Interval Calculations

Formulas used

Yellow Interval Calculation

$t + \frac{1.47(V)}{2(a)+64.4(g)}$ = *Yellow Interval in seconds*

All-Red Interval Calculation

$\frac{(W)+(L)}{1.47(V)}$ -1 = *All-Red Interval in seconds*

Values

t = reaction time (median value = 1)
a = deceleration rate (median value = 10)
V = speed limit (mph)
g = approach grade
W = width of intersection
L = length of vehicle (in feet) (20)

For more information see NCHRP Report 731 "Guidelines for Timing Yellow and All-Red intervals at Signalized Intersections"

<u>*Steptoe St*</u>

- NB Through Movement
V (Speed Limit) – 40 mph
W (width of intersection) – 115 ft
Approach Grade: - 5.5%

Yellow Interval Calculation

$1 + \frac{1.47(40)}{2(10)+64.4(-0.055)}$ = *4.573 seconds*

All-Red Interval Calculation

$\frac{(115)+(20)}{1.47(40)}$ -1 = *1.296 seconds*

Total: 5.9 secs

- NB Left Turn Movement
V (Speed Limit) – 35 mph
W (width of intersection) – 97 ft
Approach Grade: -5.5%

Yellow Interval Calculation

$1 + \frac{1.47(35)}{2(10)+64.4(-0.055)}$ = *4.126 seconds*

All-Red Interval Calculation

$\frac{(97)+(20)}{1.47(20)}$ -1 = *2.980 seconds*

Total: 7.1 secs

- SB Through Movement
V (Speed Limit) – 35 mph
W (width of intersection) – 147 ft
Approach Grade: 3.0%

Yellow Interval Calculation

$1 + \frac{1.47(35)}{2(10)+64.4(0.03)}$ = *3.346 seconds*

All-Red Interval Calculation

$\frac{(147)+(20)}{1.47(35)}$ -1 = *2.246 seconds*

Total: 5.6 secs

- SB Left Turn Movement
V (Speed Limit) – 30 mph W (width of intersection) – 140 ft
Approach Grade Northbound: 3.0%

Yellow Interval Calculation

$1+\frac{1.47(30)}{2(10)+64.4(0.03)}$ = *3.012 seconds*

All-Red Interval Calculation

$\frac{(140)+(20)}{1.47(20)}$ -*1 = 4.442 seconds*

Total: 7.5 secs

<u>*Tap Teal Dr.*</u>

- EB Through Movement
V (Speed Limit) – 30 mph W (width of intersection) – 125 ft
Approach Grade: - 0.0%

Yellow Interval Calculation

$1+\frac{1.47(30)}{2(10)+64.4(0.0)} = 3.205\ seconds$

All-Red Interval Calculation

$\frac{(125)+(20)}{1.47(30)}$-*1 = 2.288 seconds*

Total: 5.5 secs

- EB Left Turn Movement
V (Speed Limit) – 25 mph W (width of intersection) – 90 ft
Approach Grade: 0.0%

Yellow Interval Calculation

$1+\frac{1.47(25)}{2(10)+64.4(0.0)} = 2.838\ seconds$

All-Red Interval Calculation

$\frac{(90)+(20)}{1.47(20)}$-*1 = 2.741 seconds*

Total: 5.6 secs

- WB Through Movement
V (Speed Limit) – 30 mph W (width of intersection) – 120 ft
Approach Grade:4.0%

Yellow Interval Calculation

$1+\frac{1.47(30)}{2(10)+64.4(0.04)} = 2.953\ seconds$

All-Red Interval Calculation

$\frac{(120)+(20)}{1.47(30)}$-*1 = 2.175 seconds*

Total: 5.2 secs

- WB Left Turn Movement
V (Speed Limit) – 25 mph W (width of intersection) – 100 ft
Approach Grade: 4.0%

Yellow Interval Calculation

$1+\frac{1.47(25)}{2(10)+64.4(0.03)} = 2.676\ seconds$

All-Red Interval Calculation

$\frac{(100)+(20)}{1.47(20)}$-*1 = 3.082 seconds*

Total: 5.8 secs

Worst Case Conflicting Vehicle Phase YT
Yellow Interval Time: 4.6 seconds

Right-of-Way Transfer Time

	Proposed Values (Seconds)
Controller Preemption Delay Time	0.0
Controller Preemption Response Time	0.0
Minimum Green before Track Clearance	5
Walk before Track Clearance	0
Pedestrian Change before Track Clearance	0
Yellow Change before Track Clearance	4.6
Red Clearance before Track Clearance	0
Additional Right-of-Way Transfer Time	0.0
Maximum Right-of-Way Transfer Time	**9.6**

Railroad Preemption Values

Southbound Steptoe St.	Preemption Values
Minimum Time (MT)	20
Clearance Time (CT) *	12
Clearance Time - Other	0
Prescribed Warning Time or Minimum Warning Time (MT + CT + CT other)	32
Buffer Time (BT) *	5
Total Warning Time (TWT)(MT + CT + CT other + BT)	37
Equipment Response Time (ERT) *	5
Advance Preemption Time (APT)*	10*
Total Approach Time (TAT)* (MT + CT + CT other + BT + ERT + APT)	**52**
Train Design Speed (v)	**25**
Approach Length	**1907**
***Railroad to verify time needed**	

* Since the track crosses through the intersection, no track clearance is required. The amount of advance preemption must be sufficient to transfer the traffic signal from whatever phase it is in when the preemption call is received to a red indication prior to the railroad flashing-light signals (worst case right-of-way transfer time).

APPENDIX D – Railroad Magnitude of Costs

DRAFT

PREEMPTED CROSSING EVALUATION

ORDER OF MAGNITUDE COST - Alternative 1 with Pedestrian Clearance Time

LOCATION:

Crossing Street	Steptoe Street	DOT #	310397T
Parallel Street	Tapteal Drive	MP	B45.8
City	Richland	LS	
State	Washington	Subdivision	B Line (Richland Industrial Lead)

CROSSING INFORMATION:

Existing Equipment PMD-2 **Existing Preemption Type** Simultanious

Existing TAT	30 sec
Proposed TAT	67 sec
Existing Approach Length	1320 CL
Proposed Approach Length	2457
Existing Design Speed	25
Proposed Design Speed	25

		Required	Estimated Cost	Total Estimated Cost
Crossing Work:				
Complete Crossing Upgrade (includes lights and gates)		1	$250,000	$250,000
Additional Vehicle Gate		0	$30,000	$0
Pedestrian Gate		4	$20,000	$80,000
Install Advance Preemption Circuitry		0	$10,000	$0
Install Gate Down Circuitry & Island Relay		0	$5,000	$0
Minor Redesign and Reprogram		0	$4,000	$0
Install Supervised Circuitry		0	$1,000	$0
Install Simultaneous Interconnect Circuitry		0	$1,000	$0
		Crossing Work Subtotal		**$330,000**
Approaches:	**EB**	**WB**		
Clean Approach	Y	Y		
Adjacent Crossing(s)	N	N		
Control Points	N	N		
Relocate/Install Shunts	1	1	$5,000	$10,000
Install Remote House	0	0	$250,000	$0
		Approaches Subtotal		**$10,000**
Adjacent Crossings:				
Complete Crossing Upgrade (includes lights and gates)	0	0	$250,000	$0
Partial Crossing Upgrade (new bungalow, no lights & gates)	0	0	$150,000	$0
Upgrade Crossing Circuitry - new predictor	0	0	$50,000	$0
Cabling ______ ft @ $_____ per ft	0	0	$0	$0
Redesign and Reprogram	0	0	$10,000	$0
		Adjacent Crossings Subtotal		**$0**
Control Point:				
Wide Band Shunt	0	0	$20,000	$0
CP Upgrade - install Predictor/Circuits	0	0	$100,000	$0
Install Remote House	0	0	$250,000	$0
Install Insulated Joints	0	0	$11,000	$0
Cabling ______ ft @ $_____ per ft	0	0	$0	$0
Comments:		**Control Point Subtotal**		**$0**

TOTAL ESTIMATED COST $340,000

FOR DISCUSSION PURPOSES ONLY

DRAFT

PREEMPTED CROSSING EVALUATION

ORDER OF MAGNITUDE COST - Alternative 2 no Pedestrian Clearance Time

LOCATION:

Crossing Street	Steptoe Street	DOT #	310397T
Parallel Street	Tapteal Drive	MP	B45.8
City	Richland	LS	
State	Washington	Subdivision	B Line (Richland Industrial Lead)

CROSSING INFORMATION:

Existing Equipment PMD-2 **Existing Preemption Type** Simultanious

Existing TAT	30 sec
Proposed TAT	52 sec
Existing Approach Length	1320 CL
Proposed Approach Length	1907
Existing Design Speed	25
Proposed Design Speed	25

Crossing Work:		**Required**	**Estimated Cost**	**Total Estimated Cost**
Complete Crossing Upgrade (includes lights and gates)		1	$250,000	$250,000
Additional Vehicle Gate		2	$30,000	$60,000
Pedestrian Gate		4	$20,000	$80,000
Install Advance Preemption Circuitry		0	$10,000	$0
Install Gate Down Circuitry & Island Relay		0	$5,000	$0
Minor Redesign and Reprogram		0	$4,000	$0
Install Supervised Circuitry		0	$1,000	$0
Install Simultaneous Interconnect Circuitry		0	$1,000	$0
	Crossing Work Subtotal			**$390,000**
Approaches:	**EB**	**WB**		
Clean Approach	Y	Y		
Adjacent Crossing(s)	N	N		
Control Points	N	N		
Relocate/Install Shunts	1	1	$5,000	$10,000
Install Remote House	0	0	$250,000	$0
	Approaches Subtotal			**$10,000**
Adjacent Crossings:				
Complete Crossing Upgrade (includes lights and gates)	0	0	$250,000	$0
Partial Crossing Upgrade (new bungalow, no lights & gates)	0	0	$150,000	$0
Upgrade Crossing Circuitry - new predictor	0	0	$50,000	$0
Cabling ______ ft @ $_____ per ft	0	0	$0	$0
Redesign and Reprogram	0	0	$10,000	$0
	Adjacent Crossings Subtotal			**$0**
Control Point:				
Wide Band Shunt	0	0	$20,000	$0
CP Upgrade - install Predictor/Circuits	0	0	$100,000	$0
Install Remote House	0	0	$250,000	$0
Install Insulated Joints	0	0	$11,000	$0
Cabling ______ ft @ $_____ per ft	0	0	$0	$0
Comments:	**Control Point Subtotal**			**$0**

TOTAL ESTIMATED COST $400,000