Appendix E

Kalamazoo River Trail Detail

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Kalamazoo River Valley Trail Crossings - "Safety Assessment"

In general, trail crossings are likely to be used by pedestrians or cyclists engaged in leisure or fitness activity. Thus, users of these crossings have an increased likelihood of entering the crossing when it is unsafe to do so. Factors influencing this behavior include:

- Wearing earphones/earbuds will likely inhibit ability to hear both nearby audible warning systems (e.g. bells) and sounding of train horns.
- Persons with hearing loss may be unable to hear nearby audible warning systems or the sounding of train horns.
- Tendency for persons to be distracted by their electronic devices (e.g. smartphone or fitness trackers) will decrease likelihood of looking up and in both directions to recognize an approaching train.
- Individuals who regularly/frequently use the crossing may become desensitized to hazards posed by train traffic and may be more prone to at risk behavior.
- Persons who are not intimately familiar with railroad operations may lack the ability to properly judge the speed of approaching trains and subsequently may improperly judge the amount of time until an approaching train occupies the crossing.

The two crossings were reviewed and have locational specific factors that further increase the likelihood of an incident occurring. In both cases, there are directions with limited sight distance that inhibit the ability of pedestrians and cyclists to see approaching trains.

- McCollum Road:
  - Currently 79 MPH territory with a proposed speed increase to 110 MPH
  - Crossing angle is 70°
  - Curve located to the southwest of the crossing inhibits sight distance. A preliminary evaluation using Google Earth indicated that pedestrians would have approximately 20 seconds to see an approaching train at 79 MPH, and approximately 15 seconds to see an approaching train at 110 MPH.

- Dickman Road:
  - 70 MPH territory
  - Crossing angle is 40°
  - Curve located to the northeast of the crossing significantly inhibits sight distance. A preliminary Google Earth evaluation indicated pedestrians would have approximately 10 seconds to see an approaching train.

The limited sight distances at these crossings make passive-only warning devices (e.g. pedestrian maze) undesirable. Such devices rely on crossing users to individually detect an approaching train. With the ability to visually recognize the approaching train impaired by curves, audible detection becomes important. However, as noted above, crossing users in this environment are likely to be in a condition where their ability to hear nearby bells (at adjacent road crossings) or train horns is also reduced. Furthermore, train speeds at this location are likely to produce fatal consequences for crossing users struck by a train.

Therefore, installing a physical barrier that blocks the pathway that is only lowered or otherwise in place when a train is approaching or occupying the crossing will provide separation between crossing users and trains. Even users who are distracted or have other reductions in sensitivity to their means to visually and audibly detect approaching trains will make physical contact with a lowered/closed barrier that will stop their forward movement before entering the path of an approaching train. Additionally, movement of the barrier, as well as its coloring and lighting, will increase the likelihood of it being seen via peripheral vision before a user contact it. Furthermore, independent research has found a statistically significant drop in the frequency of pedestrians entering a crossing just before a train arrives attributable to the installation of automatic pedestrian gates.[1]

Consequently, System Safety supports the position of Amtrak's Engineering department that active warning systems with gates as well as fencing be installed at the designated crossing locations.

Reference:
[1] Joaquin T. Siques, "Effects of Pedestrian Treatments on Risk Pedestrian Behavior," *Transportation Research Record*
1793(1), 2002: 62-70.

Paper No. 02-2887

Effects of Pedestrian Treatments on Risky Pedestrian Behavior

Joaquin T. Siques

The effects of pedestrian treatments on risky pedestrian behavior at light rail transit grade crossings were examined. Five pedestrian treatments were evaluated—(*a*) pedestrian automatic gates, (*b*) a prototype active pedestrian warning device, (*c*) a prototype active "Look Both Ways" sign, (*d*) barrier channelization at a skewed crossing, and (*e*) a "Stop Here" pavement marking. Pedestrian grade-crossing treatments were installed at three grade crossings along the Tri-County Metropolitan Transportation District of Oregon MAX light rail system in Portland, Oregon. The pedestrian treatments and the crossing geometry varied at the three locations, providing for three unique evaluations on the effectiveness of different pedestrian treatments at grade crossings. The grade crossings were videotaped for at least 1 week both before and after the installation of the pedestrian treatments. The data were evaluated using a before-and-after statistical approach to determine the effects of the treatments on risky pedestrian behavior. The statistical evaluation of the data shows that pedestrian treatments result in a statistically significant reduction in risky pedestrian behavior. The greatest reductions were found with pedestrian automatic gates. The results, however, also demonstrate that various pedestrian treatments can sometimes increase risky pedestrian behavior.

Because many pedestrian collisions with light rail vehicles result in fatalities, the effectiveness of pedestrian treatments on risky pedestrian behavior was evaluated. This study determined the effectiveness of pedestrian treatments on risky pedestrian behavior at light rail transit (LRT) grade crossings. Five distinct pedestrian treatments were evaluated—(*a*) pedestrian automatic gates, (*b*) a prototype active pedestrian warning device, (*c*) a prototype active "Look Both Ways" sign, (*d*) barrier channelization at a skewed crossing, and (*e*) "Stop Here" pavement marking.

Pedestrian grade-crossing treatments were installed at three grade crossings along the Tri-County Metropolitan Transportation District of Oregon (Tri-Met) MAX light rail system in Portland, Oregon. The pedestrian treatments and the crossing geometry varied at the three locations, providing for three unique evaluations of the different pedestrian treatments at grade crossings. The grade crossings were videotaped for at least 1 week both before and after the pedestrian treatments. The data were evaluated using a before-and-after statistical approach to determine the effects of the treatments on risky pedestrian behavior.

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CROSSINGS SELECTED FOR EVALUATION

Three grade crossings were selected for evaluation:

1. 28th Avenue,
2. Baseline Road, and
3. 122nd Avenue.

28th Avenue

The 28th Avenue grade crossing is located in Hillsboro on the western extension of the Tri-Met MAX LRT system. Two LRT tracks run east-west across 28th Avenue, which is a north–south two-lane road, at an angle that is slightly skewed, as seen in Figure 1. The land use around the grade crossing is residential, with a park on the northeast quadrant. An elementary school is located north of the crossing, and the route is used by a handful of school children. The motorist control devices at the grade crossing include flashing lights and traffic gates, with cantilevered flashing lights facing both north and south from a cantilever structure on the southeast quadrant. Before the new devices were installed, the pedestrian crossing was equipped with "Look Both Ways" signs facing both approaches to the crossing on each side of the roadway. The southwest quadrant of the crossing is equipped with a 1.8-m (6-ft) sound wall that ends at the grade crossing. This sound wall, combined with landscaping, reduces the pedestrian sight distance at this quadrant of the crossing to a potentially hazardous limited sight distance.

For the after data collection period, the crossing was equipped with pedestrian barrier channelization on the northwest quadrant and pedestrian automatic gates on all four quadrants of the crossing, in addition to the devices already in place. The pedestrian automatic gates were also equipped with an audible warning that was localized at a pedestrian level. The pedestrian crossing on the west side of the roadway was chosen for statistical evaluation because of the limited sight distance and installation of the pedestrian gates and channelization.

Baseline Road

The Baseline Road grade crossing is located in Beaverton on the western extension of the Tri-Met MAX LRT system. Two tracks cross Baseline Road, which is a four-lane road, at a skewed angle, as seen in Figure 2. The land use around the grade crossing is light industrial in the southeast quadrant and residential in the other three quadrants. A signalized roadway intersection is located approximately 400 m (¼ mi) east of the crossing. The roadway is divided by a median with nonmountable curbs, with two lanes on each side of the

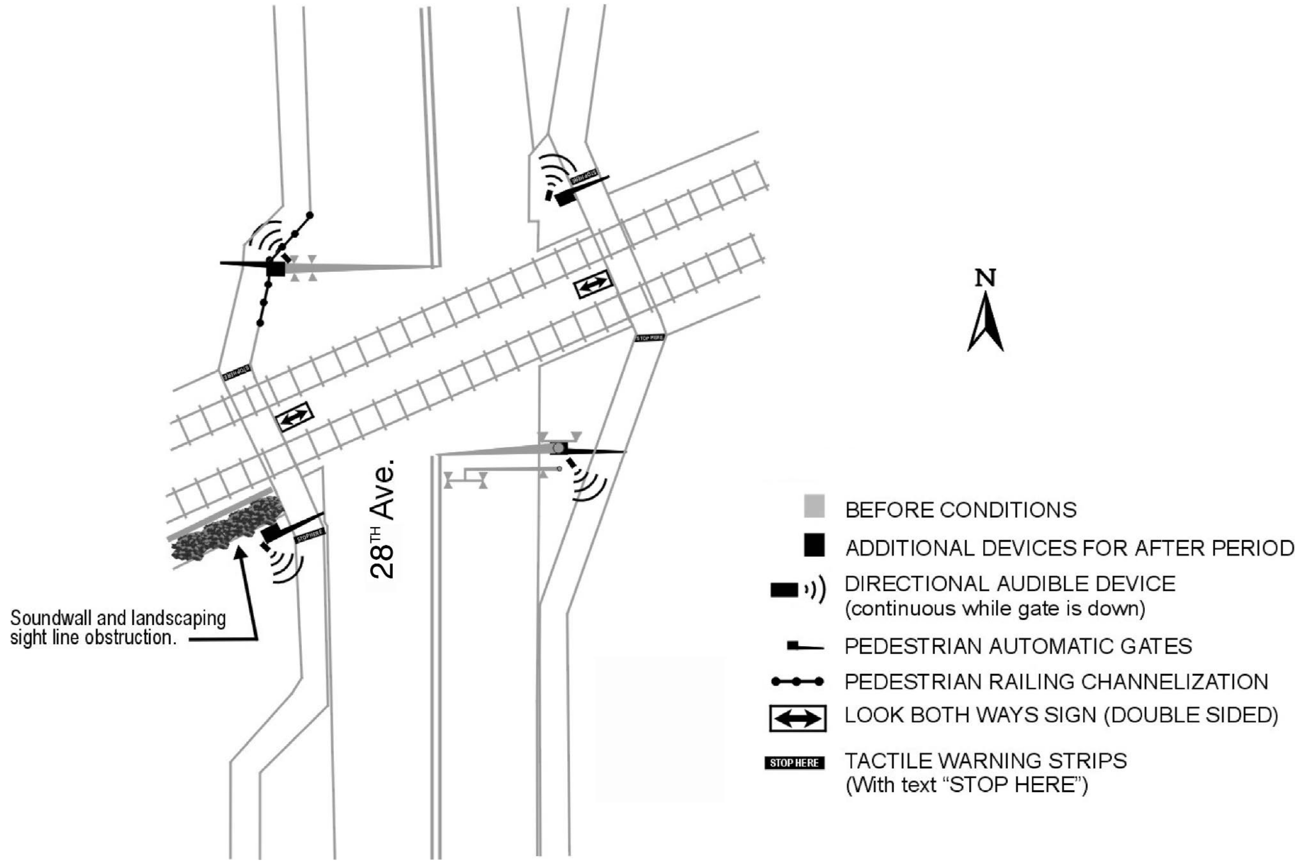

FIGURE 1 28th Avenue pedestrian treatments (not to scale).

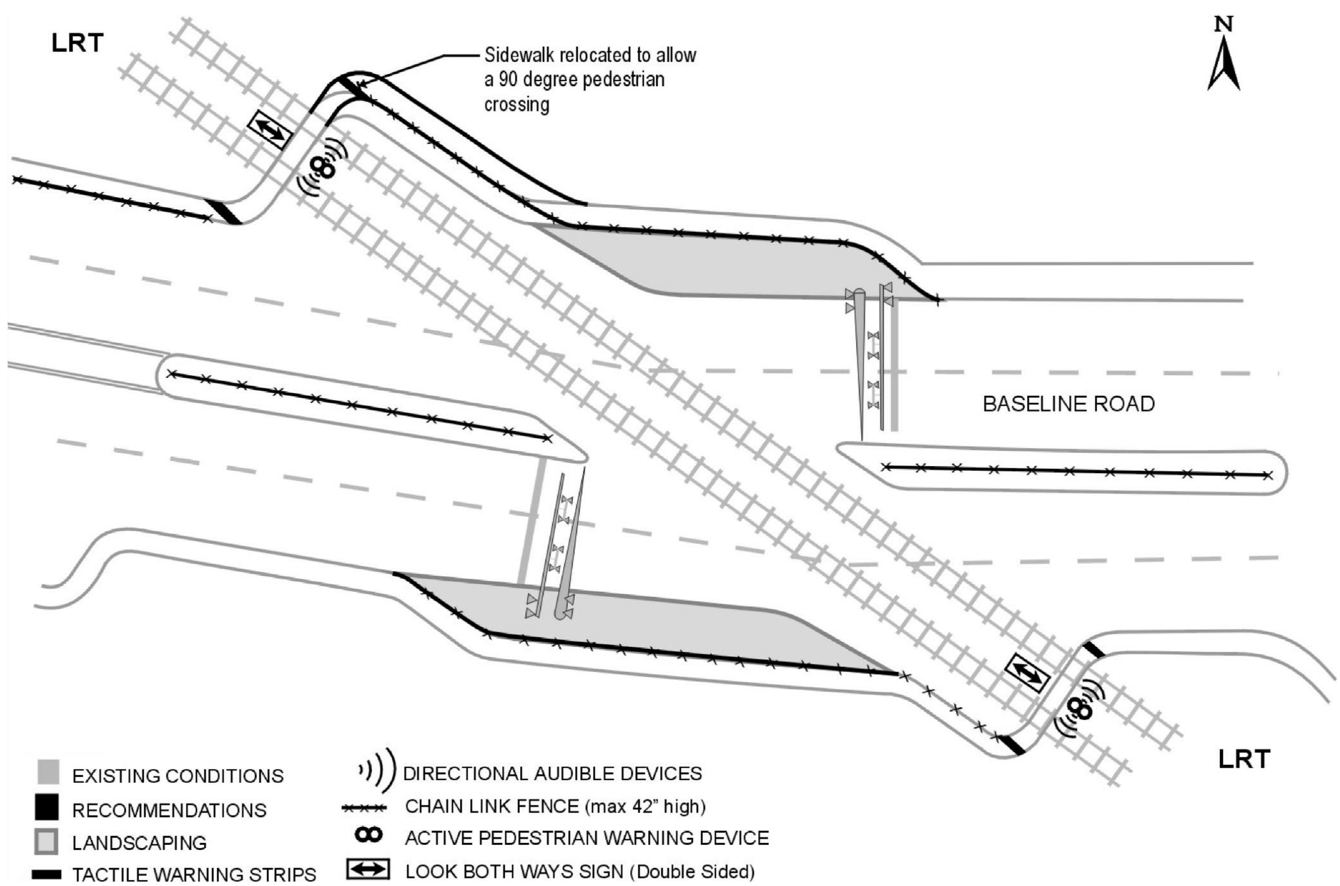

FIGURE 2 Baseline Road (not to scale).

median. A driveway to the light industrial property is located on the southeast quadrant approximately 6 m (20 ft) from the crossing. The motorist control devices at the crossing include flashing lights, motorist gates, and cantilevered flashing lights facing both the northbound and southbound traffic approaches. Before the new devices were installed, the pedestrian crossing was equipped with “Look Both Ways” signs facing both approaches to the crossing on each side of the roadway. The skewed roadway prompted Tri-Met to provide a channelized pedestrian path that crosses the tracks at a 90 degree angle. This channelization isolates the pedestrian crossing from the motorist crossing by approximately 30 m (100 ft).

In addition to the existing control devices, the crossing was equipped with extended pedestrian barrier channelization on the northeast and southwest quadrants and low fencing in the median to discourage pedestrians from crossing the roadway at the grade crossing. The pedestrian crossings were also equipped with an active pedestrian warning device that consisted of flashing lights and an audible warning. The device was approximately 1 m (3 ft) high, to provide a local audible warning and a visual warning in the pedestrians’ cone of vision.

122nd Avenue

The 122nd Avenue grade crossing is located in Gresham on the eastern portion of the Tri-Met MAX LRT system. The LRT track alignment is in the median of Burnside Avenue, as shown in Figure 3. The pedestrian crossing is at a light rail vehicle (LRV) station in the median of Burnside Avenue, with the station platform between a pair of directional tracks. Retail land use exists on all four corners of the crossing. Marked crosswalks connect the station to the adjacent sidewalks at the intersection of 122nd and Burnside Avenues, which is controlled by traffic signals and pedestrian signals (ped heads).

An active “Look Both Ways” sign was installed on the 122nd Avenue crossing at the 122nd Avenue Station, facing pedestrians crossing the tracks at the light rail station from both approaches.

CONTROL DEVICES EVALUATED

Five pedestrian treatments were evaluated in the before-and-after study:

1. Barrier channelization,
2. Prototype active pedestrian warning device,
3. Prototype active “Look Both Ways” sign,
4. Pedestrian automatic gates, and
5. “Stop Here” pavement marking.

Barrier Channelization

Barrier channelization includes low fencing, landscaping, or pedestrian railing installed to direct pedestrians to the designated crossing location, as shown in Figure 4. Barrier channelization was installed at the 28th Avenue and Baseline Road grade crossings. At 28th Avenue, pedestrian railing was installed in the northwest quadrant. At Baseline Road, pedestrian channelization was already in place on the southwest quadrant, in the form of fencing. Additional fencing and landscaping were installed in the northeast and southwest quadrants, and fencing was installed in the roadway median.

Prototype Active Pedestrian Warning Device

The prototype active warning device is the 1-m (3-ft) high flashing light device with an audible pedestrian warning, as seen in Figure 5. This device was installed on both pedestrian paths crossing the LRT tracks at Baseline Road. The sidewalk on the south side of the roadway was chosen for a statistical analysis. The flashing lights and audible warning are activated when a train is approaching the crossing. The existing audible warning devices on the motorist gates are located approximately 30 m (100 ft) from the pedestrian crossing and sound only until the motorist gate reaches the horizontal posi-

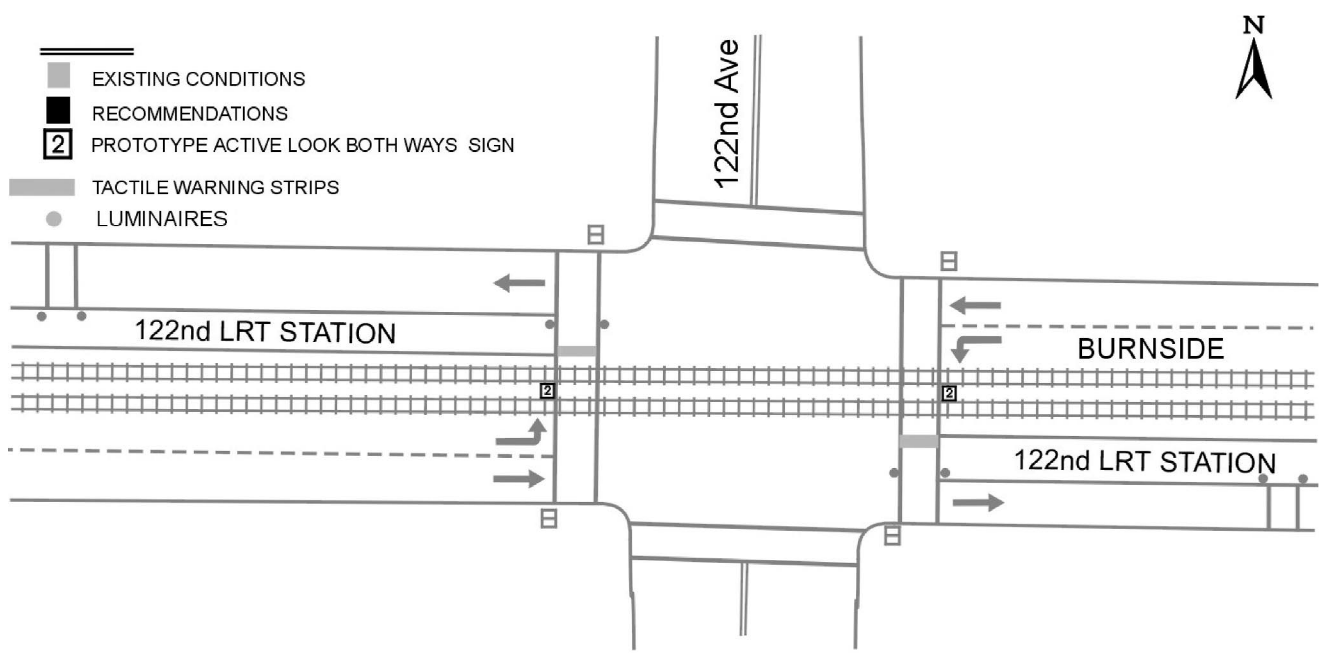

FIGURE 3 122nd Avenue pedestrian treatments (not to scale).

FIGURE 4 Channelization at Baseline Road (facing southeast).

tion. The audible device on the prototype pedestrian active warning device continues to sound when the gate arm is in the horizontal position, until the train has passed the crossing and deactivated the circuit. The audible device is directed at the pedestrian path to reduce the noise impact on the surrounding environment.

Prototype Active "Look Both Ways" Sign

The active "Look Both Ways" sign was another prototype active warning device that was evaluated. This sign is approximately 0.6×0.6 m (2×2 ft) and double sided, as shown in Figure 6. When activated by an approaching train, a yellow LRV icon depicting a side view of an LRV remains lit continuously. The LRV icon spans most of the LED sign width. One red arrow above the LRV icon pointing to the right and one red arrow below the LRV icon pointing to the left alternately flash to advise pedestrians to look both ways. An audible pedestrian warning is also emitted from the sign. The sign was installed on the 122nd Avenue crossing at the 122nd Avenue Station, facing pedestrians crossing the tracks at the light rail station from both approaches.

Pedestrian Automatic Gates

Pedestrian automatic gates are similar to motorist gates, except that the gate arm is shorter and goes across the pedestrian path, as seen in Figure 7. The gate arm is lowered when a train is approaching, and flashing lights on top of the gate arm warn pedestrians of the arm. Pedestrian automatic gates were installed on all four quadrants of the 28th Avenue grade crossing. Also, an audible warning device was installed on the gate mechanism to warn pedestrians of an approaching train. The existing audible warning devices on the motorist gates only sound until the motorist gate reaches the horizontal position. The audible device on the pedestrian gate mechanism remains sounding when the gate arm is in the horizontal position, until the train has passed the crossing and deactivated the circuit. The audible device is directed at the pedestrian path to reduce the noise impact on the surrounding environment. The pedestrian gates are located an adequate distance from the track to allow for a refuge area between the tracks and the gate.

FIGURE 5 Prototype pedestrian flashers at Baseline Road.

FIGURE 6 Prototype pedestrian "Look Both Ways" sign at 122nd Avenue (facing north).

"Stop Here" Pavement Marking

The "Stop Here" pavement marking is a red-and-white sidewalk treatment that is painted onto the pedestrian path at the safe stopping location for pedestrians, as seen in Figure 8. "Stop Here" is displayed in white, with a red background. Between the words "Stop" and "Here" is a white octagon to symbolize a stop sign. This treatment is supplemented with a tactile pavement treatment of scored concrete, to further define the safe stopping area. The tactile warning is intended to warn those who are visually impaired.

Table 1 indicates the control devices that were present at the grade crossing during the before-and-after evaluation.

FIGURE 7 Pedestrian automatic gates at 28th Avenue (facing north).

FIGURE 8 "Stop Here" pavement marking at Baseline Road.

TYPES OF BEHAVIOR ANALYZED

Traditionally, the number of collisions at a grade crossing location has been used as a safety indicator. However, because pedestrian collisions at grade crossings are relatively infrequent, the number of collisions has limited statistical significance. It is just as likely to see zero collisions in a given period because of the randomness related to the traffic engineering treatment. Therefore, alternative measures are needed to evaluate the effectiveness of pedestrian treatments at grade crossings. A more meaningful indicator of treatment effectiveness is risky pedestrian behavior. Risky behavior incidents are pedestrian movements that present a threat of collision with a train without an actual collision occurring. Because risky pedestrian behavior incidents are proportional to pedestrian collisions at crossings, they indicate a location's collision potential. Also, because risky behavior movements are more frequent than collisions, they can be used as a surrogate safety indicator in lieu of the number of collisions.

It is hypothesized that the installation of pedestrian treatments will significantly reduce risky pedestrian behavior. The following five risky pedestrian behaviors have been selected for analysis, because they represent risky pedestrian behavior that may contribute to pedestrian-related LRV collisions.

Do Pedestrians Deviate from a Sidewalk or Pathway?

Although a pedestrian sidewalk or pathway may exist at a grade crossing, pedestrians sometimes choose not to follow the path. Deviation from the sidewalk or pathway may result in a pedestrian crossing the trackway at a potentially hazardous location where the line of sight may be inadequate or where the pedestrian is in the motorist's right-of-way. Channelization through fencing or landscaping may discourage pedestrians from deviating from the desired path.

Do Pedestrians Stop or Slow Down Before Entering a Trackway?

When a pedestrian approaches a light rail grade crossing and an LRV is approaching, the pedestrian should stop and wait outside of the trackway, clear of the LRV's dynamic envelope. Entering into the trackway as a train is approaching can be potentially hazardous—a pedestrian may be struck by an LRV if standing away from the tracks but inside of the LRV's dynamic envelope. A tactile warning strip with the text "Stop Here" embedded into the strip may reduce the possibility of a pedestrian entering into the trackway as an LRV approaches.

Do Pedestrians Look Both Ways Before Entering a Crossing?

Because trains may approach a crossing from two directions at a grade crossing, pedestrians must look both ways before entering the crossing, especially when two trains meet at or near a crossing or station. Pedestrians may see the first train pass and assume that it is safe to cross the trackway, without noticing that a second train may be approaching from the opposite direction. Although signs have been installed at every gated grade crossing reminding pedestrians to look both ways, the signs may sometimes be ignored or missed. Directional audible devices for pedestrians and pedestrian positive control devices such as swing gates or pedestrian automatic gates may increase the likelihood of pedestrians looking both ways before entering a crossing.

Do Pedestrians Enter a Crossing Before a Train Comes but with Bells, Lights, and Gates Activated?

Pedestrians may walk into the path of an oncoming train at a pedestrian crossing if inattentive to the surrounding environment. They also may choose to ignore the flashing lights and bells and walk into the trackway as a train is approaching in an effort to beat the train. Both

TABLE 1 Control Devices at Selected Crossings

	28^{th} Avenue		Baseline Road		122^{nd} Avenue	
Control Device	**Before**	**After**	**Before**	**After**	**Before**	**After**
Motorist Gates and Flashing Lights	X	X	X	X		
"Look Both Ways" Sign	X	X	X	X		X
Pedestrian Barrier Channelization		X	X	X		
Median Barrier Channelization				X		
Prototype Active Pedestrian Warning Device				X		
Prototype Active "Look Both Ways" Sign						X
Pedestrian Signal (ped head)					X	X
Pedestrian Automatic Gates		X				
"Stop Here" Pavement Marking		X		X		

of these situations are potentially hazardous at the grade crossing. Pedestrians trying to beat the train may slip or trip while crossing the tracks and be struck by an oncoming LRV. For inattentive pedestrians, directional audible warning devices, active train approaching signs, or swing gates may reduce the likelihood of their risky behavior. For pedestrians trying to beat the train, pedestrian automatic gates may reduce the likelihood of risky behavior.

Do Pedestrians Enter a Crossing After a Train Has Passed but Before the Gates Fully Ascend?

Sometimes pedestrians enter a crossing after a train has passed but before the gates fully ascend to the vertical position and the lights deactivate. This behavior is considered risky because a second train could be approaching the crossing from the opposite direction. Automatic pedestrian gates or "Second Train Approaching" signs may reduce the likelihood of this risky pedestrian behavior.

STATISTICAL ANALYSIS METHODOLOGY

The statistical analysis methodology is presented, describing the process of evaluating the data collected at the crossings. The effectiveness of pedestrian control devices at highway rail grade crossings is evaluated by statistically analyzing the collected data. Before-and-after field evaluations are used to determine the effects of pedestrian crossing treatments on risky pedestrian behavior.

The first step in the analysis compares the proportion of times a behavior occurred before a pedestrian treatment to the proportion of times it occurred after the treatment, to obtain a general comparison of before and after behavior.

The next step determines if a pedestrian treatment has a statistically significant effect in reducing risky pedestrian behavior. This determination can be made using a *t*-test. This test is a statistical analysis to compare the means between two samples and determine if a statistically significant change has occurred. In a before-and-after safety study, the change can be attributed to a treatment installed at the study location, assuming that all other factors remained constant between the two periods. The benefit of a *t*-test is that the two samples can differ in size. This is an important factor in this study because the before and after periods at the three locations were not always consistent, because of the time required to videotape and tabulate the data.

A two-tailed *t*-test is used to determine any change in pedestrian behavior between the before and after periods, using a .05 level of significance. The Z_{crit} for this analysis is +1.960. If Z_{obs} falls within ±1.960, a statistically significant change in pedestrian behavior did not occur. A null hypothesis, H_o, was developed stating that post-installation pedestrian behavior will not change; that is, H_o: $x_b - x_a = 0$.

The alternate hypothesis, H_1, is that a statistically significant change did occur in pedestrian behavior at the crossing as a result of the pedestrian treatment; that is, H_1: $x_b - x_a \neq 0$.

If Z_{obs} falls between −1.960 and +1.960, the null hypothesis is accepted; that is, a statistically significant change in pedestrian behavior did not occur. Conversely, if Z_{obs} does not fall within the critical region, a statistically significant change in pedestrian behavior did occur.

ANALYSIS

A preliminary analysis of the before and after data collected at Baseline Road and 28th Avenue produced the initial results presented in Tables 1 to 4. These results provide an overview of the difference in the percentage of times that pedestrians exhibited certain behaviors.

On the basis of the data, a *t*-test was conducted. The critical region at .05 significance level is +1.960 for a two-tailed *t*-test. As such, for the change in pedestrian behavior to be statistically significant, Z_{obs} must be greater than +1.960 or less than −1.960. Table 5 lists the Z_{obs} for each behavior at all three crossings and indicates whether or not the change in pedestrian behavior was statistically significant.

In comparing Tables 2 to 4 with Table 5, if Z_{obs} is greater than +1.960, a statistically significant increase in the pedestrian behavior occurred at the .05 level. Similarly, if Z_{obs} is less than −1.960, a statistically significant decrease in the pedestrian behavior occurred at the .05 level.

Sidewalk or Pathway Deviations

At 28th Avenue, the change in pedestrians deviating from the sidewalk or pathway during the before and after periods was not statistically significant.

At Baseline Road, the percentage of pedestrians deviating from the sidewalk or pathway dropped from 14% in the before period to 5% in the after period. The *t*-test found this to be a statistically significant reduction in risky pedestrian behavior. The geometry of the Baseline Road grade crossing may have contributed to pedestrians deviating from the sidewalk in the before period. The installation of fencing in the roadway median and extended pedestrian channelization may have contributed to the lower percentage of pedestrians deviating from the sidewalk in the after period.

TABLE 2 Comparative Analysis at 28th Avenue

	BEFORE				AFTER			
Behavior	**Yes**	**No**	**Total**	**% Yes**	**Yes**	**No**	**Total**	**%Yes**
Deviates From Sidewalk Or Pathway	17	417	434	**3.92**	19	305	324	**5.86**
Stops Or Slows Before Entering Trackway	357	81	438	**81.51**	18	298	316	**5.70**
Looks Both Ways Prior To Entering Crossing	379	5	384	**98.70**	24	0	24	**100.00**
Enters Crossing Just Prior To Train Coming	51	381	432	**11.81**	1	314	315	**0.32**
Enters Crossing After Train Has Passed, But Prior To Gates Ascending	54	374	428	**12.62**	0	315	315	**0.00**

TABLE 3 Comparative Analysis at Baseline Road

	BEFORE				AFTER			
Behavior	**Yes**	**No**	**Total**	**% Yes**	**Yes**	**No**	**Total**	**%Yes**
Deviates From Sidewalk Or Pathway	47	284	331	**14.20**	12	231	243	**4.94**
Stops Or Slows Before Entering Trackway	261	60	321	**81.31**	17	226	243	**7.00**
Looks Both Ways Prior To Entering Crossing	283	22	305	**92.79**	23	220	243	**9.47**
Enters Crossing Just Prior To Train Coming	12	381	330	**3.64**	5	216	221	**2.26**
Enters Crossing After Train Has Passed, But Prior To Gates Ascending	16	374	330	**4.85**	3	218	221	**1.36**

At 122nd Avenue, the percentage increase in pedestrians deviating from the sidewalk or pathway was statistically significant. However, the treatments installed at this crossing for the after data collection period were not intended to modify this type of behavior.

Stopping or Slowing Before Entering a Trackway

At 28th Avenue and Baseline Road, the percentage of pedestrians stopping or slowing before entering a trackway decreased from approximately 81% in the before period to 6% and 7%, respectively, in the after period. The *t*-test determined these changes to be statistically significant. The changes may be attributed to a sense of security felt by pedestrians when an automatic pedestrian gate or active pedestrian warning device is installed. With the installation of the active devices, pedestrians may not think that they are at risk even if an active device is not activated.

At the 122nd Avenue grade crossing, the percentage of pedestrians stopping or slowing before entering the trackway increased from 20% in the before period to approximately 66% in the after period. This change was found to be statistically significant using a *t*-test. The geometry of the 122nd Avenue crossing, combined with the existing pedestrian control devices at the intersection, may have made the treatments at this crossing more effective than the treatments at the 28th Avenue or Baseline Road crossing.

Looking Both Ways Before Entering a Crossing

The data collected at the 28th Avenue grade crossing are inconclusive as far as the percentage of pedestrians that looked both ways. In the after data collection period, out of 316 pedestrians, 292 pedestrians could not be distinguished as to whether or not they looked both ways, because of the camera angle placement.

The percentage of pedestrians who looked both ways before entering the crossing at Baseline Road dropped from 93% in the before period to 9% in the after period, a statistically significant change. Similar to the situation of pedestrians stopping at the grade crossing, this finding may be attributed to an increased sense of security when an active pedestrian warning device is installed.

At 122nd Avenue, the percentage of pedestrians who looked both ways before entering the crossing dropped from 65% in the before period to 50% in the after period, a statistically significant change. This finding also may be attributed to an increased sense of security when an active pedestrian warning device is installed.

Entering a Crossing Just Before a Train Arrives

At the 28th Avenue grade crossing, the percentage of pedestrians entering the crossing just before a train arrived at the crossing dropped from 12% in the before period (51 of 432) to less than 1% in the after period (1 of 315). This statistically significant drop may be primarily attributed to the installation of the automatic pedestrian gates at the crossing. The reduction in this type of risky pedestrian behavior underlines the effectiveness of pedestrian gates at highway rail grade crossings, because the gate physically blocks the path of a pedestrian who may try to beat the train.

At Baseline Road, where automatic gates were not installed but active warning devices were, the change in pedestrian behavior is not considered statistically significant using the *t*-test.

At 122nd Avenue, the percentage of pedestrians entering the crossing just before the arrival of a train increased from 3.5% in the before period to 7.0% in the after period. This increase is statistically significant. Because the active "Look Both Ways" sign alerts a

TABLE 4 Comparative Analysis at 122nd Avenue

	BEFORE				AFTER			
Behavior	**Yes**	**No**	**Total**	**% Yes**	**Yes**	**No**	**Total**	**% Yes**
Deviates From Sidewalk Or Pathway	178	4338	4516	**3.94**	137	1856	1993	**6.87**
Stops Or Slows Before Entering Trackway	904	3612	4516	**20.02**	1272	648	1920	**66.25**
Looks Both Ways Prior To Entering Crossing	2944	1572	4516	**65.19**	974	966	1940	**50.21**
Enters Crossing Just Prior To Train Coming	178	4338	4516	**3.49**	134	1786	1920	**6.98**
Enters Crossing Immediately After Train Departure	14	4502	4516	**0.31**	114	1806	1920	**5.94**

TABLE 5 *t*-Test Results

Behavior	28th Ave		Baseline Rd		122nd Ave	
	Z_{obs}	Statistically Significant	Z_{obs}	Statistically Significant	Z_{obs}	Statistically Significant
Deviates From Sidewalk Or Pathway	1.663	No	-4.228	Yes	6.671	Yes
Stops Or Slows Before Entering Trackway	-34.784	Yes	-29.797	Yes	50.600	Yes
Looks Both Ways Prior To Entering Crossing	-0.338	No	-50.330	Yes	-13.878	Yes
Enters Crossing Just Prior To Train Coming	-6.406	Yes	-1.271	No	6.782	Yes
Enters Crossing Immediately After Train Departure	-6.829	Yes	-2.573	Yes	44.151	Yes

pedestrian about a train approaching the station, this sign may actually be enticing pedestrians to cross the tracks to catch the train. However, because the data do not provide directionality, it cannot be stated whether pedestrians crossing just before a train arrived were crossing to board a train or had just alighted from a train.

The prototype active "Look Both Ways" was developed to warn pedestrians that a second train might be approaching the crossing at the station location. The sign illuminates whenever a train is approaching the station. Initially this sign was intended to be a "Second Train Coming" sign similar to those used in Los Angeles, California, and Calgary, British Columbia, Canada. However, the track circuitry required to operate the sign as a "Second Train Coming" sign was cost prohibitive and the "Look Both Ways" sign was selected instead. The effectiveness of the "Second Train Coming" sign has been studied by the Los Angeles Metropolitan Transit Authority (LAMTA) and found to be effective. The active "Second Train Coming" sign installed at the Vernon Avenue station on the Los Angeles MTA Metro Blue Line illuminates only when a second train is approaching. On the basis of an interview with Vijay Khawani of LAMTA, a preliminary analysis of the data shows a 75% drop in risky pedestrian behavior at the Vernon Avenue crossing after installation of the "Second Train Coming" sign.

Entering a Crossing After a Train Has Passed but Before the Gates Ascend

The number of pedestrians entering the crossing after a train had passed, but before the gates ascended, dropped from 54% in the before period (12% of the total number of pedestrians) to 0% in the after period at 28th Avenue. This is a statistically significant change from the *t*-test results. This reduction in risky pedestrian behavior can be directly attributed to the pedestrian automatic gates and further demonstrates the effectiveness of that device.

At Baseline Road, the number of pedestrians entering the crossing after a train had passed, but before the gates ascended, dropped from 16.0% in the before period (5.0% of the total number of pedestrians) to 3.0% in the after period (1.4% of the total number of pedestrians). This change in pedestrian behavior is statistically significant. The prototype pedestrian active warning device installed was effective in reducing risky pedestrian behavior at this crossing.

At 122nd Avenue, the number of pedestrians entering the crossing immediately after the departure of a train increased from 14% in the before period (0.3% of the total number of pedestrians) to 114% in the after period (6% of the total number of pedestrians). This is a statistically significant change. Combined with the increase in pedestrians who did not look both ways at this crossing, this statistic is troubling. The prototype active "Look Both Ways" sign was not effective in reducing risky pedestrian behavior when a train was at the crossing. In fact, the risky pedestrian behavior when a train was present increased a statistically significant amount.

ASSUMPTIONS AND CAVEATS

This statistical analysis provides the best evaluation possible with the data provided. The assumptions in the statistical analysis are as follows:

1. Pedestrian behavior at grade crossings was not influenced by any extraneous factors at the crossings, and the differences in pedestrian behavior in the before and after periods were primarily influenced by the new treatments at the grade crossings.
2. Each sample of pedestrian behavior is independent of other samples.
3. The large number of samples allows the assumption of a normal distribution even though the pedestrian behavior is binomial in nature, with the data collected in "yes" and "no" form.
4. In the data tabulation effort, the data tabulators were directed in the same way for both the before and after periods on how to tabulate the data and what to look for.
5. The new pedestrian treatments were installed at least 1 month before the collection of the after data, to eliminate the novelty effect of the new devices.

Several caveats apply to the data collection and statistical analysis of the risky behavior at the two grade crossings.

1. Because the before data were tabulated by a different Tri-Met staff member than the after data, inconsistency in the tabulation may exist related to judgments made by the person tabulating the data from the video.
2. Various categories of the data tabulation sheet were left blank. The blank categories involved observations of pedestrian behavior when both a pedestrian and a train were at a grade crossing (i.e., pedestrian entering a crossing just before a train arrives, pedestrian crossing immediately after a train has passed). To compare the data between the before and after periods for these categories, the total number of pedestrians observed during the data collection period was used, not the number of pedestrians at the crossing when a train was present.
3. Construction at the 28th Avenue crossing during the after period may have influenced pedestrian behavior during that time.

CONCLUSIONS

The statistical evaluation of the data shows that the use of pedestrian gates reduces the likelihood of pedestrians entering a crossing after an active warning device has been activated. The statistical analysis also shows that at 28th Avenue and Baseline Road, the treatments significantly reduced the number of pedestrians crossing immediately after a train had departed. The effectiveness of the pedestrian treatments when a train was present at these two locations provides a foundation for the use of these devices in future applications. The statistical analysis also shows that the channelization at Baseline Road is effective in reducing the number of pedestrians deviating from the sidewalk. At the 122nd Avenue crossing, the pedestrian treatments were effective in increasing the percentage of pedestrians stopping or slowing before entering the crossing.

However, the evaluation also shows that pedestrians are less likely to look both ways or stop before entering a crossing when a pedestrian automatic gate or pedestrian flashing light is installed at the pedestrian crossing. This behavior may be attributed to pedestrians becoming dependent on the active warning device to provide them with a warning (and in the case of the pedestrian automatic gate, a barrier) rather than pedestrians making the decision to cross on the basis of seeing an approaching train. Because active warning devices such as pedestrian automatic gates and pedestrian flashing lights warn pedestrians of an approaching train, these devices take the decision of crossing the tracks away from pedestrians and warn them that they must stop at the crossing. The statistical evaluation also shows that the 122nd Avenue grade crossing had a statistically significant increase in the number of pedestrians entering the crossing immediately after a train had departed. The installation of the prototype "Look Both Ways" sign was not effective in reducing this type of behavior. An active "Second Train Approaching" sign may be an improved treatment at this type of crossing. The Los Angeles Metro Blue Line installation of the active "Second Train Approaching" sign has demonstrated the effectiveness of this sign in reducing risky pedestrian behavior.

ACKNOWLEDGMENTS

The author would like to thank Harry Saporta and Mike Russell of the System Safety Department, Tri-Met, for their assistance in this project and for allowing the presentation and publication of the results of this study. The study was funded by, and conducted with the assistance of, the System Safety Department, Tri-Met.

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Engineering PMO Estimate Report

Billing Detailed Project Estimate with Resources

Run: 4/19/2020 12:56:23 PM

Unapproved Project ID: A859
Project Description: TKRH CEN DIV - TRACK REHABILITATION - MDOT

Project Definition: A859-TKRH CEN DIV – TRACK REHABILITATION - MDOT
Project Manager Roberts, Dave
Project Funding Source: MDOT - Michigan DOT
Billing Rate Schedule: MDOT - Michigan DOT

G&A rates: 0.0724 | 0.0724 | 0.0724

Contingency rate: 0.0000
Management rate: 0.0000

WBS ID	WBS Element	WBS Description	Forecast T/O Qty	Unit of Meas	UM / Shift	Shifts (Total)	Man Count	Hrs / Shift	Total Man Hours	ST %	OT %	Labor Costs	Material Costs	Rental Equ. Total Cost	Fees Total Cost	Owned Equ. Total Cost	Other Total Cost	Subcontract Total Cost	Total Costs	Add-ons	Grand Total
62	0062	A859.0062 TKRH CEN DIV - MP 129.7 KRVT	1	LS	0.03	36.00	0.00	8	160		0.00	355,405	17,415	0	20,810	3,388	0	40,000	437,019	31,640	468,659
62.1	**HD.0001115**	**Labor**	**160**	**HR**	**8.00**	**20.00**	**0.00**	**8**	**160**		**0.00**	**11,245**	**0**	**0**	**0**	**0**	**0**	**0**	**11,245**	**814**	**12,060**
62.1.1	HD.0001163	TK FOREMAN	32	HR	8.00	4.00	1.00	8	32	100.00	0.00	2,635	0	0	0	0	0	0	2,635	191	2,826

Resource Information

Row	Code	Description	Waste	Percent	Quantity	Measure	Work Hrs	Pay Hrs	Unit Cost	Total Cost
1	CENTK6006	CEN - TK FOREMAN	1	0	1	Each	32.	32.	82.34	2,634.88

WBS ID	WBS Element	WBS Description	Forecast T/O Qty	Unit of Meas	UM / Shift	Shifts (Total)	Man Count	Hrs / Shift	Total Man Hours	ST %	OT %	Labor Costs	Material Costs	Rental Equ. Total Cost	Fees Total Cost	Owned Equ. Total Cost	Other Total Cost	Subcontract Total Cost	Total Costs	Add-ons	Grand Total
62.1.2	HD.0001203	TK TRACKMAN	64	HR	8.00	8.00	1.00	8	64	100.00	0.00	4,053	0	0	0	0	0	0	4,053	293	4,347

Resource Information

Row	Code	Description	Waste	Percent	Quantity	Measure	Work Hrs	Pay Hrs	Unit Cost	Total Cost
1	CENTK6015	CEN - TK TRACKMAN	1	0	1	Each	64.	64.	63.33	4,053.12

WBS ID	WBS Element	WBS Description	Forecast T/O Qty	Unit of Meas	UM / Shift	Shifts (Total)	Man Count	Hrs / Shift	Total Man Hours	ST %	OT %	Labor Costs	Material Costs	Rental Equ. Total Cost	Fees Total Cost	Owned Equ. Total Cost	Other Total Cost	Subcontract Total Cost	Total Costs	Add-ons	Grand Total
62.1.3	HD.0001161	TK MACHINE OPERATOR	64	HR	8.00	8.00	1.00	8	64	100.00	0.00	4,557	0	0	0	0	0	0	4,557	330	4,887

Resource Information

Row	Code	Description	Waste	Percent	Quantity	Measure	Work Hrs	Pay Hrs	Unit Cost	Total Cost
1	CENTK6011	CEN - TK MACHINE OPERATOR	1	0	1	Each	64.	64.	71.21	4,557.44

WBS ID	WBS Element	WBS Description	Forecast T/O Qty	Unit of Meas	UM / Shift	Shifts (Total)	Man Count	Hrs / Shift	Total Man Hours	ST %	OT %	Labor Costs	Material Costs	Rental Equ. Total Cost	Fees Total Cost	Owned Equ. Total Cost	Other Total Cost	Subcontract Total Cost	Total Costs	Add-ons	Grand Total
62.2	**HD.0001113**	**Equipment**	**128**	**HR**	**8.00**	**16.00**	**0.00**	**8**	**0**		**0.00**	**0**	**0**	**0**	**0**	**3,388**	**0**	**0**	**3,388**	**245**	**3,633**
62.2.1	HD.0001198	6 Man Pickup Truck 9100 gvw **	64	HR	8.00	8.00	0.00	8	0	100.00	0.00	0	0	0	0	741	0	0	741	54	795

Resource Information

Row	Code	Description	Waste	Percent	Quantity	Measure	Work Hrs	Pay Hrs	Unit Cost	Total Cost
1	94300.E0730	6 Man Pickup Truck 9100 gvw	1	0	1	Each	64.	64.	11.58	741.12

WBS ID	WBS Element	WBS Description	Forecast T/O Qty	Unit of Meas	UM / Shift	Shifts (Total)	Man Count	Hrs / Shift	Total Man Hours	ST %	OT %	Labor Costs	Material Costs	Rental Equ. Total Cost	Fees Total Cost	Owned Equ. Total Cost	Other Total Cost	Subcontract Total Cost	Total Costs	Add-ons	Grand Total
62.2.2	HD.0001156	Backhoe Loader	32	HR	8.00	4.00	0.00	8	0	100.00	0.00	0	0	0	0	919	0	0	919	67	986

Resource Information

Row	Code	Description	Waste	Percent	Quantity	Measure	Work Hrs	Pay Hrs	Unit Cost	Total Cost
1	92100.E0010	Backhoe Loader	1	0	1	Each	32.	32.	28.73	919.36

WBS ID	WBS Element	WBS Description	Forecast T/O Qty	Unit of Meas	UM / Shift	Shifts (Total)	Man Count	Hrs / Shift	Total Man Hours	ST %	OT %	Labor Costs	Material Costs	Rental Equ. Total Cost	Fees Total Cost	Owned Equ. Total Cost	Other Total Cost	Subcontract Total Cost	Total Costs	Add-ons	Grand Total
62.2.3	HD.0001157	2 Man 22' Platform Tie Grapple Truck,	32	HR	8.00	4.00	0.00	8	0	100.00	0.00	0	0	0	0	1,727	0	0	1,727	125	1,852

Resource Information

Row	Code	Description	Waste	Percent	Quantity	Measure	Work Hrs	Pay Hrs	Unit Cost	Total Cost
1	94300.E0080	2 Man 22' Platform Tie Grapple Truck, w/Magnet and Hyrail, 72,000 gvw	1	0	1	Each	32.	32.	53.98	1,727.36

WBS ID	WBS Element	WBS Description	Forecast T/O Qty	Unit of Meas	UM / Shift	Shifts (Total)	Man Count	Hrs / Shift	Total Man Hours	ST %	OT %	Labor Costs	Material Costs	Rental Equ. Total Cost	Fees Total Cost	Owned Equ. Total Cost	Other Total Cost	Subcontract Total Cost	Total Costs	Add-ons	Grand Total
62.3	**HD.0001168**	**Material**	**1**	**LS**	**0.00**	**0.00**	**0.00**	**8**	**0**	**100.00**	**0.00**	**0**	**17,415**	**0**	**0**	**0**	**0**	**0**	**17,415**	**1,261**	**18,676**

Resource Information

Row	Code	Description	Waste	Percent	Quantity	Measure	Work Hrs	Pay Hrs	Unit Cost	Total Cost
1	5000002715	CROSSING, CONCRETE WITH RUBBERINTERFACE, 10' PREFABRICATED PANELLENGTHS FOR 136RE ON 10' WOOD TIESWITH CUT SPIKES AND UNIT 5 DRIVE ONRAIL ANCHORS. INCLUDES ALL HOLDDOWNFASTENERS. PRICE IS PER TRACK FOOT.FOR 8' PANELS USE 5000002698.FOR SIDESHIELDDEFLECTO	2	0	2	EA	0.	0.	1,832.44	3,664.88
2		Amtrak Signal Material	1	0	1	LS	0.	0.	13,750.00	13,750.00

WBS ID	WBS Element	WBS Description	Forecast T/O Qty	Unit of Meas	UM / Shift	Shifts (Total)	Man Count	Hrs / Shift	Total Man Hours	ST %	OT %	Labor Costs	Material Costs	Rental Equ. Total Cost	Fees Total Cost	Owned Equ. Total Cost	Other Total Cost	Subcontract Total Cost	Total Costs	Add-ons	Grand Total
62.4	**HD.0001158**	**Amtrak Signal Work**	**1**	**LS**	**0.00**	**0.00**	**0.00**	**8**	**0**	**100.00**	**0.00**	**326,000**	**0**	**0**	**0**	**0**	**0**	**0**	**326,000**	**23,602**	**349,602**

Resource Information

Row	Code	Description	Waste	Percent	Quantity	Measure	Work Hrs	Pay Hrs	Unit Cost	Total Cost
1		Signal Works	1	0	1	LS	0.	0.	326,000.00	326,000.00

WBS ID	WBS Element	WBS Description	Forecast T/O Qty	Unit of Meas	UM / Shift	Shifts (Total)	Man Count	Hrs / Shift	Total Man Hours	ST %	OT %	Labor Costs	Material Costs	Rental Equ. Total Cost	Fees Total Cost	Owned Equ. Total Cost	Other Total Cost	Subcontract Total Cost	Total Costs	Add-ons	Grand Total
62.5	**HD.0001162**	**Amtrak Signal Labor**	**1**	**LS**	**0.00**	**0.00**	**0.00**	**8**	**0**	**100.00**	**0.00**	**11,760**	**0**	**0**	**0**	**0**	**0**	**0**	**11,760**	**851**	**12,611**

Resource Information

Row	Code	Description	Waste	Percent	Quantity	Measure	Work Hrs	Pay Hrs	Unit Cost	Total Cost
1		Signal Labor	1	0	1	LS	0.	0.	11,760.00	11,760.00

WBS ID	WBS Element	WBS Description	Forecast T/O Qty	Unit of Meas	UM / Shift	Shifts (Total)	Man Count	Hrs / Shift	Total Man Hours	ST %	OT %	Labor Costs	Material Costs	Rental Equ. Total Cost	Fees Total Cost	Owned Equ. Total Cost	Other Total Cost	Subcontract Total Cost	Total Costs	Add-ons	Grand Total
62.6	**HD.0001164**	**Amtrak PM & Engineering**	**1**	**LS**	**0.00**	**0.00**	**0.00**	**8**	**0**	**100.00**	**0.00**	**6,400**	**0**	**0**	**0**	**0**	**0**	**0**	**6,400**	**463**	**6,863**

Resource Information

Row	Code	Description	Waste	Percent	Quantity	Measure	Work Hrs	Pay Hrs	Unit Cost	Total Cost
1		PM & Engineering	1	0	1	LS	0.	0.	6,400.00	6,400.00

WBS ID	WBS Element	WBS Description	Forecast T/O Qty	Unit of Meas	UM / Shift	Shifts (Total)	Man Count	Hrs / Shift	Total Man Hours	ST %	OT %	Labor Costs	Material Costs	Rental Equ. Total Cost	Fees Total Cost	Owned Equ. Total Cost	Other Total Cost	Subcontract Total Cost	Total Costs	Add-ons	Grand Total
62.7	**HD.0001165**	**Paving Contractor**	**1**	**LS**	**0.00**	**0.00**	**0.00**	**8**	**0**	**100.00**	**0.00**	**0**	**0**	**0**	**0**	**0**	**0**	**40,000**	**40,000**	**2,896**	**42,896**

Resource Information

Row	Code	Description	Waste	Percent	Quantity	Measure	Work Hrs	Pay Hrs	Unit Cost	Total Cost
1		Paving	1	0	1	LS	0.	0.	40,000.00	40,000.00

WBS ID	WBS Element	WBS Description	Forecast T/O Qty	Unit of Meas	UM / Shift	Shifts (Total)	Man Count	Hrs / Shift	Total Man Hours	ST %	OT %	Labor Costs	Material Costs	Rental Equ. Total Cost	Fees Total Cost	Owned Equ. Total Cost	Other Total Cost	Subcontract Total Cost	Total Costs	Add-ons	Grand Total
62.8	**HD.0001159**	**Contingency (5%)**	**1**	**LS**	**0.00**	**0.00**	**0.00**	**8**	**0**	**100.00**	**0.00**	**0**	**0**	**0**	**20,810**	**0**	**0**	**0**	**20,810**	**1,507**	**22,317**

Resource Information

Row	Code	Description	Waste	Percent	Quantity	Measure	Work Hrs	Pay Hrs	Unit Cost	Total Cost

Note: This is only an estimate. Final billing will be based on the actual labor, material, equipment and subcontract costs incurred.
Labor costs include Benefits and Overheads; Fees Total Cost include material handling additive; If a

![AMTRAK]

Engineering PMO Estimate Report

Billing Detailed Project Estimate with Resources

Run: 4/19/2020 12:56:23 PM

		1	Contingency									0.05	0	0.05	PC	0.	0.	416,208.16	20,810.41		
		Report Total							**160**			**355,405**	**17,415**	**0**	**20,810**	**3,388**	**0**	**40,000**	**437,019**	**31,640**	**468,659**

Note: This is only an estimate. Final billing will be based on the actual labor, material, equipment and subcontract costs incurred.
Labor costs include Benefits and Overheads; Fees Total Cost include material handling additive; If a