

Rail Crossing Gate Optimization Project

Recipient: Los Angeles County Metropolitan Transportation Authority (Metro)

FY 2023 Stage One

Period of Performance: July 1, 2024 – July 31, 2026

Organizations Preparing the Implementation Report: Los Angeles County
Metropolitan Transportation Authority (Metro), Wabtec

Submittal Date: September 11, 2026



Definitions

Term	Description
Active Wireless Session	A wireless crossing session that is initiated by an inhibit message.
Approach Circuit	A wired track circuit that, when shunted by the train wheels, activates a crossing's Preemption (if so equipped) and Warning cycles.
Critical Point	The critical point is a location where the on-board must be assured that the path ahead is clear. If the path isn't clear by the time the train reaches the critical point, a wireless activation session shall not be initiated. The critical point is defined by a time WATBC5 plus WATBC1 times (WATBC10+1) seconds ahead of the Time at Approach if the train is travelling at or below the circuit design speed or WATBC5 plus WATBC1 times (WATBC10+1) seconds ahead of the high-speed communication point if the train is travelling above the circuit design speed.
Dwell Time	The amount of time the train is expected to be stopped at a station platform. Each wayside can be programmed to have a dwell time that is sent to the on-board via a Crossing Timers Message. A default for this value (WATBC6) is stored in a configuration file and will only be used if the Crossing Timers Message is not received.
Inhibit	The process of the PTC on-board engaging with a grade crossing equipped with Wireless Crossing technology to prevent the crossing warning equipment from activating as the PTC enabled passenger train is approaching a scheduled passenger station stop and adjacent grade crossing.
Station Stop Indicator	A virtual signal used to indicate an unenforced stop. Primarily used to identify the general location of a station and to indicate a station stop.
On-board	Wabtec's Positive Train Control computer and display system that is located on the train. Also referred to as a Train Management Computer.
Penalty/Emergency Recovery	The process of recharging the brakes after being stopped by a PTC imposed penalty or a crew activated emergency.
Preemption	An activation signal provided to the auto traffic control system via the xWIU indicating a train is approaching. This signal is usually sent several seconds prior to the warning system operation.
Station Stop Location	The location of the station platform defined by WATBC20 feet in advance of the Station Stop Indicator and 4 x WATBC20 feet behind the Station Stop Indicator.
Unhealthy Crossing	A crossing that has received a Crossing Status Message with the health bit set to "0" or has not received a Crossing Status Message with the health set to "1" within 12 seconds.
Unplanned Stop	An instance where the train has stopped due to a condition exclusive of a station stop, penalty or an emergency brake application.
Warning Time	The time from the start of a crossings warning system (bells, lights, gates) until the leading edge of the train reaches the nearside island.
Wireless Island	A location used for wireless crossing targeting. It is represented as an offset value from the centerline of the road and is independent of the surveyed highway-grade crossing island.
xWIU	Crossing Wayside Interface Unit that is configured to process Positive Train Control Messages and Wireless Activation.

Acronyms

Acronym	Description
CDU	Computer Display Unit (aka Cab Display Unit)
ICD	Interface Control Document
ETA	Estimated Time of Arrival
PTC	Positive Train Control
WATBC	Wireless Activation To Be Configured
xWIU	Crossing Wayside Interface Unit

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Executive Summary

The Los Angeles County Metropolitan Transportation Authority (Metro) evaluated Wabtec's Wireless Crossing Activation technology under the U.S. DOT SMART Program to determine whether wireless train-based crossing activation can reduce gate down time, improve traffic flow, and maintain safe railroad operations. Testing was conducted in shadow mode using two light rail vehicles and five crossings on the A and E Lines.

Key Findings

The demonstration validated onboard prediction, train-to-wayside communications, crossing control logic, and back-office integration. The wireless system consistently reduced warning and preemption times compared to conventional fixed activation approaches. Several locations demonstrated total warning time reductions of approximately 53% to 61%, while preemption time reductions frequently exceeded 70%.

Operational Insights

Performance was strongest at crossings without governing signals. Existing signal and station-stop constraints affected arrival-time prediction accuracy, but iterative tuning significantly improved performance. Results demonstrated flexibility through software configuration changes rather than infrastructure-intensive modifications.

Deployment Considerations

A production implementation would require permanent onboard installations, cab signal integration, light-rail-specific software enhancements, predictor improvements, selected wayside modifications, and regulatory approvals from the CPUC and other stakeholders. Planning assumptions identified estimated costs of approximately \$229,080 per trainset and \$479,230 per crossing for a large-scale deployment.

Conclusion

The Stage One demonstration successfully proved the technical feasibility of Wireless Crossing Activation within Metro's light rail environment. The technology demonstrated meaningful reductions in crossing activation durations while maintaining safety and provides a strong foundation for future systemwide deployment.

Chapter 1: Introduction

The Los Angeles County Metropolitan Transportation Authority (Metro) pursued an innovative wireless crossing gate activation system to improve the performance, safety, and reliability of grade crossing operations on its light rail network. This Stage One evaluation, funded under the U.S. DOT SMART Program, assessed whether wireless activation can safely and accurately optimize crossing gate downtimes—addressing significant congestion and safety issues at urban rail crossings. The proposed wireless intelligent sensor based system calculated real-time train position, speed, and direction to activate gates dynamically reducing unnecessary gate downtime while maintaining safety.

Metro currently uses hardwired loop circuits that activate crossing gates based on assumptions about Light Rail Vehicle (LRV) speeds. When LRVs travel slower than expected—due to station dwell time, congestion, or operational conditions—gates remain down longer than necessary, creating localized roadway congestion and risky vehicle and pedestrian behavior, such as gate violations. These issues are expected to worsen with major upcoming events like the 2026 FIFA World Cup and 2028 Olympic & Paralympic Games.

When implemented at scale, Metro anticipates that optimizing crossing gate downtime will deliver two major benefits: 1) reduce instances of localized congestion due to long crossing gate downtimes and 2) mitigate risky behaviors (i.e., pedestrians and drivers passing through or around crossing gates).

1.1 Community Benefits

The Rail Crossing Gate Optimization Project will benefit disadvantaged communities and the areas surrounding the five at-grade crossing test locations by reducing localized congestion and increasing the safety of motorists and pedestrians. These benefits extend beyond the specific testing locations for Stage One. While two test locations were within disadvantaged communities, other test locations were in proximity or adjacent to disadvantaged communities. Given the distances that residents commute or travel for errands, it is likely that many trips originate from or end in a disadvantaged community. Shorter gate downtimes would reduce delays that travelers experience, thereby reducing overall travel times. If implemented systemwide, this crossing gate technology would directly benefit many disadvantaged communities that intersect with Metro's service area.

1.2 Scale of Deployment

Stage One tested the feasibility, accuracy, and safety of the wireless system in shadow mode, meaning it did not control operations and did not replace existing safety systems.

Deployment for Stage One included:

- Two LRVs equipped with onboard wireless systems
- Five crossings equipped with wireless controllers
- Data collection via log files to compare wireless activation timing with legacy loop circuits

Testing was conducted at five at-grade crossing locations along Metro's A and E light rail lines:

1. **Del Mar Boulevard (City of Pasadena):** This crossing is three blocks east of the 710 Freeway spur, where traffic from two freeways spills onto Del Mar Boulevard.
2. **Mountain Avenue (Cities of Duarte and Monrovia):** Mountain Avenue borders the suburban cities of Duarte and Monrovia. This crossing spans two disadvantaged communities (Census tracts 06037430101 and 06037430102) and is one block south of the 210 Freeway, whose on-ramps spill directly onto the corridor.
3. **Spring Street (City of Long Beach):** Spring Street runs parallel to a section of the 405 Freeway, one of the most congested interstates in the nation. It also serves as one of the main east-west connections in Long Beach to the L.A. River bike path, which is approximately 3/4-mile west of the crossing.
4. **11th Avenue (City of Los Angeles):** This crossing is located in a disadvantaged community (Census tract 06037219300), surrounded by industrial and residential land uses.
5. **Stewart Street (City of Santa Monica):** Stewart Street is a local street with two lanes in each direction. Traffic delays resulting from the at-grade crossing on Stewart Street also affect circulation on Olympic Boulevard, a major east-west thoroughfare in Santa Monica, which is located 100 feet north of the crossing.

Metro partnered with Wabtec to test whether a wireless crossing system can trigger the opening and closing of the crossing gate systems safely and reliably. The technology was tested in shadow mode with no impact to current operations and communicated between the crossing activation system and onboard vehicle systems to record the point of gate crossing activation. This allowed the team to compare wireless activation times to activation times using the conventional loop circuit. Rather than a fixed point of activation, as is the current default, this technology would allow for a more dynamic warning system sensitive to the train's speed, position, and direction.

During a potential Stage Two deployment, Metro would seek approval from the California Public Utilities Commission (CPUC) to allow the wireless system to activate the crossing gates, rather than operating in shadow mode as was done during Stage One. The rail operator would have a graphical interface unit that provides prompts on how he or she

should handle the train within the crossing approach, providing further potential improvements in warning times. If Metro does not receive CPUC approval, Metro could conduct testing on non-gated crossings, as these crossings are located on streets managed by local cities and would not require CPUC approval.

1.3 Stage One Activities

A representative set of crossings was selected to exercise the system under varied operating conditions, including straight-through and express movements, station stop operations, and a location with a tunnel approach. These scenarios enabled evaluation across multiple operational use cases relevant to light rail operations.

The wayside, communications, and office system configurations used were highly representative of a production environment. The onboard installation, however, was temporary in nature, but included key components: the Train Management Computer (TMC), display, communications and GPS subsystem. Certain onboard inputs, such as brake pipe pressure, required simulation. The onboard unit (Locomobile) was installed within the passenger compartment and interfaced with the light rail vehicle to capture wheel tachometer data, with additional cabling required to connect to a roof-mounted GPS antenna.

For a two-week period, the demonstration was conducted between 9 p.m. and 3:30 a.m. on two trains along the A and E lines. Because the demonstration was performed during non-revenue service hours, the trains did not have to complete the full timetable route to satisfy the end-to-end run criterium. It was sufficient for the runs to begin outside the approach circuit at a station ahead of the approach or at a location that allowed the train to reach normal operating speeds prior to reaching the approach circuit. The team aimed to achieve 15 to 20 runs for each crossing to provide a sufficient representation of the expected warning times. Onboard and Wayside log files were collected and analyzed to assess the performance of the Wireless Crossing System, as well as collection of actual warning time data.

Chapter 2: Proof of Concept Evaluation Findings

The demonstration successfully validated deployment of the core wireless system infrastructure, including wayside, communications, office, and onboard components. It also successfully validated the system's ability to operate within the Metro light rail environment.

Temporary deployment of hardware and communications enabled effective operation of onboard prediction, train-to-wayside communication, and crossing control. On a crossing-by-crossing basis, several locations demonstrated more efficient activation using the wireless system in its current configuration, despite not being specifically designed for light rail. Other crossings required configuration tuning, highlighting the flexibility of the system. Station-stop crossings with governing signals demonstrated strong potential but would require targeted design enhancements to fully optimize performance. Despite demonstration limitations, the results show that the wireless system provides a strong foundation for improving traffic flow and offers future opportunities to extend functionality to crossings governed solely by traffic signal operation.

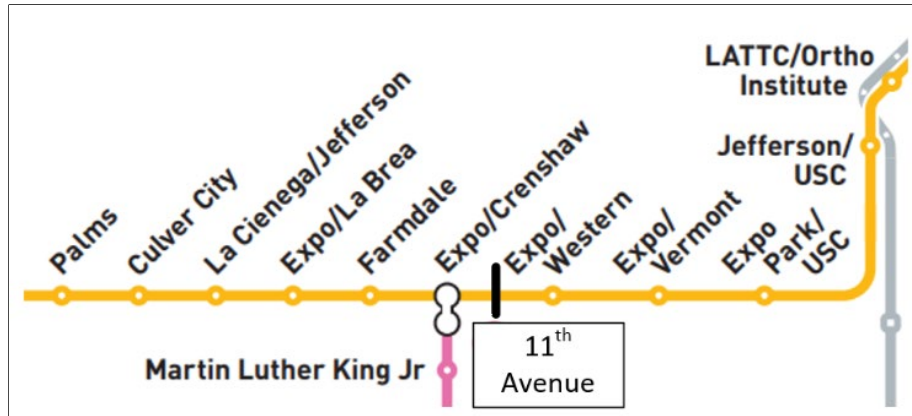
2.1 Detailed Findings

Further tuning of the wireless system would be needed to lower the crossing's warning cycle, but the fixed preemption cycle and the dynamic change in ETA allowed for a 60.7% lower total warning time and 77.1% lower preemption time with the wireless system. Crossing activation time was 11% higher with wireless. Detailed findings by crossing are summarized below.

E Line Crossings

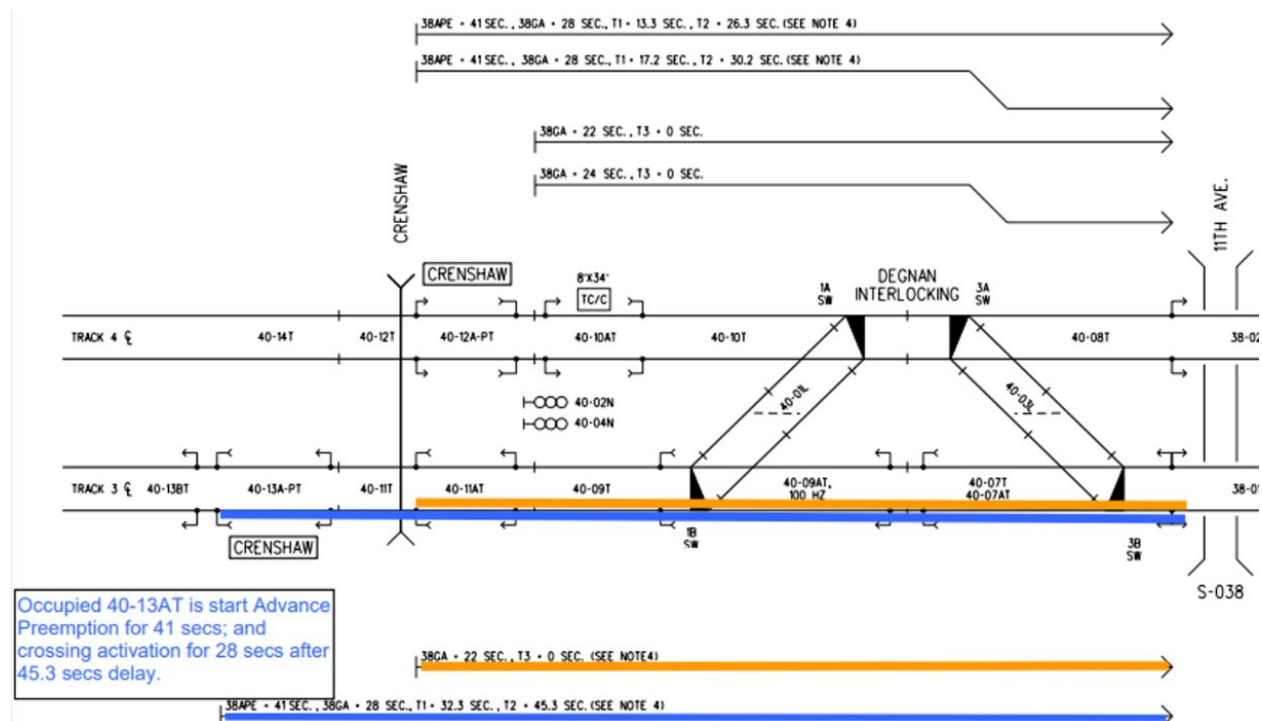
11th Avenue

11th Avenue in the northbound direction is subjected to a station stop at Expo/Crenshaw Station. In the southbound direction the train stops at Expo/Western Station, but the station is not located on the approach to 11th Avenue. In both directions, the warning system is influenced by station stops.



Northbound

Operations in the northbound direction at 11th Avenue contain a signal that is red until the track circuit (XR) is shunted. This means that all trains stop at the signal until the crossing gates are horizontal. After the gates are horizontal, the signal turns green and the train may proceed through the crossing. Prior to shunting the XR circuits, the train shunts the preemption circuits, sending a signal to the traffic controller. The shunting occurs before stopping at Crenshaw Station.



Operational Impact on Results

The results collected from the demonstration are impacted by operations on the Metro alignment that are atypical for the wireless design. In essence, the presence of a signal ahead of the crossing is not required for normal wireless operations. Instead, the onboard will calculate an estimated time of arrival at the crossing and set a speed target at the nearside island. This allows for coordination between the onboard and wayside controllers. In the case of 11th Avenue northbound, the presence of the stop signal interferes with the predictor and causes limitations in the ability of the wireless crossing system to provide accurate estimated time of arrivals.

Results

		Wireless							
		Total Warning				Time in Seconds			
Run	Date	Inhibit	Approach	Start	End	Total	Warning	Preemption	
Pre Tuning	1	2/2/2026	23:05:53	23:06:01	23:07:01	23:10:07	202	186	16
	2	2/3/2026	1:33:33	1:33:40	1:34:39	1:36:13	110	94	16
	3	2/3/2026	2:43:12	2:43:19	2:44:20	2:45:39	95	79	16
	4	2/4/2026	0:38:10	0:38:17	0:39:17	0:40:47	106	90	16
	5	2/4/2026	1:24:37	1:24:54	1:25:55	1:28:54	195	179	16
	6	2/4/2026	2:12:17	2:12:23	2:13:12	2:16:30	214	198	16
	7	2/4/2026	2:44:20	2:43:20	2:44:20	2:45:39	95	79	16
Average						145.3	129.3	16.0	
Post Tuning	8	2/4/2026	22:47:54	22:48:02	22:49:39	22:50:16	53	37	16
	9	2/5/2026	1:27:07	1:27:13	1:30:23	1:31:00	53	37	16
	10	2/5/2026	2:36:57	2:37:03	2:38:31	2:39:08	53	37	16
	11	2/5/2026	22:48:38	22:48:45	22:50:12	22:50:57	61	45	16
	12	2/6/2026	0:05:36	0:05:41	0:07:08	0:07:42	50	34	16
	13	2/6/2026	1:22:20	1:22:28	1:24:03	1:24:38	51	35	16
Average						53.5	37.5	16.0	

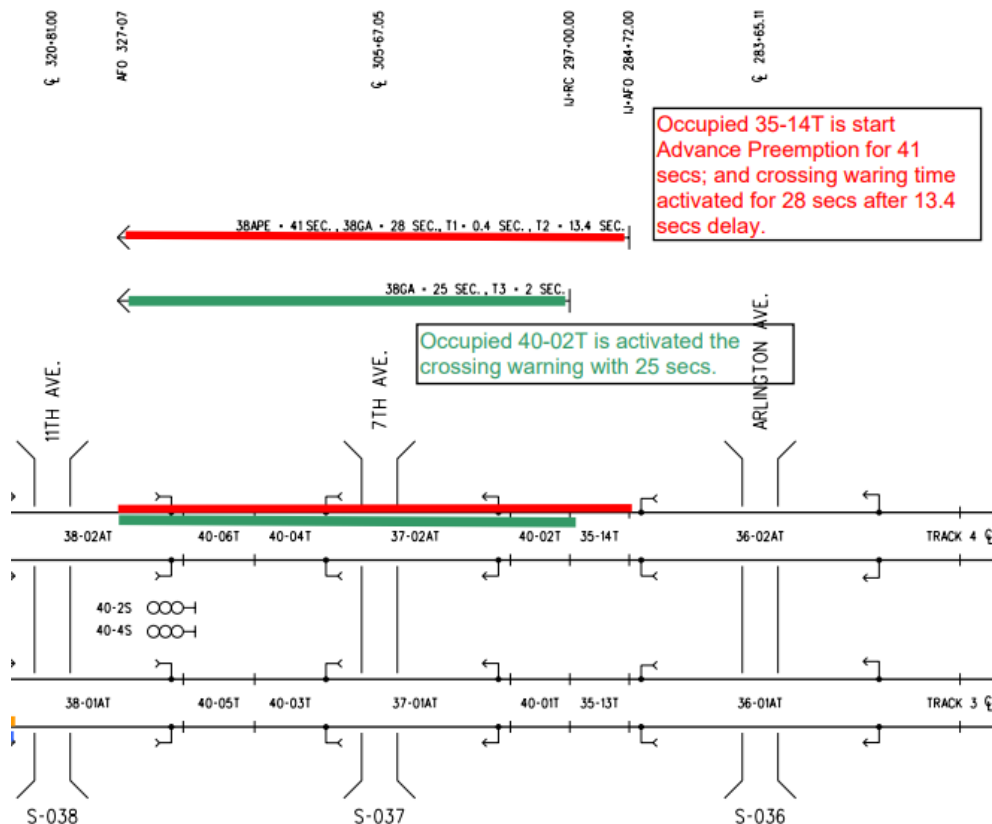
		Conventional						
		Total Warning			Time in Seconds			
Run	Date	Approach	Start	End	Total	Warning	Preemption	
1	2/2/2026	23:06:41	23:09:34	23:10:07	206	33	173	
2	2/3/2026	1:34:23	1:35:37	1:36:13	110	36	74	
3	2/3/2026	2:44:02	2:45:03	2:45:39	97	36	61	
4	2/4/2026	0:39:00	0:40:13	0:40:47	107	34	73	
5	2/4/2026	1:25:38	1:28:20	1:28:54	196	34	162	
6	2/4/2026	2:13:04	2:15:53	2:16:30	206	37	169	
7	2/4/2026	2:44:01	2:45:05	2:45:39	98	34	64	
8	2/4/2026	22:48:02	22:49:43	22:50:16	134	33	101	
9	2/5/2026	1:27:13	1:30:26	1:31:00	227	34	193	
10	2/5/2026	2:37:03	2:38:34	2:39:08	125	34	91	
11	2/5/2026	22:49:21	22:50:25	22:50:57	96	32	64	
12	2/6/2026	0:06:11	0:07:12	0:07:42	91	30	61	
13	2/6/2026	1:22:57	1:24:06	1:24:38	101	32	69	
Average					138.0	33.4	104.6	

Conclusion

Initial northbound runs used conservative acceleration and deceleration assumptions that did not match actual train behavior. These overly high values caused arrival times to be calculated too early and led to premature crossing activation. Adjusting the parameters to better reflect observed train handling improved alignment between predicted and actual arrival times. The 11th Avenue northbound case demonstrates how predictor performance can be significantly improved through parameter refinement.

The northbound results showed that the wireless system reduced the total warning time by 61% after tuning was performed. Additionally, the warning times were more favorable as adjustments were made to the predictor, but a redesign of the crossing would be required to fully take advantage of the wireless systems' functionality. In essence, the presence of the governing signal is not required and would enable a more accurate time of arrival calculation if removed. As an overlay to the existing system, the benefit would primarily be a reduction in the time when the preemption call is made to the traffic system. Warning times would be similar.

Southbound



Operational Impact on Results

Southbound trains depart Expo/Western Station (about 2,000 feet ahead of Arlington Avenue) accelerate toward 11th Avenue and then decelerate for a stop at Crenshaw Station. The wireless system is designed to accommodate station departures, and configuration adjustments were implemented to better tune the predictor for this acceleration and subsequent deceleration. Initial southbound runs required additional refinement to achieve acceptable warning times. An Approach Condition Adjustment Factor (ACAF) was applied to the onboard system to account for the post-departure acceleration from Expo/Western Station. Through data collection and iterative tuning, warning times were reduced from those observed during the initial demonstration runs.

Results

			Wireless				
			Crossing Warning		Time in Seconds		
	Run	Date	Start	End	Total	Warning	Preemption
Pre Tuning	1	2/2/2026	23:22:58	23:23:44	62	46	16
	2	2/3/2026	0:38:13	0:38:51	54	38	16
	3	2/3/2026	1:47:24	1:48:03	55	39	16
	4	2/3/2026	2:56:04	2:56:43	55	39	16
	5	2/4/2026	1:02:13	1:02:48	51	35	16
	6	2/4/2026	1:45:50	1:46:23	49	33	16
	7	2/4/2026	2:30:27	2:30:58	47	31	16
Average					53.3	37.3	16.0
Post Tuning	8	2/4/2026	23:02:29	23:03:02	49	33	16
	9	2/5/2026	0:26:53	0:27:22	45	29	16
	10	2/5/2026	1:40:54	1:41:23	45	29	16
	11	2/5/2026	2:50:03	2:50:33	46	30	16
	12	2/5/2026	23:03:04	23:03:33	45	29	16
	13	2/6/2026	0:24:40	0:25:09	45	29	16
Average					45.8	29.8	16.0

Run	Date	Conventional						
		Total Warning		Crossing Warning		Time in Seconds		
		Approach	End	Start	End	Total	Warning	Preemption
1	2/2/2026	22:22:36	23:23:44	23:22:41	23:23:44	68	63	5
2	2/3/2026	0:37:55	0:38:51	0:38:14	0:38:51	56	37	19
3	2/3/2026	1:47:08	1:48:03	1:47:26	1:48:03	55	37	18
4	2/3/2026	2:55:49	2:56:43	2:56:08	2:56:43	54	35	19
5	2/4/2026	1:01:58	1:02:48	1:02:15	1:02:48	50	33	17
6	2/4/2026	1:45:42	1:46:23	1:45:53	1:46:23	41	30	11
7	2/4/2026	2:30:18	2:30:58	2:30:29	2:30:58	40	29	11
8	2/4/2026	23:02:14	23:03:02	23:02:14	23:03:02	48	48	0
9	2/5/2026	0:26:37	0:27:22	0:26:54	0:27:22	45	28	17
10	2/5/2026	1:40:38	1:41:23	1:40:55	1:41:23	45	28	17
11	2/5/2026	2:49:48	2:50:33	2:50:05	2:50:33	45	28	17
12	2/5/2026	23:02:10	23:03:33	23:03:04	23:03:33	46	29	17
13	2/6/2026	0:24:25	0:25:09	0:24:41	0:25:09	44	28	16
Average						49	35	14

Conclusion

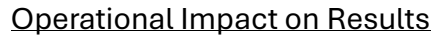
The wireless system will work effectively in the southbound direction. The predictor, after adjustment, accurately predicted the time of arrival and optimized the sending of the preemption call based on this time. Total warning time was reduced by 6.5% with similar crossing warning times, but more consistent preemption times with the wireless system.

Stewart Street

Stewart Street is located Santa Monica between 26th/Bergamot Station and Expo/Bundy Station. The crossing's approach extends over 26th/Bergamot Station in the northbound direction. In the southbound direction, the crossing's approach does not extend to a station, but the warning times are influenced by the acceleration out of Expo/Bundy Station.



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Results

		Wireless							
		Total Warning				Time in Seconds			
	Run	Date	Inhibit	Approach	Start	End	Total	Warning	Preemption
Pre Tuning	1	2/2/2026	22:48:19	22:48:02	22:49:00	22:50:22	121	82	39
	2	2/3/2026	0:07:36	0:07:54	0:08:52	0:10:15	122	83	39
	3	2/3/2026	1:14:38	1:14:55	1:15:52	1:17:32	139	100	39
	4	2/3/2026	2:25:46	2:26:04	2:27:01	2:28:14	112	73	39
	5	2/3/2026	22:48:47	22:49:10	22:50:08	22:51:47	138	99	39
	6	2/4/2026	0:18:27	0:18:46	0:19:43	0:21:31	147	108	39
Average							130	91	39

Post Tuning	7	2/4/2026	22:29:57	22:30:12	22:31:51	22:32:49	97	58	39
	8	2/4/2026	23:48:07	23:48:21	23:50:01	23:50:56	94	55	39
	9	2/5/2026	1:09:48	1:10:04	1:11:21	1:12:30	108	69	39
	10	2/5/2026	2:17:09	2:17:28	2:19:00	2:20:08	107	68	39
	11	2/5/2026	22:31:11	22:31:21	22:33:02	22:33:49	86	47	39
Average							98	59	39

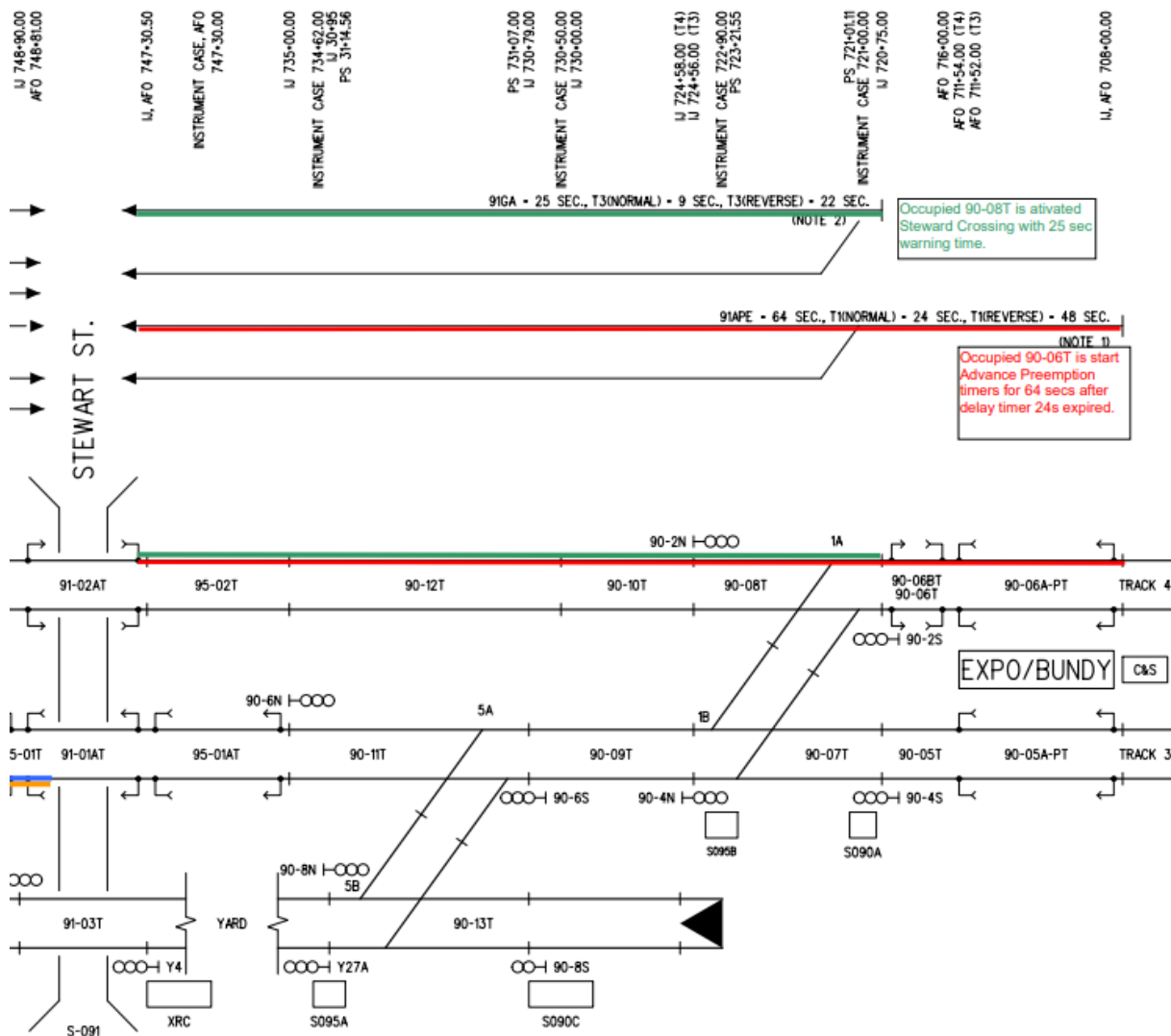
		Conventional					
		Total Warning			Time in Seconds		
Run	Date	Approach	Start	End	Total	Warning	Preemption
1	2/2/2026	22:48:38	22:49:49	22:50:22	104	33	71
2	2/3/2026	0:08:30	00:09:45	0:10:15	105	30	75
3	2/3/2026	1:16:00	01:14:52	1:17:32	92	40	52
4	2/3/2026	2:26:37	02:27:44	2:28:14	97	30	67
5	2/3/2026	22:49:50	22:51:13	22:51:47	117	34	83
6	2/4/2026	22:30:54	22:32:20	22:32:49	115	29	86
7	2/4/2026	23:49:02	23:50:27	23:50:56	114	29	85
8	2/5/2026	1:10:46	01:11:59	1:12:30	104	31	73
9	2/5/2026	2:18:23	02:19:38	2:20:08	105	30	75
10	2/5/2026	22:32:04	22:33:20	22:33:49	105	29	76
11	2/5/2026	23:49:09	23:50:18	23:50:48	150	30	120
Average					105.9	31.8	74.1

Conclusion

The Initial time of arrival data at Stewart was improved by adjusting the acceleration and deceleration curves and utilizing an ACAF. After the initial adjustment, the predictor was more accurate demonstrated by the final five runs. Post-tuning data showed a 7.1% reduction in total warning time and a 47.4% reduction in preemption call time. Warning time was greater with the wireless system, but further tuning can be utilized to reduce this time. Although the ETA Release algorithm used was accurate over the last six runs, the

consistency of the Station Stop Release algorithm could be improved further by exploring the Station Stop Release algorithm.

Southbound



Operational Impact on Results

A signal located between Expo/Bundy Station and Stewart Street interferes with the wireless predictor's ability to accurately calculate arrival times. The wireless system does not require this signal, as the onboard targeting prevents trains from arriving early at the crossing.

Results

		Wireless				
		Crossing Warning		Time in Seconds		
Run	Date	Start	End	Total	Warning	Preemption
1	2/2/2026	23:40:44	23:41:48	87	64	23
2	2/3/2026	02:04:39	2:05:38	82	59	23
3	2/3/2026	3:13:48	3:14:49	84	61	23
4	2/3/2026	23:50:00	23:50:56	79	56	23
5	2/5/2026	0:44:16	0:45:06	73	50	23
6	2/5/2026	1:56:36	1:57:25	72	49	23
7	2/5/2026	3:05:36	3:06:22	69	46	23
8	2/5/2026	23:18:06	23:18:58	75	52	23
9	2/6/2026	0:42:04	0:42:57	76	53	23
Average				77.4	54.4	23.0

		Conventional						
		Total Warning		Crossing Warning		Time in Seconds		
Run	Date	Approach	End	Start	End	Total	Warning	Preemption
1	2/2/2026	23:40:10	23:41:48	23:41:04	23:41:48	98	44	54
2	2/3/2026	2:04:10	2:05:38	02:05:02	2:05:38	88	36	52
3	2/3/2026	3:13:19	3:14:49	3:14:09	3:14:49	90	40	50
4	2/3/2026	23:49:22	23:50:56	23:50:22	23:50:56	94	34	60
5	2/5/2026	0:43:39	0:45:06	00:44:36	0:45:06	87	30	57
6	2/5/2026	1:55:59	1:57:25	01:56:54	1:57:25	86	31	55
7	2/5/2026	3:04:55	3:06:22	03:05:51	3:06:22	87	31	56
8	2/5/2026	23:17:29	23:18:58	23:18:25	23:18:58	89	33	56
9	2/6/2026	0:41:21	0:42:57	00:42:07	0:42:57	96	50	46
Average						90.6	36.6	54.0

Conclusion

Consistent warning times on the onboard side can only be achieved if the crossing signal is removed or set to a clear aspect. This condition could not be met during testing because the onboard system was operating in data-collection mode only. While total warning time reduced by 14.5% with the wireless system, the presence of the governing signal extended the activation time beyond the desired duration. Removing the signal or maintaining a clear aspect would allow the wireless system to more accurately calculate arrival times and reduce gate down-time.

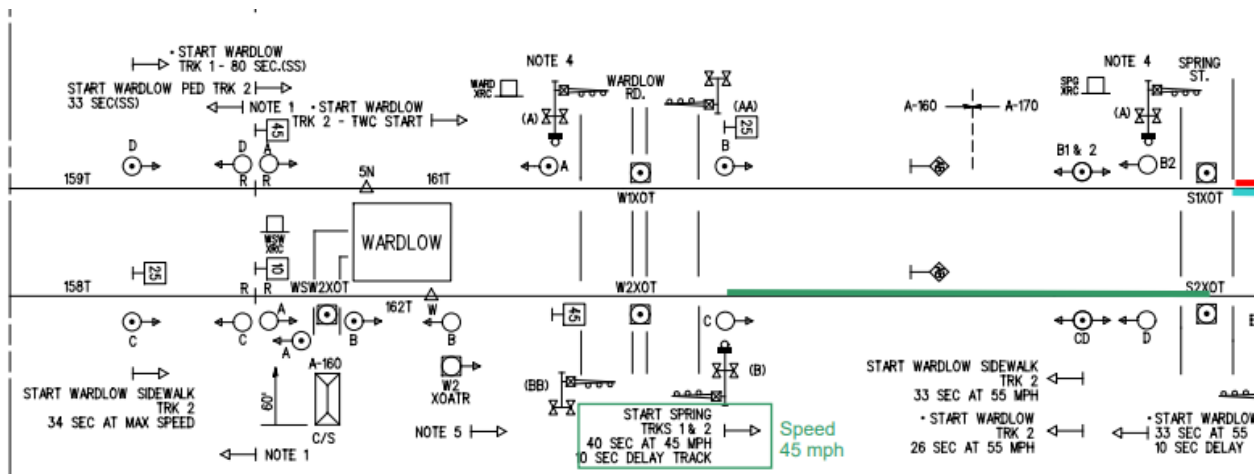
A Line Crossings

Spring Street

Spring Street is in Long Beach near the end of the line in the western portion of the alignment. Warning times for northbound moves are impacted by the acceleration out of Willow Street Station and southbound moves are impacted by acceleration out of Wardlow Station. In both directions, the stations are far enough away from the crossing that only the express algorithm is utilized.



Northbound



Operational Impact on Results

The approach to Spring Street in the northbound direction provided a solid proving ground for the wireless predictor. No significant operational issues were present.

Results

		Wireless				
		Crossing Warning		Time in Seconds		
Run	Date	Start	End	Total	Warning	Preemption
1	2/9/2026	23:02:35	23:02:56	44	21	23
2	2/9/2026	23:44:49	23:45:15	49	26	23
3	2/10/2026	1:28:51	1:29:25	57	34	23
4	2/10/2026	1:59:42	2:00:18	59	36	23
5	2/10/2026	2:29:47	2:30:19	55	32	23
6	2/10/2026	22:24:15	22:24:35	43	20	23
7	2/10/2026	23:04:25	23:04:58	53	30	23
8	2/11/2026	1:33:34	1:34:04	53	30	23
9	2/11/2026	21:53:08	21:53:38	53	30	23
10	2/13/2026	22:37:51	22:38:21	53	30	23
Average				51.9	28.9	23

		Conventional						
		Total Warning		Crossing Warning		Time in Seconds		
Run	Date	Approach	End	Start	End	Total	Warning	Preemption
1	2/9/2026	23:02:01	23:02:56	23:02:31	23:02:56	55	25	30
2	2/9/2026	23:43:00	23:45:15	23:44:44	23:45:15	135	31	104
3	2/10/2026	1:27:30	1:29:25	1:28:49	1:29:25	115	36	79
4	2/10/2026	1:58:20	2:00:18	1:59:39	2:00:18	118	39	79
5	2/10/2026	2:28:27	2:30:19	2:29:44	2:30:19	112	35	77
6	2/10/2026	22:22:40	22:24:35	22:24:10	22:24:35	115	25	90
7	2/10/2026	23:03:01	23:04:58	23:04:23	23:04:58	117	35	82
8	2/11/2026	1:32:04	1:34:04	1:33:31	1:34:04	120	33	87
9	2/11/2026	21:49:45	21:53:38	21:53:03	21:53:38	233	35	198
10	2/13/2026	22:36:36	22:38:21	22:37:49	22:38:21	105	32	73
Average						122.5	32.6	89.9

Conclusion

Data in the northbound direction the wireless system showed a 57.6% reduction in total warning time over the conventional system. Preemption time was reduced by 74.4% and crossing activation time was reduced by 11.3%. Further tuning via ACAF adjustments could further reduce the crossing activation time. From a preemption perspective, the wireless system delayed the start of the cycle based on leveraging a dynamic ETA algorithm.

[illegible]

The approach to Spring Street in the southbound direction includes a stop at Willow Station just ahead of the approach circuits. Consequently, the time of arrival calculations are impacted by acceleration out of Willow Station towards Spring Street. Additionally, a governing signal exists between the station and crossing which negatively impacted the time of arrival calculations.

		Wireless				
		Crossing Warning		Time in Seconds		
Run	Date	Start	End	Total	Warning	Preemption
1	2/9/2026	23:13:30	23:14:05	58	35	23
2	2/9/2026	23:58:23	23:59:00	60	37	23
3	2/10/2026	0:39:17	0:39:53	59	36	23
4	2/10/2026	0:53:37	0:54:17	63	40	23
5	2/10/2026	1:37:12	1:37:47	58	35	23
6	2/10/2026	2:08:05	2:08:39	58	35	23
7	2/10/2026	21:46:14	21:47:09	78	55	23
8	2/10/2026	23:20:16	23:21:08	75	52	23
9	2/10/2026	0:14:38	0:15:26	71	48	23
10	2/11/2026	21:48:20	21:49:08	71	48	23
			Average	65.1	42.1	23

Run	Date	Conventional						
		Total Warning		Crossing Warning		Time in Seconds		
		Approach	End	Start	End	Total	Warning	Preemption
1	2/9/2026	23:12:03	23:14:05	23:13:33	23:14:05	122	32	90
2	2/9/2026	23:56:49	23:59:00	23:58:22	23:59:00	131	38	93
3	2/10/2026	0:37:32	0:39:53	0:39:11	0:39:53	141	42	99
4	2/10/2026	0:51:52	0:54:17	0:53:26	0:54:17	145	51	94
5	2/10/2026	1:35:44	1:37:47	1:37:10	1:37:47	122	37	85
6	2/10/2026	2:06:33	2:08:39	2:08:01	2:08:39	126	38	88
7	2/10/2026	21:44:34	21:47:09	21:46:14	21:47:09	155	55	100
8	2/10/2026	23:18:32	23:21:08	23:20:16	23:21:08	146	52	94
9	2/10/2026	0:12:54	0:15:26	0:14:33	0:15:26	152	53	99
10	2/11/2026	21:46:44	21:49:08	21:48:16	21:49:08	144	52	92
Average						138.4	45	93.4

Conclusion

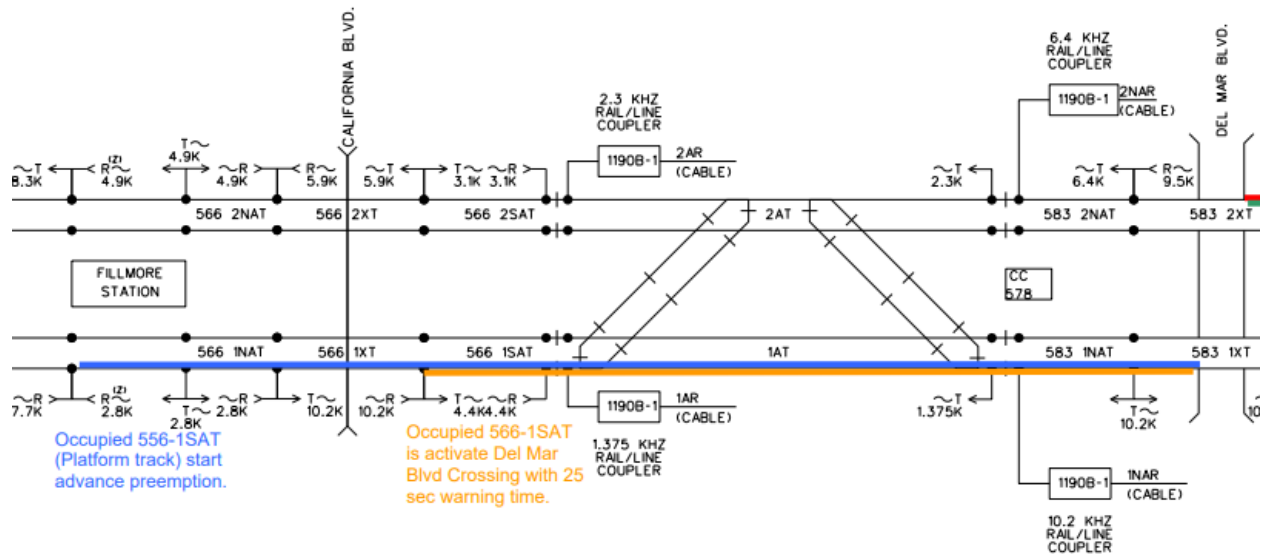
Total warning time was reduced by 53% with the wireless system. Crossing activation time was reduced by 6.4% and the preemption call time was reduced by 75.4%. The predictor allowed the preemption call to be sent closer to the train's arrival time. Although the warning times are still higher than desired, further adjustments can be made to reduce the gate downtime through further tuning and removal of the governing signal or coordinating a clear aspect utilizing the time of arrival calculation.

Del Mar

Del Mar Boulevard is influenced by a stop at Fillmore Station in the northbound direction and a stop at Del Mar Station in the southbound direction. Additionally, the train traverses a tunnel in the southbound direction that is approximately a half mile long with a couple of open-air breaks. Movements in the southbound direction use the ETA release station stop algorithm whereas movements in the northbound direction utilize the express algorithm.



Northbound



Operational Impact on Results

The approach to Del Mar Boulevard in the northbound direction includes a stop at Fillmore Station on the approach circuits. The time of arrival calculations are impacted by acceleration out of Willow Station towards Del Mar and a deceleration into Del Mar Station after the crossing.

Results

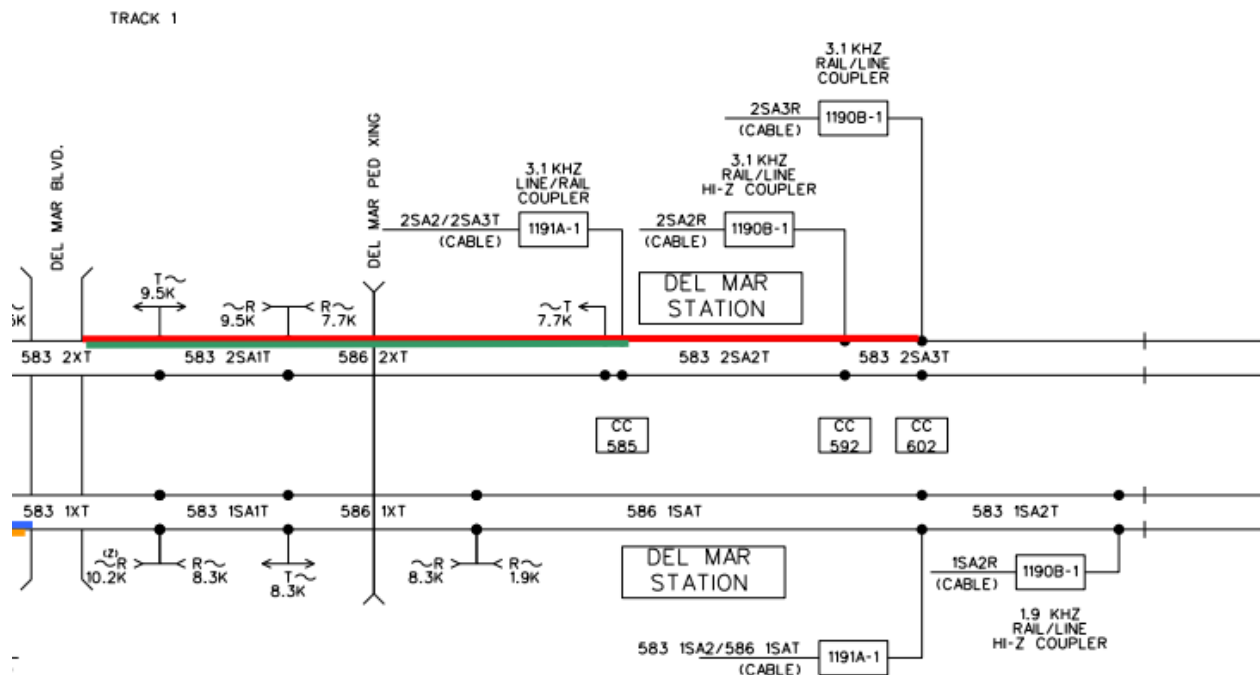
Run	Date	Wireless				
		Crossing Warning		Time in Seconds		
		Start	End	Total	Warning	Preemption
1	2/10/2026	1:57:32	1:58:11	66	39	27
2	2/10/2026	23:13:23	23:14:13	77	50	27
3	2/11/2026	0:11:18	0:11:56	65	38	27
4	2/11/2026	23:02:39	23:03:35	83	56	27
5	2/12/2026	0:17:58	0:18:50	79	52	27
6	2/12/2026	1:29:20	1:30:09	76	49	27
7	2/12/2026	2:39:14	2:40:13	86	59	27
8	2/12/2026	3:41:15	3:41:53	65	38	27
Average				74.6	47.6	27.0

Run	Date	Conventional						
		Total Warning		Crossing Warning		Time in Seconds		
		Approach	End	Start	End	Total	Warning	Preemption
1	2/10/2026	1:57:31	1:58:11	1:57:38	1:58:11	40	33	7
2	2/10/2026	23:13:09	23:14:13	23:13:29	23:14:13	64	44	20
3	2/11/2026	0:10:56	0:11:56	0:11:22	0:11:56	60	34	26
4	2/11/2026	23:02:24	23:03:35	23:02:46	23:03:35	71	49	22
5	2/12/2026	0:17:25	0:18:50	0:17:58	0:18:50	85	52	33
6	2/12/2026	1:29:03	1:30:09	1:29:24	1:30:09	66	45	21
7	2/12/2026	2:39:02	2:40:13	2:39:21	2:40:13	71	52	19
8	2/12/2026	3:40:55	3:41:53	3:41:19	3:41:53	58	34	24
Average						64.4	42.9	21.5

Conclusion

The Del Mar northbound movement represents an express operation consistent with the operating scenarios for which the wireless crossing system is designed. In accordance with system design parameters, the wireless system consistently issued the traffic preemption call approximately 27 seconds in advance of activation of the crossing warning (XR) relay. Observed warning times on the wireless system exceeded those of the conventional crossing system; however, these timings can be readily refined through configuration file adjustments to better represent the acceleration out of Filmore Station and the deceleration into Del Mar Station.

Southbound



Operational Impact on Results

The presence of a motorman light at the crossing delays train departures until the crossing arms are fully lowered. This delay degrades the accuracy of the wireless predictor and results in longer-than-desired warning times. Additionally, tunnel approaches to Del Mar Station cause temporary loss of GPS signals.

Results

Wireless								
		Total Warning				Time in Seconds		
Run	Date	Inhibit	Approach	Start	End	Total	Warning	Preemption
1	2/10/2026	1:41:02	1:42:29	1:43:41	1:44:25	71	44	27
2	2/10/2026	21:55:08	21:55:14	21:56:32	21:57:40	95	68	27
3	2/10/2026	22:57:45	22:57:51	22:59:08	22:59:52	71	44	27
4	2/11/2026	22:40:30	22:40:35	22:41:55	22:42:51	83	56	27
5	2/12/2026	2:23:20	2:23:26	2:24:49	2:25:50	88	61	27
6	2/12/2026	3:26:00	3:26:07	3:27:30	3:28:24	83	56	27
Average						81.8	54.8	27.0

Conventional							
		Total Warning			Time in Seconds		
Run	Date	Approach	Start	End	Total	Warning	Preemption
1	2/10/2026	1:42:00	1:43:52	1:44:25	145	33	112
2	2/10/2026	21:55:57	21:57:04	21:57:40	103	36	67
3	2/10/2026	22:58:22	22:59:21	22:59:52	90	31	59
4	2/11/2026	22:41:10	22:42:15	22:42:51	101	36	65
5	2/12/2026	2:24:04	2:25:10	2:25:50	106	40	66
6	2/12/2026	3:26:45	3:27:49	3:28:24	99	35	64
Average					107.3	35.2	72.2

Conclusion

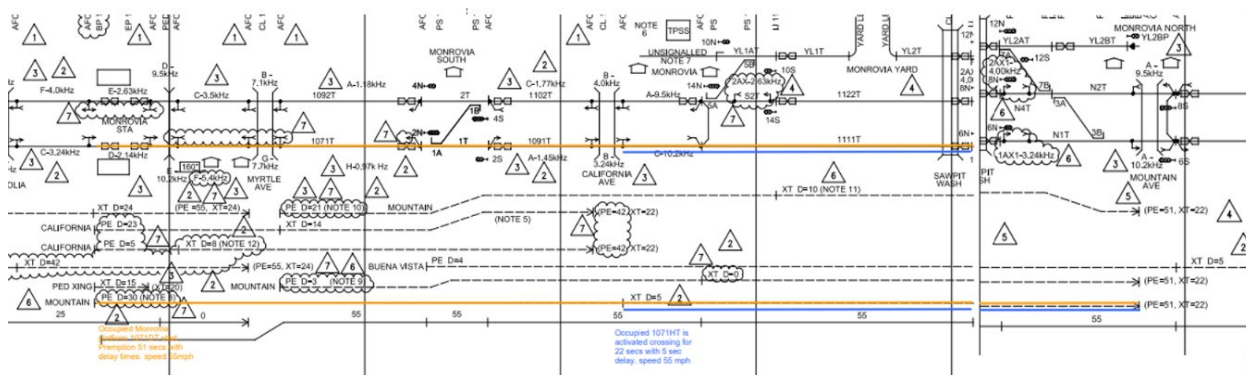
Log data from the Del Mar wayside unit showed no inhibit timeouts, confirming uninterrupted communications through the tunnels. A wheel slip sensor anomaly was observed while the I-ETMS system transitioned to Dead Reckoning mode following GPS loss; however, consistent train handling minimized any operational impact. Wheel slip detection has since been enhanced in subsequent software releases, significantly improving reliability.

Preservation of location integrity and continuous tunnel communications was a key success factor and enabled stable wireless performance. Conventional total warning times

Mountain Avenue

Map of the San Gabriel Valley Metro A Line Extension Project. The map shows a blue line with stations: Del Mar, Memorial Park, Lake, Allen, Sierra Madre Villa, Arcadia, Monrovia, Duarte/City of Hope, Irwindale, Azusa Downtown, and APU/Citrus College. A vertical line segment labeled 'Mountain Avenue' is shown between Arcadia and Monrovia. The text 'METRO A LINE EXTENSION PROJECT' is on the right, and 'SAN GABRIEL VALLEY' is at the bottom.

Northbound



Operational Impact on Results

Moves in the northbound direction are influenced by acceleration out of Monrovia Station. No other operational impacts were observed.

Results

		Wireless				
		Crossing Warning		Time in Seconds		
Run	Date	Start	End	Total	Warning	Preemption
1	2/10/26	01:04:01	01:04:32	60	31	29
2	2/10/26	02:13:56	02:14:26	59	30	29
3	2/10/26	23:30:43	23:31:12	58	29	29
4	2/11/26	00:28:34	00:29:05	59	30	29
5	2/11/26	23:21:53	23:22:25	61	32	29
6	2/12/26	01:46:37	01:48:20	72	43	29
7	2/12/26	02:57:17	02:57:46	58	29	29
		Average		61.0	32.0	29.0

		Conventional						
		Total Warning		Crossing Warning		Time in Seconds		
Run	Date	Approach	End	Start	End	Total	Warning	Preemption
1	2/10/26	1:02:21	01:04:32	01:04:06	01:04:32	131	26	105
2	2/10/26	2:12:19	02:14:26	02:14:00	02:14:26	127	26	101
3	2/10/26	23:28:55	23:31:12	23:30:46	23:31:12	137	26	111
4	2/11/26	0:26:27	00:29:05	00:28:39	00:29:05	158	26	132
5	2/11/26	23:20:09	23:22:25	23:21:55	23:22:25	136	30	106
6	2/12/26	1:44:50	01:48:20	01:46:40	01:48:20	210	40	170
7	2/12/26	2:55:20	02:57:46	02:57:19	02:57:46	146	27	119
				Average		149.3	28.7	120.6

Conclusion

Wireless warning times were marginally higher than conventional warning times, indicating that additional system tuning is warranted. From a preemption standpoint, the wireless system optimized initiation of the preemption sequence by dynamically updating the train's time of arrival based on real-time speed, resulting in a 59% reduction in total warning time. Preemption duration was reduced by 75.9%, while crossing activation time experienced a modest increase of 11.7% under the wireless configuration.

The chart displays the following information:

- Stations and Frequencies:**
 - XT D-3: 1130.000, 1130.000
 - XT D-1: 1130.000, 1130.000
 - XT D-5: 1130.000, 1130.000
 - XT D-4: 1130.000, 1130.000
 - XT D-32: 1130.000, 1130.000
 - XT D-31: 1130.000, 1130.000
 - PE D-0: 1130.000, 1130.000
 - PE D-1: 1130.000, 1130.000
 - PE D-32: 1130.000, 1130.000
 - PE D-31: 1130.000, 1130.000
 - PE D-30: 1130.000, 1130.000
 - PE D-29: 1130.000, 1130.000
 - PE D-28: 1130.000, 1130.000
 - PE D-27: 1130.000, 1130.000
 - PE D-26: 1130.000, 1130.000
 - PE D-25: 1130.000, 1130.000
 - PE D-24: 1130.000, 1130.000
 - PE D-23: 1130.000, 1130.000
 - PE D-22: 1130.000, 1130.000
 - PE D-21: 1130.000, 1130.000
 - PE D-20: 1130.000, 1130.000
 - PE D-19: 1130.000, 1130.000
 - PE D-18: 1130.000, 1130.000
 - PE D-17: 1130.000, 1130.000
 - PE D-16: 1130.000, 1130.000
 - PE D-15: 1130.000, 1130.000
 - PE D-14: 1130.000, 1130.000
 - PE D-13: 1130.000, 1130.000
 - PE D-12: 1130.000, 1130.000
 - PE D-11: 1130.000, 1130.000
 - PE D-10: 1130.000, 1130.000
 - PE D-9: 1130.000, 1130.000
 - PE D-8: 1130.000, 1130.000
 - PE D-7: 1130.000, 1130.000
 - PE D-6: 1130.000, 1130.000
 - PE D-5: 1130.000, 1130.000
 - PE D-4: 1130.000, 1130.000
 - PE D-3: 1130.000, 1130.000
 - PE D-2: 1130.000, 1130.000
 - PE D-1: 1130.000, 1130.000
 - PE D-0: 1130.000, 1130.000
- Repeaters and Frequencies:**
 - A: 1130.000, 1130.000
 - B: 1130.000, 1130.000
 - C: 1130.000, 1130.000
 - D: 1130.000, 1130.000
- Locations and Roads:**
 - Buena Vista St
 - Mountain Ave
 - Highland Ave
 - California
 - TO YL2
- Notes:**
 - Occupied 1162CT as 1162CT and 1162CT time 5 seconds with delay times, speed 50mph
 - Occupied 1162CT as 1162CT and 1162CT time 5 seconds with delay times, speed 50mph

Moves in the southbound direction are influenced by acceleration out of Duarte Station. No other operational impacts were observed.

		Wireless				
		Crossing Warning		Time in Seconds		
Run	Date	Start	End	Total	Warning	Preemption
1	2/10/2026	02:13:56	02:14:26	59	30	29
2	2/10/2026	23:30:43	23:31:12	58	29	29
3	2/11/2026	00:28:34	00:29:05	59	30	29
4	2/12/2026	01:46:37	01:48:20	72	43	29
5	2/12/2026	02:57:17	02:57:46	58	29	29
			Average	61.2	32.2	29.0

Conclusion

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Chapter 3: Anticipated Costs and Benefits of At-Scale Implementation

3.1 Anticipated Impacts

Based on the findings discussed in Chapter Two, the anticipated impacts of at-scale implementation include: optimized gate downtimes, potential improvements to bus on-time performance where routes cross rail tracks, and reduced vehicle idling at crossings and traffic lights.

Impacts by Goal Area

Potential impacts during at-scale implementation are described below.

- **Safety and reliability:** Shorter crossing gate downtimes decrease the likelihood of risky behavior among drivers and pedestrians. The wireless crossing system is designed to mitigate early train arrivals at at-grade crossings by actively managing train approach speeds. The system calculates the predicted time of arrival of the train and establishes a variable speed target at that point. If the train exceeds the expected approach speed, the system issues a warning to the operator to slow down. If the operator does not respond, the system lowers the speed target and issues a subsequent warning. Continued noncompliance results in an automatic brake application to ensure safe crossing activation timing.
- **Resiliency:** The wireless crossing system would allow for centralized data reporting for improved diagnostics and maintenance, increasing the resiliency of the crossing gate system.
- **Partnerships:** At-scale implementation would result in collaboration across many parties including Metro, project partners, CPUC, surrounding cities, and the community.
- **Integration:** Broader implementation of wireless technology is an opportunity to improve integration between new technology and Metro's current crossing gate signal detection and vehicle systems. There could be potential for integration with traffic control systems for rail signal prioritization and preemption.
- **Workforce Development:** Wireless crossing technologies could present workforce development and training opportunities for intelligent sensor systems.

Anticipated Costs

The estimated cost calculation was based on the existing Wabtec I-ETMS system. To date, over 25,000 trains are running with the I-ETMS solution. For the demonstration, a modified deployment of existing I-ETMS hardware and software was utilized. Since a complete install of the hardware was not possible, a portable system was developed that integrated and simulated, if necessary, all the components of a deployed onboard I-ETMS installation. For the sake of performing an at-scale cost estimation, the currently commercialized hardware and software was the cornerstone of the cost profile. This includes onboard, wayside, communication and back-office products.

The following assumptions were made to estimate the costs of at-scale implementation:¹

- Modifications required to onboard software to improve operations in a light rail environment
- Addition of Cab Signal Interface
- 337 Units (AnsoBreda, Siemens, Kinki Sharyo)
- 89 Crossings (77 Station Stop, 12 Express Only)
- 4 Year OB Installations
- Unit pricing is predicated on the listed vehicle and crossing quantities (a change in quantities will impact the unit price)

Based on the assumptions, unit cost estimates are as follows:

- Cost for Vehicle System Installation - \$229,080 per Trainset
- Cost for Crossing System Installation - \$479,230 per Crossing

Anticipated Benefits

The following benefits could be realized during at-scale implementation:

- **Safety**
 - Managing gate operations for near station operations
 - Managing variable train speeds for optimized crossing activations
 - Preventing early arrivals of trains that are accelerating towards a crossing
 - Reduction in activation failures as health monitoring integrated with onboard
 - Reduction of track circuit issues – loss of shunt, salted crossing approaches, inductive interference

¹ This estimate is subject to revision in the event of material disruptions to the supply chain, including but not limited to shortages of semiconductor components or memory devices.

- Reporting of issues (allowing for real time reporting capabilities at the crossing)
- Elimination of disabling crossing for track work (circuit-less crossings)
- **Efficiency**
 - Leverage existing onboard and wayside infrastructure
 - Track maintenance not affecting crossing (reduced maintenance)
 - When configured, crossing information could be integrated and displayed to the train operator
 - Station stop dwell times, which impact crossing operations, are displayed to the train operator
 - Design simplification (different looks and long approaches for preemption become unnecessary)
 - Speed changes are accomplished with better efficiency
 - Analytics (potential for automated testing due to every warning time being measured)
- **Energy Savings and Pollution Reduction**
 - Reduction of energy consumption (less bungalows necessary, especially for bunched crossings)
 - Reduction of pollution (less idling at crossings due to consistent warning times)

3.2 Baseline Data to Evaluate At-Scale Implementation

Onboard Hardware

Since the wireless crossing system is leveraged on the Interoperable Electronic Train Management System (I-ETMS), compatible hardware must be installed. For each car, a Train Management Computer and two display units must be installed. Ideally, the TMC will be installed at a centralized location on the car with each display wired from the cabin to the TMC.

Onboard Software

For the demonstration, the onboard used software version 6.5.5. This version was chosen because it has the most wireless crossing features available. For deployment, a newer version would be preferred since it best represents the I-ETMS product moving forward and contains improved wheel tach slip handling.

The onboard system should also have a connection to cab signal system to provide the most accurate time of arrivals possible. Without this connection, the wireless system will not be aware of any cab codes that may reduce the train speed from the maximum speed listed in the track database. If the train is held below track speed due to a cab code, the onboard will assume track speed and an earlier time of arrival. This mismatch in estimated time of arrival will result in a longer than designed warning time and an earlier than desired preemption call.

Wayside Hardware and Software

The Wayside Segment uses existing, regulation-compliant signaling infrastructure enhanced with Wayside Interface Units (WIUs) to monitor and report switch positions, signal aspects, and track status to the Locomotive and Office Segments. I-ETMS operates as a vital overlay, relying on this infrastructure with WIUs acting as data-gathering devices approved through safety and standards verification. Wayside status information can be communicated through three configurations: direct WIU peer-to-peer communication, WIU communication via a Wayside Status Relay Service (WSRS), or through the locomotive's onboard cab signal system.

For deployment, hardware that was provided for the demonstration would also be utilized. This includes the Alstom XP4, house wiring, cell modem and a power supply. Licenses to enable the wireless feature would have to be purchased.

Communication

The Communications Segment, provided by the railroad, consists of a messaging system and multiple wireless networks that enable communication between the Locomotive, Wayside, and Office Segments. It includes Office Control Messaging (OCM) to manage interoperable, priority-based message exchanges across networks, a mandatory system for systemwide interoperability, and optional networks such as 802.11 for file transfers during initialization and commercial cellular services to supplement communications.

Cell communication would be employed for crossing status messages, crossing activation messages, and back-office communications.

Back Office

The Office Segment consists of one or more I-ETMS Back Office Servers (BOS) that interface with dispatch and other railroad back-office systems. It supports train initialization and control, switch and signal management, alerts and logging, and distribution of software and track databases via interoperable communications. The segment will include WSRS for subscription to wayside and crossing status messages.

Chapter 4: Challenges and Lessons Learned

Project Approvals and Procurement

Upon receiving the SMART Grant award, the first obstacles for Metro to overcome was the agency's internal approvals process. Staff needed Board approval to accept the award from USDOT. Metro's Board meets monthly, and Board Reports need to be drafted at least one to two months in advance to meet internal approval deadlines. Staff also need to obtain approval for a sole source procurement to officially bring on Wabtec as a partner. This procurement and the Board approvals process delayed the start of the project by approximately one year.

Technology Suitability / Integration with Incumbent Systems

Light rail and heavy rail systems differ in operating rules, signaling practices, and train handling techniques. Metro light rail operations include both dedicated right-of-way and street-running segments; however, specific street-running operations were not a part of the current wireless crossing design, which was originally developed for dedicated heavy rail passenger environments. Accordingly, the demonstration was intended to identify which elements of the existing design could be applied directly and which would require modification or enhancement to effectively support light rail operations.

Due to implementation constraints inherent to a temporary demonstration, certain assumptions were required and limited functionality was adapted. Notably, real-time railroad signal status was unavailable because onboard and wayside signaling systems were not interconnected. Under normal operations, signal status would be used to determine routing, track occupancy, and train behavior. As a result, portions of the demonstration served as a direct comparison between light rail and heavy rail operational characteristics, but other portions did not. Crossings featuring straight-through movements without governing signals enabled validation of the wireless crossing predictor and provided an opportunity to exercise system tuning capabilities, which can be achieved efficiently through configuration file adjustments. Several crossings effectively illustrated differences between heavy rail and light rail operations, while others demonstrated wireless performance during station stop scenarios.

Demonstration of wireless capabilities at station-stop crossings was partially constrained by operational parameters imposed by conventional crossing systems. For example, heavy rail wireless deployments do not rely on signal indications confirming gate horizontality prior to providing a clear aspect and typically benefit from an unobstructed path between the station and the crossing. This clear path enables more accurate time-of-arrival (ETA) calculations, which are critical for optimized wireless crossing performance. In contrast,

light rail environments frequently include governing signals that limit this capability. To address these limitations, the station stop demonstration utilized an ETA Release algorithm based on experience from a prior deployment on an electrified railroad. This algorithm was selected due to its similarity to existing applications and because it was the least intrusive option, allowing demonstration of predictor performance without requiring an in-cab display. Alternative station stop algorithms typically depend on audible or visual operator prompts, which were not available within the constraints of the demonstration environment.

Workforce Capacity (e.g., impacts on jobs)

Because of the size of the wireless system, it could not be installed on trains with passengers and needed to be conducted during non-revenue hours. This required extensive coordination between Wabtec and Metro staff to ensure that support would be consistently available throughout the duration of the testing. Additionally, any track work or other maintenance being conducted within the testing sites needed to be communicated to the project team to ensure alignment and coordination while the test trains were run.

Chapter 5: Deployment Readiness

Successful implementation of a crossing control system involves streamlined regulatory approvals, reduced warning times, and more efficient system operations. These outcomes will improve overall traffic flow, increase light rail throughput, and reduce pollution, while enhancing the travel experience and generating positive public feedback.

5.1 Obstacles

Legal, Policy, and Regulatory Requirements

Any proposed changes to crossing activation or train handling at crossings will require approval from the California Public Utilities Commission (CPUC). Modifications to roadway traffic control devices are governed by the Federal Highway Administration (FHWA) in accordance with the Manual on Uniform Traffic Control Devices (MUTCD).

Metro's at-grade light-rail crossings operate under a multi-jurisdictional regulatory framework involving state, federal, regional, and local agencies. As an urban rapid transit system outside the national railroad network, Metro is not subject to Federal Railroad Administration (FRA) oversight.

The CPUC serves as the primary regulator with exclusive authority over the design, construction, modification, and cost allocation of rail crossings, including warning devices and pedestrian treatments; no crossing may be constructed or modified without CPUC approval. FHWA, through the MUTCD as adopted by California, establishes standards for roadway signage, signals, markings, and signal preemption at rail crossings. Transit safety oversight is provided by the Federal Transit Administration (FTA) and California's State Safety Oversight (SSO) agency, which monitor system safety, investigations, and corrective actions.

While Metro is responsible for operations, maintenance, and operator training, it cannot self-approve crossing changes. Local cities and Los Angeles County retain responsibility for roadway ownership, traffic signal operations, enforcement, and coordination with rail preemption.

Function	Governing Entity
Crossing approval & modification	CPUC
Warning devices (gates, flashers)	CPUC
Roadway signs & traffic signals	FHWA / CA MUTCD
Transit system safety	FTA + CA SSO
Train operations	Metro
Local streets & enforcement	Cities / LA County

Technology Suitability / Integration with Incumbent Systems

With permanent onboard hardware installed, the wireless system can be more effectively configured to support light rail–specific operational requirements. This would enable use of additional station stop algorithms and further refinement of onboard behavior to optimize crossing performance. Once hardware integration is complete, new software-based operational strategies can be developed to improve overall light rail efficiency. These enhancements may also involve modifications to wayside crossing logic and signaling configurations. Optimal performance will require coordinated design between onboard algorithms and wayside systems. For example, removal or modification of governing signals, in conjunction with optimized onboard logic, can result in improved warning times, more precise preemption calls, and increased system throughput while maintaining safe operation.

Chapter 6: Wrap-Up

Overall, the demonstration successfully validated the wireless system infrastructure and its ability to operate within Metro's light rail environment. Advice to other agencies interested in conducting similar demonstrations are to:

1. Obtain necessary approvals from decision-making bodies while or before preparing for grant applications
2. Ensure wayside team members and those conducting work that may impact the demonstration are aware of the details of the project, including when and where it is taking place. In the event of emergency repairs or other unexpected events, there should be a way to quickly communicate the status of the event so the project team can pivot quickly and safely, if necessary.