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RESEARCH RESULTS

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ENHANCED AUTOMATIC TRAIN CONTROL BRAKING ALGORITHM RESEARCH AND DEVELOPMENT

SUMMARY

Transportation Technology Center, Inc. (TTCI), as part of a project sponsored by the Federal Railroad Administration (FRA), evaluated the safety and operational performance of the Enhanced Automatic Train Control (E-ATC) braking enforcement algorithm and found it exceeds previously established safety objectives, but also may introduce operational inefficiencies. The evaluation was performed using a simulation methodology over a broad range of operating scenarios and equipment used by railroads deploying the E-ATC system. Figure 1 shows the users of the E-ATC system considered in the study.

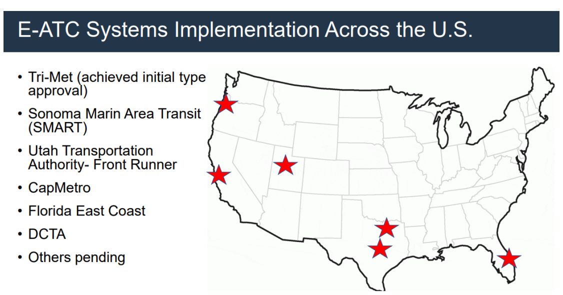

Figure 1. E-ATC railroads

As part of the project, TTCI also identified the following potential enhancements to the E-ATC braking algorithm that may reduce the potential for operational inefficiencies, while still maintaining system safety:

- Update the time-in-block timers. The time-in-block timer measures the delay time, allowing a train to travel into the block before the onboard calculation for penalty enforcement begins.
- Modify the calculation for the minimum block length (MBL), which is used by the onboard system to set the target stopping location.
- Modify the braking curve used by the onboard system for the enforcement braking calculation that determines when the penalty brake needs to engage.

BACKGROUND

One objective of Positive Train Control (PTC) is to improve the safety of the railroad operation through the enforcement of certain operational limits, including authority and speed limits. In the E-ATC PTC system, movement authority information is transmitted to a locomotive onboard computer from the wayside signaling system. The locomotive onboard computer also contains a braking enforcement algorithm, which predicts the stopping distance of the train and enforces limits by automatically initiating a penalty brake application to prevent a violation. Braking enforcement is conceived as the final opportunity to safely prevent a violation, stopping the train only when the locomotive crew has failed to take adequate action.

TTCI and FRA have worked together with U.S. Class I freight railroads and commuter/passenger railroads to develop a methodology for analyzing PTC braking algorithm safety and performance characteristics. The methodology developed has been accepted by the industry and FRA and has been used to demonstrate that the braking algorithms used by PTC systems to stop trains short of a target violation do so within an acceptable safety margin.

The braking enforcement function of the system is critical in ensuring that trains comply with movement authorities and speed limits. There are several parameters that can affect the braking distance of a train, and it is not practical, or even possible, to provide the onboard system with all the information required to predict the stopping distance with absolute certainty. Many of the necessary data elements are not provided to the onboard system, and there is a level of uncertainty in those that are. Thus, there can be a significant difference between the stopping distance predicted by the braking enforcement algorithm and the actual stopping distance of a given train. This can be described by a statistical distribution of potential stopping locations about the predicted stopping location, as Figure 2 illustrates.

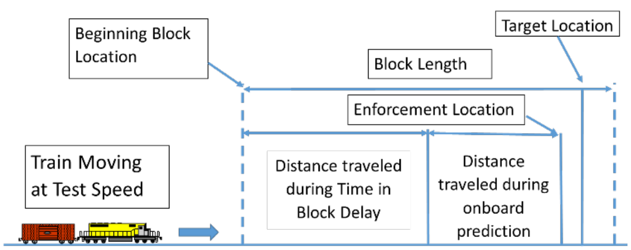

Figure 2. E-ATC enforcement methodology

OBJECTIVES

The specific objectives of this project were to:

- Develop a software test application that implements the E-ATC braking enforcement methodology.
- Integrate the E-ATC test application into current freight and passenger PTC braking algorithm simulation environments.
- Evaluate the E-ATC algorithm using the Monte Carlo simulation methodology used for other PTC braking enforcement algorithms.
- Identify potential future enhancements to the E-ATC braking algorithm that could improve safety and/or operational efficiency.

METHODS

Research efforts associated with PTC braking enforcement algorithms for freight operations have demonstrated a successful methodology for evaluating algorithm safety and performance for a broad range of operations [1]. Using computer modeling, the methodology has proven to be a cost-effective and safe technique for demonstrating algorithm accuracy and reliability. The same methodology has been applied to algorithms for passenger and commuter rail operations.

The enforcement algorithm evaluation methodology combines computer simulation and field testing to provide a high level of statistical confidence in the result. The purpose of the simulation component of the methodology is to statistically quantify the safety and performance characteristics of the enforcement algorithm. This is achieved by running large batches of braking enforcement simulations with Monte Carlo variation of train and environmental characteristics that affect train stopping distance over a broad range of operational scenarios. Then, a limited amount of field testing is used to provide verification of the simulation results using actual hardware inputs to the enforcement algorithm. Figures 3 and 4 show the scenarios used to populate the freight and passenger simulation matrices.

Freight Simulation Matrix

Speed (mph) \ Grade (percent)	-1	-0.75	-0.5	-0.25	0	0.25	0.5	0.75	1
40				x	x		x		
30	x		x		x			x	
20	x	x			x	x	x	x	x
10			x		x				
0									

Figure 3. Freight simulation matrix

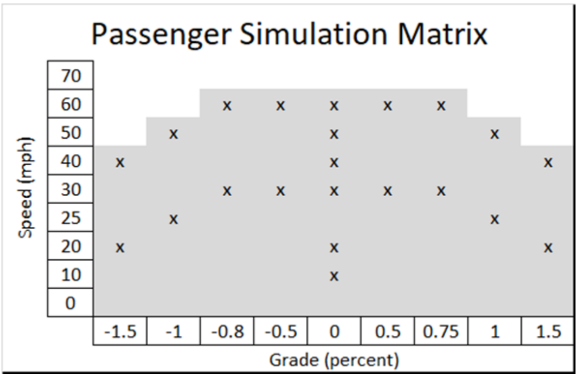

Figure 4. Passenger simulation matrix

This evaluation methodology provides the capability to evaluate the enforcement algorithm over a broad range of operating scenarios that could not be tested efficiently in revenue service.

RESULTS

Figure 5 shows the overall results of the freight and passenger simulations, by presenting two main statistics:

- Probability of stopping short of target: The probability that a given train, under the given operating conditions, will stop short of the given stopping target following a PTC enforcement.
- Probability of stopping short of performance limit (undershoot): The probability that a given train, under the given operating conditions, will stop short of the target by more than 500 feet for speeds less than 30 mph, and by more than 1,200 feet for speeds greater than or equal to 30 mph.

There were no overruns in either the passenger or freight simulations. However, the probability of stopping short of the performance limit is very high for both the freight and passenger simulations.

The simulation results indicate that the E-ATC system may be overly conservative in predicting the stopping location of the train. It would be desirable to improve the operational efficiency by reducing the conservatism of the stopping distance prediction while still meeting the safety objectives that E-ATC is designed to achieve. The analysis of the results from this project identified several potential enhancements to the system that could help the railroads achieve this goal.

Train Type	Speed	Probability of Stopping Short of Target	Probability of Stopping Short of Performance Limit
Freight	< 30 mph	99.99%	99.99%
	>= 30 mph	99.99%	99.99%
Passenger	< 30 mph	99.99%	96.21%
	≥30 mph	99.99%	98.99%

Figure 5. Simulation results

The first potential enhancement would be to review all the time-in-block timers. Many of these timers could be increased to allow the train to travel further into the block while still meeting the safety objectives.

The next potential enhancement would be to modify the calculation used to determine the MBL. The existing calculation was developed using a generalized worst-case train consist. Using the data gathered in this effort as a starting point, a more accurate calculation could be developed using regression analysis and simulated data.

The last potential enhancement would be to modify the slowing/stopping braking curve used in the enforcement braking calculation. This analysis would be very similar to what would be done for the MBL equation. By improving this equation, a train could get closer to the stop target without being forced to apply the brakes.

CONCLUSIONS

The project primarily evaluated the E-ATC enforcement braking methodology using simulation of freight and passenger equipment and operational scenarios expected to be encountered by the E-ATC system. E-ATC was shown to meet the previously established safety objective of having a probability of stopping short of the target of greater than 99.5 percent.

To achieve these results, an E-ATC enforcement algorithm software test application was created and evaluated that replicates the functionality of the E-ATC systems implemented in the field. This test application can also be used as a foundation for developing and evaluating potential improvements to the E-ATC systems. A list of potential enhancements was developed based on the analysis of the simulations results, which could be developed and evaluated further in a follow-on phase.

FUTURE ACTION

The railroads implementing E-ATC and their suppliers may consider the potential improvements identified to reduce conservatism, while maintaining the high level of safety with the E-ATC system. The tools and methodology developed as part of this project can be used to support regression analysis to implement some of the potential improvements identified. Additionally, as any changes to the enforcement methodology are implemented, the simulation process developed here can be implemented to evaluate those changes in the future.

REFERENCES

Federal Railroad Administration. (August 2013). Development of an Operationally Efficient PTC Braking Enforcement Algorithm for Freight Trains [DOT/FRA/ORD-13/34]. Washington, DC: U.S. Department of Transportation.

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