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Communication Timeout and Latency Effect on Positive Train Control System for the IDOT Corridor

SUMMARY

The Federal Railroad Administration (FRA) sponsored an independent analysis to evaluate the influence of the communication timeout threshold and latency of the North American Joint Positive Train Control (NAJPTC) system. The analysis focused on the overall safety performance as compared with a cab signal system with continuous Automatic Train Stop (ATS) and a four-aspect cab signal system with speed control, or an Automatic Train Control (ATC) system, configured as currently used in Amtrak's Northeast Corridor (NEC). ATS and ATC are known to provide satisfactory levels of safety at speeds up to 110 mph. This study builds upon research described in RR08-01, published in June 2008.

The analysis considered the effects of timeout and latency on safety performance with average daily traffic comprised of six passenger trains, between 0.86 and 1.07 Positive Train Control (PTC)-equipped freight trains, and between 0.36 and 2.30 unequipped freight trains, depending on the time of the year and location on the Illinois Department of Transportation (IDOT) Corridor, between N. Ridgley and Mazonia, IL. Maximum speeds considered were 110 mph for passenger trains and 60 mph for freight traffic. PTC latency values (See Background) were allowed to vary from 5 to 20 seconds and communication timeout values extended from 20 to 360 seconds. Conclusions from this risk assessment are for the traffic volume and traffic mix. PTC latency and timeout values *considered on this particular corridor*, did not have a material effect on safety. Instead non-safety considerations such as route capacity, delay reduction and cost may be the governing factors in specifying timeout and latency. This is contrary to pre-analysis expectations where safety considerations were the primary factors in specifying the maximum acceptable timeout and latency for a PTC system. The analysis also showed that the NAJPTC system, as analyzed, passed the test of being as safe as, or safer than, either the cab signal system with ATS or the NEC ATC system.

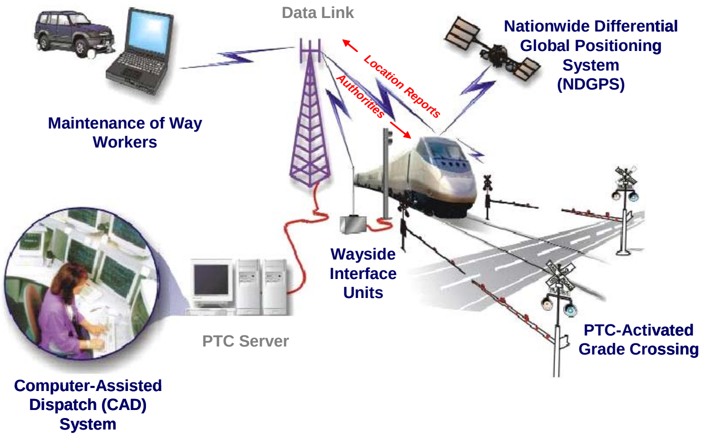

Figure 1. A Typical Positive Train Control System Configuration as Established by the North American Joint Positive Train Control Program

BACKGROUND

PTC employs wireless communication technologies, locomotive tracking with Global Positioning System (GPS)/inertial navigation systems, and central processors to prevent train collisions, derailments due to overspeed, and incidents involving roadway workers operating within their authority limits (see Figure 1). In January 1998, the Association of American Railroads (AAR) and IDOT, in conjunction with FRA, began to develop a high-speed PTC project for implementation on the Union Pacific Railroad (UP) between St. Louis, MO, and Chicago, IL, referred to as the IDOT Corridor. Although this development has been terminated and restarted at the Transportation Test Center, Inc. (TTCI) in Pueblo, CO, the analysis of the NAJPTC system on the IDOT Corridor provides valuable insight on the general question of the influence of timeout and latency on the safety performance of PTC and other train control systems using wireless communications.

In general, two types of messages are transmitted through a PTC communication system: those carrying functional data (e.g., location and speed of equipped trains, authorities for action, track circuit status, switch status) and system heartbeats. These heartbeat messages from each system element inform other elements, including the central office system that each element is healthy and the communication system is intact, thereby achieving a closed loop. Two fundamental aspects of the communication system are defined as follows:

- Timeout - the length of time that the PTC system detects no communication or heartbeat message from a device within the system, before it declares a “fault condition” and imposes appropriate actions for fail-safe protection.
- Latency - the length of time from when a communication message is initiated at the point of origin to when appropriate actions corresponding to that message are initiated at the destination system. This time interval includes the response time of any PTC subsystems involved in the message path and communication queuing delays.

Originally, to be realistic, the NAJPTC PTC system had targeted a timeout specification of approximately 120 seconds and a latency of 10 seconds due to communication capacity limits. These high intervals gave rise to concerns about the potential safety impact. This analysis was designed to evaluate this concern, and to provide insight on the general question of the influence of timeout and latency on the safety performance of PTC and other wireless communication-based train control systems.

RESEARCH OBJECTIVE

The objectives of this analysis were to compare the safety performance of the NAJPTC communication-based train control system, having a range of timeout and latency values, with two base cases:

- UP cab signal system with continuous ATS system, providing in-cab signal indications, a warning of a more restrictive signal aspect change, and automatic braking if the warning is not acknowledged, but no speed enforcement.
- Amtrak’s NEC cab signal system with ATC, which combines cab signals with speed enforcement similar to that installed on Amtrak’s NEC.

Both ATS and ATC systems allow trains to operate at up to 110 mph in accordance to FRA regulations.

RESEARCH METHODS

The results from a series of quantitative risk models were used to compare accident risk of a PTC with different timeout and latency values versus the ATS and ATC base cases. Risk is expressed in quantitative terms as estimated injuries, fatalities, and property damage during a specified period of operation. The models are intended for risk comparisons between cases rather than to provide stand-alone absolute risk results. For this analysis, risk comparisons are more appropriate than absolute results because each case is evaluated using comparable methods and data sources and are only compared to each other rather than an absolute standard. This method minimizes the effect of uncertainty in the absolute values of accident frequencies and consequences.

The basic building block of any risk analysis is the relationship between risk and accident frequencies and consequences:

[TOTAL RISK] = Σ {[ACCIDENT FREQUENCY]
x [ACCIDENT CONSEQUENCE]}

where:

- [RISK] is the total harm caused by accidents, measured by estimated FRA-reportable fatalities, injuries, and property damage. A total financial risk measure was also calculated, using standard U.S. Department of Transportation dollar values for injuries and fatalities.
- [ACCIDENT FREQUENCY] is an accident rate expressed as the number of accidents per unit of exposure. The unit of exposure used reflects key drivers behind accident causation. For example, accidents per million train miles for train collision accidents.
- [ACCIDENT CONSEQUENCE] is the harm caused by a single accident (injuries, fatalities, and property damage) and varies by train type, train size, speed, accident scenario, and similar factors.

To estimate total risk on a specific railroad corridor with a specific train control system, risk is calculated for each accident scenario, temporal and spatial variation in operating conditions (speeds, traffic volume, and mix), and for NAJPTC, train control system operating state (normal and timeout).

The steps in performing the risk analysis are:

Step 1: Identify all PTC-relevant accident scenarios, where application of PTC or the base case train control systems may change accident frequency or consequences. These scenarios comprise all kinds of collisions, including those at diamonds and grade crossings, overspeed derailments, and work zone incursions.

Step 2: Estimate risk parameters (frequency and consequences) for each accident scenario, temporal and spatial variation in operating conditions, and each train control system operating state. The approach to this step relied on first estimating risk parameters for a *reference analysis case* (the same test corridor with Centralized Traffic Control operated at 79 mph) from historical accident data to provide a starting point for all analysis cases. Then risk parameters for each train control system are estimated as variances from reference case values, based on control system capabilities and operating experience with the base case systems. For NAJPTC, this involved estimating the effect of timeout on risk parameters for each scenario, as well as for NAJPTC when operating normally.

Step 3: Calculate individual risks for each accident scenario, temporal and spatial variation and operating state, and total to give overall risk for the corridor.

Step 4: Compare risk analysis results for the whole corridor between cases to meet the objectives of the analysis.

A multiple-worksheet spreadsheet model was used to perform the risk calculations and sum the results for each analysis case.

FINDINGS AND CONCLUSIONS

There are two primary conclusions from this analysis. The first is for this specific corridor, traffic volume, and traffic mix, PTC timeout and latency values do not have a material effect on safety. The second conclusion is that the NAJPTC system as analyzed, with a timeout of 120 seconds and latency of 10 seconds, showed substantially lower total accident costs than either ATC or ATS.

The risk analysis results for timeout and latency are shown in Table 1. Differences are shown as a percentage change in total accident costs (sum of injuries, fatalities, and property damage) from the estimated accident costs associated with the NAJPTC system as originally planned, estimated at $2.73 million.

Table 1: Total Accident Cost Effects of Varying Timeout and Latency

Analysis Case	Timeout (secs)	Latency (secs)	Accident Cost Variation
NAJPTC Plan	120	10	0
Timeout Variations	20	10	-0.14%
	60	10	-0.08%
	240	10	+0.16%
	360	10	+0.31%
Latency Variations	120	5	-0.59%
	120	20	+1.44%

As can be seen from the table, the maximum change in accident costs is less that 1.5 percent showing the effects of varying latency and timeout within the range analyzed are minimal. This result is for a corridor with about nine trains per day, of which fewer than three trains per day are not equipped with PTC. Results may be different with higher traffic levels and a larger fraction of unequipped trains.

Results of the comparison between NAJPTC with a timeout value of 120 seconds and latency of 10 seconds, and the base case train control systems are illustrated in Figure 2.

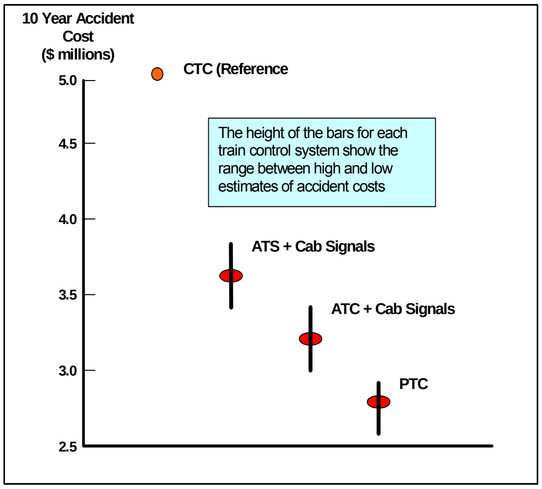

Figure 2: Results of Comparison between NAJPTC and Base Case Control Systems

Risk calculations were performed for each case using best estimates of frequencies for each accident scenario (shown as a red oval in Figure 2), and using high and low frequency values to investigate the sensitivity of the results to these inputs. The results show that NAJPTC system has lower accident costs than either of the base case systems. The best estimate results show that NAJPTC accident costs are 24 percent lower than cab signals with ATS and 14 percent lower than NEC ATC. The principal sources of the advantage of the NAJPTC system are fewer train-to-train collisions, overspeed derailments, and work zone incursions. The difference in train-to-train collisions between the NAJPTC and the ATS base case is much more pronounced than the difference between the IDOT PTC and the NEC ATC base case. Cab signals with ATS or ATC exhibited slightly lower accident costs than the NAJPTC system only for freight trains involved in train-to-train collisions, and in intrusion and broken rail accidents. Explanations for these differences are provided are provided in reference [1].

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KEYWORDS

Positive train control, IDOT Corridor, timeout, latency, risk assessment.