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Of Transportation

**Federal Railroad
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Research Results

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Development of a General Train Movement Simulator for Safety Evaluation

SUMMARY

A simulation modeling capability has been developed to replicate a rail line operation, including the detailed movement of trains and the functioning of the traffic control system. The simulation system allows users to input track plans, train control blocks, trains and their consists, train schedules, and random schedule delays. The simulator reports detailed time-position-speed information for each train, as well as the status of movement authorities for each train and each control block. The "meet and pass" is handled by the simulator using the normal dispatching practice with preset train priorities. The simulator generates metrics of exposure (i.e., frequencies of specific use-related system events), which are a primary input to the analysis of accident risk.

The simulator was developed using standard software development tools, so it is readily extendable and requires no special licensing for distribution. The system is currently run in a multi-user environment on a central server that is accessible over the Internet.

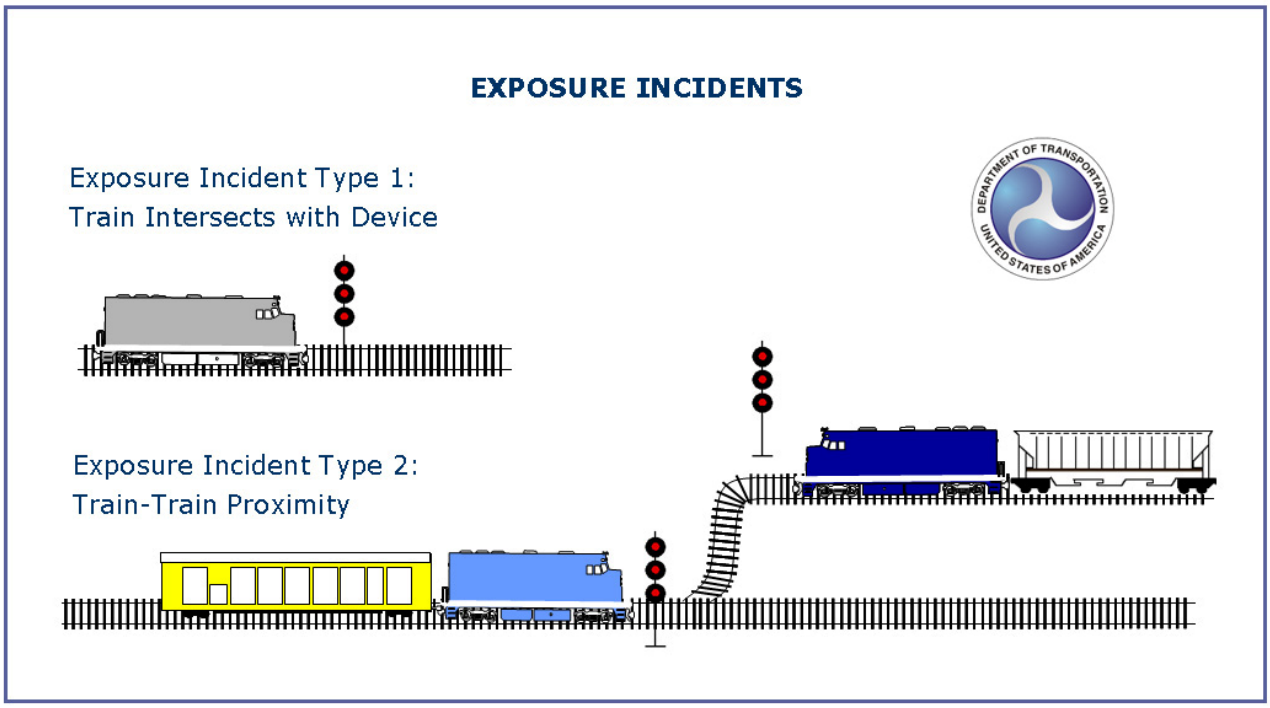

Figure 1. Generalized Train Movement Model for Exposure Determination

INTRODUCTION

A principal challenge in introducing new railroad traffic control technology, like positive train control (PTC), is to convincingly demonstrate that safety will not be compromised. The Federal Railroad Administration (FRA) has established guidelines for submitting a performance-based Product Safety Plan (PSP), which is to include a risk analysis of potential accident scenarios. A key driver of risk is the frequency with which events occur that may be precursors to hazardous situations leading to accidents. Such events may be the intersection of a train with a device or certain situations of train-to-train proximity. Reliable estimates of the probabilities of these events, or exposure metrics, can be derived through the simulation of a rail line operation, which realistically replicates train movements and the system of traffic control.

The General Train Movement Simulator for Safety Evaluation was designed with the short-term goal of supporting the risk analysis of new rail technology. The simulator can be extended to enable the analysis of additional sources of risk, and it may have additional applications as well, such as the analysis of rail line capacity.

TECHNICAL DESCRIPTION

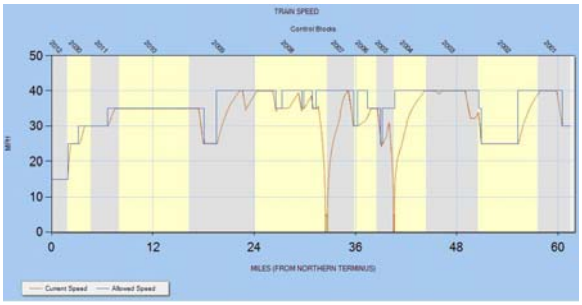

Figure 2. Train Speed Profile

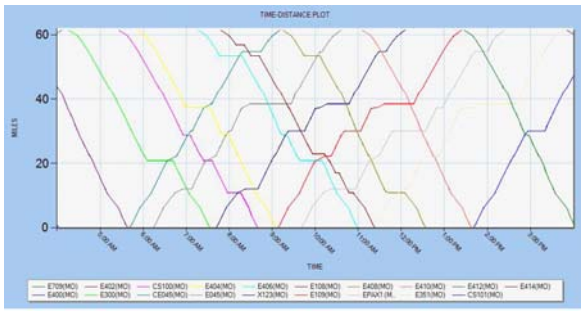

Figure 3. String Chart Displaying Train Time and Position

The simulator uses a hybrid of fixed time interval and discrete event simulation: Train movements are calculated as discrete events, and these are synchronized to a fixed time interval of 30 seconds.

The two principal analytic components of the simulator are the train movement model and the dispatcher model. The train movement model calculates the forces on the train, including the tractive effort, the braking force, and the resistance forces—grade, curve, and aerodynamics. The train receives its routing information and authority to move from the dispatcher, and it accelerates and decelerates according to its effective speed limit, which is derived from the track speed limit and the authority granted to the train. Trains advance with small incremental changes in speed until the forces on the train are in balance (subject to the speed limit). The resistance forces on the train are recalculated on a car-by-car basis every 500 feet to account for changes in speed, grade, and track curvature.

The dispatcher model operates on a node network that is overlaid on the real world network of control blocks. A node represents a minimally sized resource that can only be authorized to a single train at a time. The dispatcher determines the path of trains through the network and grants authorities for movement. Authorities are granted in order to achieve safe separation of trains, facilitate train meets, and overtake lower priority trains. The dispatcher model grants an authority to a train only if the movement of the train is free of conflict and will not cause a deadlock. Authorities are revoked only after a train has traversed and exited the authorized block. Through the dispatcher model and the configuration of control blocks, alternative train control systems can be simulated.

Each iteration of train movement and authority's status is recorded in the system database. Each train-mile of operations generates between 25 and 35 rows of output data, and a typical simulation can generate hundreds of thousand or millions of rows of data. The system derives summary and exposure metrics through an analytic process that is performed on the simulation output data.

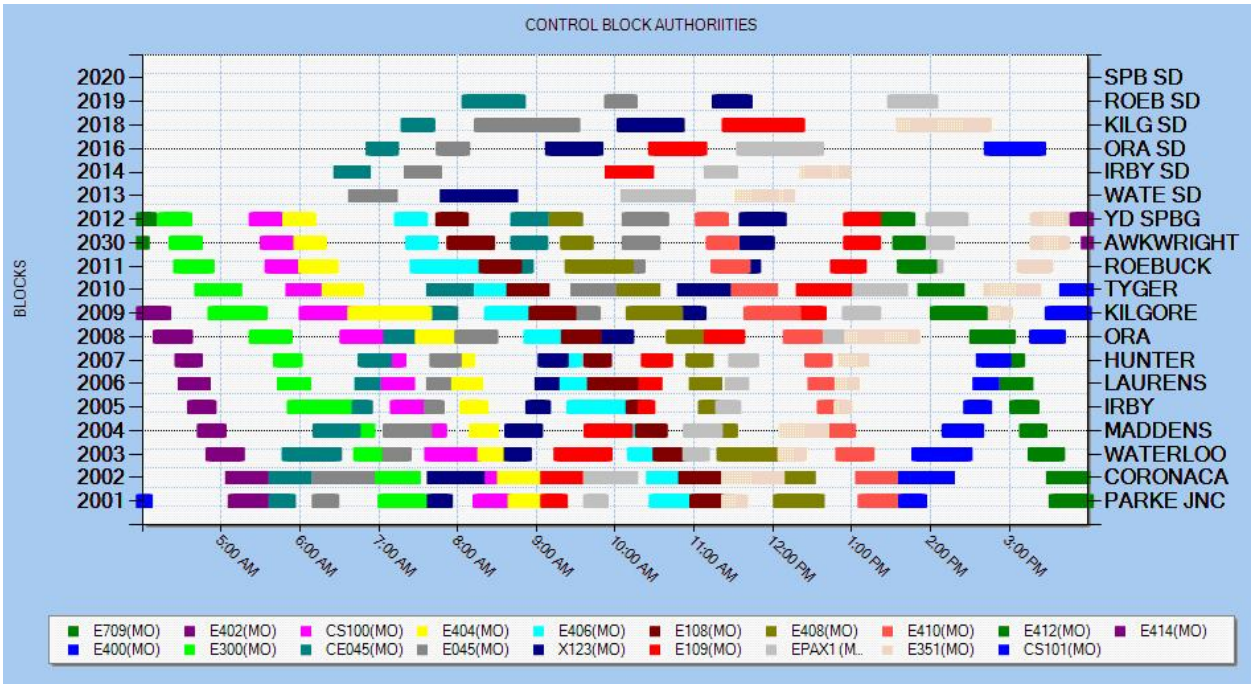

Figure 4. Chart of Control Block Authorities

RESULTS SUMMARY		INTERSECTIONS WITH SEGMENTS				
Name	FULL WEEK 2	1	2	3	4	5
Version	0.1.1.20	283	283	283	182	182
Sim Start Time	2/6/2007 0:00	6	7	8	9	10
Sim End Time	2/12/2007 23:59	283	283	283	283	282
Period of Operations	7days 0hr 0min	11	12	13	14	15
Run Start Time	2/6/2007 16:16	175	175	175	282	282
Run End Time	2/6/2007 17:51	16	17	18	19	20
Start of First Train	2/6/2007 1:11	282	282	282	282	282
End of Last Train	2/12/2007 21:20	21	22	23	24	25
Simulation Check Value	14110.90099	282	282	282	174	174
Number of Trains	282	26	27	28	29	30
Minimum Average Train Speed	12	283	283	283	283	169
Maximum Average Train Speed	30	31	32	33	34	35
Mean Average Train Speed	22.2	169	282	282	282	282
Total Train-Miles	17274.08	36	37	38	391	392
of total, on main	16570.24	282	176	176	282	282
of total, on sidings	703.84	40	41	42	43	44
Total Authorities Granted	4263	282	282	281	281	281
of total, on main	3719	45	46	47	48	49
of total, on sidings	544	281	281	281	281	281
		1001	1011	1012	1013	1016
Total Meets and Passes	657	101	107	109	109	113
of this, using siding 2013	126	1017	1022	1023	1024	1025
of this, using siding 2014	131	106	0	0	0	0
of this, using siding 2016	132					
of this, using siding 2018	138					
of this, using siding 2019	130					

Table 1. Simulation Results Table (Partial View)

IMPLEMENTATION AND TESTING

The simulator software was implemented using MS Visual Studio© 2005 and deployed on a dual-core, dual-processor server. The system database was deployed on a separate server. In its current configuration, the simulator performs calculations for 250 train-miles per minute.

The simulator software includes user-friendly interfaces for uploading, downloading, and sharing data. The software readily accommodates the development of multiple simulation scenarios. The simulator enables the review of results in both tabular and chart formats (see Figures 2 though 4).

The simulator was tested using data from CSX Transportation, Inc. (CSXT). The subdivision is single-track with six two-ended sidings for meets and passes which traverses undulating terrain with some very steep grades. Tests were conducted with loads and traffic mixes on the network well in excess of its regular usage. The simulator succeeded in replicating movements and managing traffic as expected while generating the metrics of interest.

NEXT STEPS

The Office of Research and Development expects to use the simulator in the ongoing analysis of risk for new traffic control technologies. FRA anticipates expanding the capabilities of the simulator to cover a wider range of metrics that are critical to safety evaluation.

ACKNOWLEDGMENTS

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Terry Tse, from FRA's Office of Research and Development, and Karen McClure, from FRA's Office of Policy, provided technical support and direction. Robert McCown, a consultant to FRA, provided technical review and recommend-ations. Special thanks go to CSXT for providing the test bed data for the simulator.

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[1] 49 CFR § 236.913 "Filing and Approval of Product Safety Plans (PSPs)."

[2] Transportation Systems Center, U.S. Department of Transportation, "User's Manual for the Train Performance Simulator (TPS) Version 5C," March 1988.

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