Florida Tech Senior Design Project

Railroad Signaling Block Design Tool

Project Scope:

Develop a software application (tool) that verifies, and recommends improvements, in railroad signaling block design.

Requirements:

I. The software application shall include formulas on the following specific parameters stated below, that will be an intrinsic part of the analysis of signal block characteristics, and allow recommendations on signal block improvements.

1. Safe Braking Calculations – is the distance the train travels from when the train driver makes a full-service brake application to when the train stops (see figure 1).
2. Headway Calculations - headway is the time spacing between trains (see figure 1).
3. Runtime Performance Calculations – Run time is the time of travel between any two points, but is normally given from the start of a run – departure from the initial station, to the end of a run – arrival at the final station.
4. Clear Time Calculations – The clear time of a track circuit is the time from a train entering a track circuit to the time the rear of that train is clear of the track circuit ahead which permits this track circuit to return to the maximum cab signal speed provided by the block layout
5. Approach Locking Time Calculations - the locking of any route from a signal, when the driver has seen or may have seen a proceed aspect at a signal that would indicate to the driver that the former signal is displaying a proceed aspect. If the signal is replaced to danger, the approach locking prevents the immediate release of the route because it is possible that an approaching train may be unable to stop (see figure 1).

Below is a sample layout of the parameters the calculations is determined for 1, 2 and 5 above:

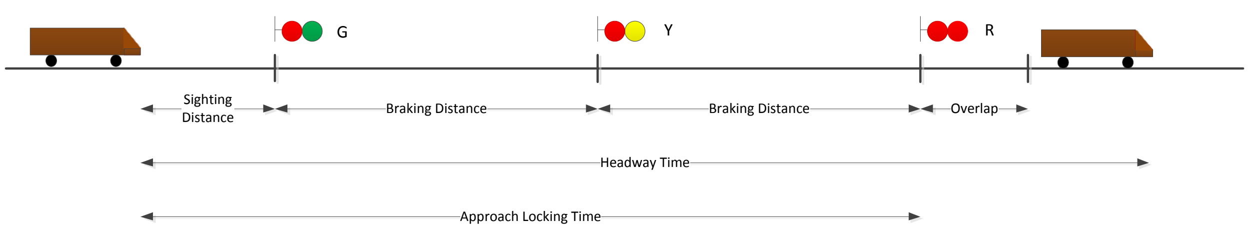

Figure 1 – Safe Braking Distance-Headway and Approach Locking Time

II. The software application shall include the capability for database and application user inputs for parameters such as train acceleration, train deceleration; maximum authorized track segment speed, operator reaction time, civil restrictions, track curve data, track grades and more.

III. With both the signaling design formulas in section I, and the data entry in section II, the software application shall perform automated analysis, and display the pertinent railroad signaling design output.

IV. The output of the software application shall determine for any given Railroad Signaling Design the safe train braking distance, the train headway times, the run time performance, clearing times, and approach locking times given the paramaters entered into the system. The application shall support display and output of:

- Excel formatted Spreadsheet
- Track and Train Graphs
- Train Simulations

V. The Development Tools, Database technology selection, and specific output formats are to be determined during the initial stages of the project.

GE Points of Contact:

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Algorithms and Data:

Sample Data 3 – Raw Safe Braking Data Output

Analysis		Initial Speed	Initial Speed	Final	Final	Simulated	35% Net	Provided	Net	
Signal/Bond Name	Chainage/Stationing	(Nominal)	(Actual)	Speed	Chainage/Stationing	Braking Distance	Braking Distance	Distance	Safety Factor	Worst Case Train
Identifier	Feet	Mph	Mph	Mph	Feet	Feet	Feet	Feet	percent	Train Composition
SB Sig 12/14	3403 + 83.00	49.35	49.35	0	3428 + 49.48	2466.48	3329.75	6772	203	Sample 4 car
SB Sig 12/14		65.1	65.1	0	3442 + 35.38	3852.38	5200.71	11932	309	Sample 1 car

The Safe Braking Data Table includes the all the details. Location name, chain, initial speed, final speed, braking distance, buffer, and train type.

Sample Data 4 – Raw Runtime Data Output

Mode	Distance	Acceleration	Tf Acc.	Bf Acc.	Tractve/Braking Force	Train Class	Time	Chainage/Stationing	Velocity	Civil Speed Limit	Grade	Curve Acc.	Grade Acc.	Resistance Acc.	Train ATC Speed
State	Feet	Mphps	Mphps	Mphps	Pounds of Force		Min:Sec	Feet	Mph	Mph	Percent	Mph/Seconds	Mph/Seconds	Mph/Seconds	Mph
Braking effort	2315.06	-1.18	0	-1.2	-100130.74	TPC Run	02:45.5	3396 + 84.10	3.07	79	-0.12	0	0.03	-0.01	65.1
Braking effort	2317.1	-1.18	0	-1.2	-100130.74	TPC Run	02:46.0	3396 + 86.14	2.48	79	-0.12	0	0.03	-0.01	65.1
Braking effort	2318.7	-1.18	0	-1.2	-100130.74	TPC Run	02:46.5	3396 + 87.74	1.89	79	-0.12	0	0.03	-0.01	65.1
Braking effort	2319.87	-1.18	0	-1.2	-100130.74	TPC Run	02:47.0	3396 + 88.91	1.3	79	-0.12	0	0.03	-0.01	65.1
Braking effort	2320.6	-1.18	0	-1.2	-100130.74	TPC Run	02:47.5	3396 + 89.64	0.7	79	-0.12	0	0.03	-0.01	65.1
Braking effort	2320.9	-1.18	0	-1.2	-100130.74	TPC Run	02:48.0	3396 + 89.94	0.11	79	-0.12	0	0.03	-0.01	65.1
Stopped	2321.96	0	0	-1.08	-90700.51	TPC Run	02:48.1	3396 + 91.00	0	79	-0.12	0	0.03	-0.01	65.1
Stopped	2321.96	0	0	0	0	TPC Run	03:08.1	3396 + 91.00	0	79	-0.12	0	0.03	-0.01	65.1
Tractive Effort	2322.1	0.91	0.9	0	74991.11	TPC Run	03:08.6	3396 + 91.14	0.41	79	-0.12	0	0.03	-0.01	65.1
Tractive Effort	2322.56	0.91	0.9	0	74978.4	TPC Run	03:09.1	3396 + 91.60	0.86	79	-0.12	0	0.03	-0.01	65.1
Tractive Effort	2323.36	0.91	0.9	0	74965.7	TPC Run	03:09.6	3396 + 92.40	1.32	79	-0.12	0	0.03	-0.01	65.1
Tractive Effort	2324.49	0.91	0.9	0	74953	TPC Run	03:10.1	3396 + 93.53	1.77	79	-0.12	0	0.03	-0.01	65.1
Tractive Effort	2325.96	0.91	0.9	0	74940.3	TPC Run	03:10.6	3396 + 95.00	2.22	79	-0.12	0	0.03	-0.01	65.1
Tractive Effort	2327.75	0.91	0.89	0	74927.61	TPC Run	03:11.1	3396 + 96.79	2.68	79	-0.12	0	0.03	-0.01	65.1

Runtime Data above shows a station stop evaluated at ½ second intervals.

Sample Data 5 – Raw Headway Data

Signal/bond name	Chainage	Circuit length	Total length	Entry time	Speed	Headway	Number
Identifier	Feet	Feet	Feet	Min:Sec	Mph	Min:Sec	Circuits
XX Station	26+65.4	84.60	365.4	00:29.9	60.00	01:53.7	4
27+50IJ	27+50.0	1500.00	450	01:07.8	60.00	01:52.4	3
S42+50IJ	42+50.0	1640.22	1950	02:16.0	60.00	01:40.0	2

RAILSIM® - Track Data Input Template							
**	Segment Data						
Data Type	Units (M,I)	Track SG ID	Location of Start (x100)	Location of End (x100)			
SG		01	0	10000000			
**	Grade Data						
Data Type	Units (M,I)	Track SG ID	Location of Start (x100)	Grade (%x1000)			
GR	I	01	5000000	0			
**	Platform Data						
Data Type	Units (M,I)	Track SG ID	Location of Start (x100)	Location of End (x100)	Station ID	Station Name	
PL		01	500000	550000	GIL	Gilbert	
**	Speed Data						
Data Type	Units (M,I)	Track SG ID	Location Start Speed (x100)	Location End Speed (x100)	Speed	C (Civil), T (Target), H (Head End)	
CS		01	0	1000000	10		
**	Braking Location Data Type						
Data Type	Units (M,I)	Track SG ID	Braking Location (x100)	Optional Initial Velocity (mph/kph) 0=MAS	Optional Final Velocity (mph/kph)	Optional Over-speed (mph/kph)	Brake Location Designation (ie: signal name)
BL	I	01	200000	90	0	0	CP5-4E

SG = Track Segment entry

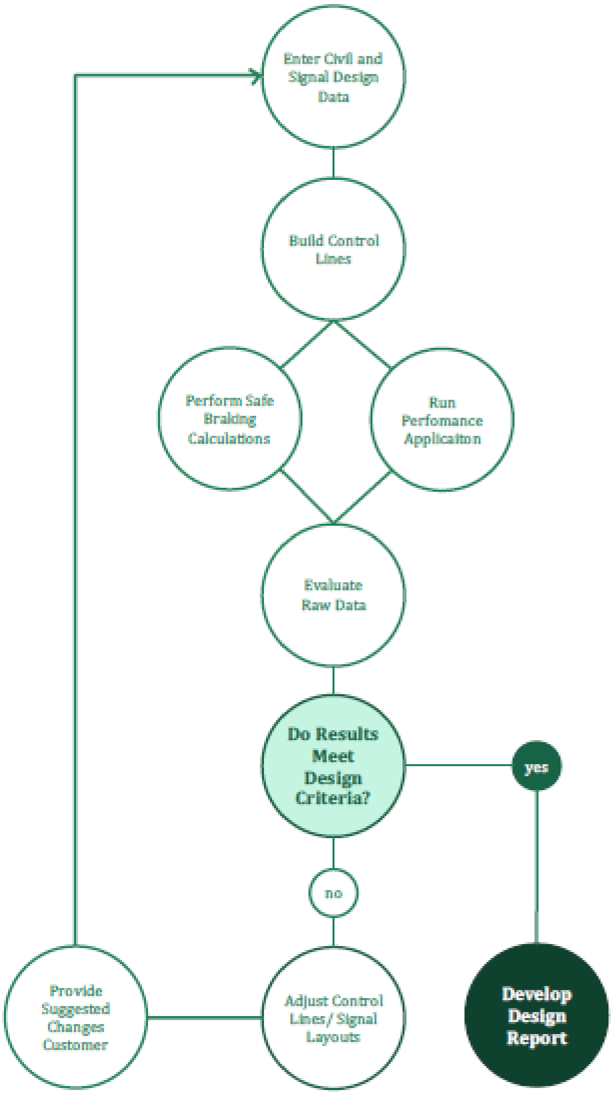
GR = Grade data entry

PL = Platform Data

C = Civil Speed zones

BL = braking location (signal)

8 Block Design Development Flowchart



5 Calculating Runtimes

Runtime performance will be evaluated for normal and reverse running. Nominal 4-Car trains will be used for the evaluation and will follow ATP and station stop operation. Clear routing will be used.

Runtimes will also be performed to show turn-back operation for 200th Street Station, and detailed boundary crossings.

6 Calculating Headway / Clearing Time

Headways will be verified to 150 seconds and will be evaluated using the nominal 4-car train as used in runtime calculations. The most restrictive block will be identified in the headway determination.

The clearing time for each block for MAS and intermediate speeds will be provided for reference.

If the headways are not met, alternative block boundaries will be submitted for review in an effort to meet the criteria.

Headways are evaluated for verification of normal running. Reverse running will be provided for information.

7 Calculating Approach Locking

Approach locking will be calculated using a nominal 4-car at MAS. Per the specification, this time is determined by calculating the runtime of the most distant affecting control line from entry of the control line to reaching the signal.

This calculation method assumes that any downgrade of speed after entering the control line will result in the train stopping short of the signal, or that the train will stop in less time than it takes to cover the distance at MAS.

4 Calculating Safe Braking Distance

Safe Braking Distance for train is given by the sum of the following:

- Distance traveled during equipment reaction, speed maintained (Non-Grade Adjusted).
- Distance traveled while braking to a complete stop (Grade Adjusted).
- Safety factor of 35% added to the braking distance.
- Overhang.

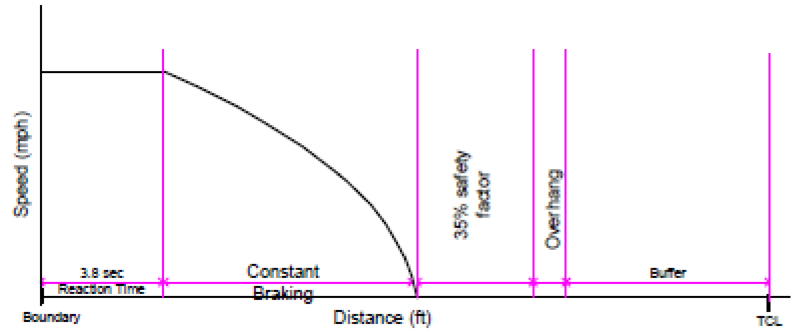


Figure 2 – Safe Braking Graph

Safe braking calculations will be made for normal and reverse directions and across normal and reverse routes. The calculations will very safe braking distance for train separation and adherence to civil speed restraints.

The safe braking calculations will be performed on 4 train models; Light 1-car, Heavy 1-car, Light 4-car, and Heavy 4-car.

The calculations will provide data to ensure the block design is providing the best possible highest ATP speeds as well as the best possible intermediate speeds.

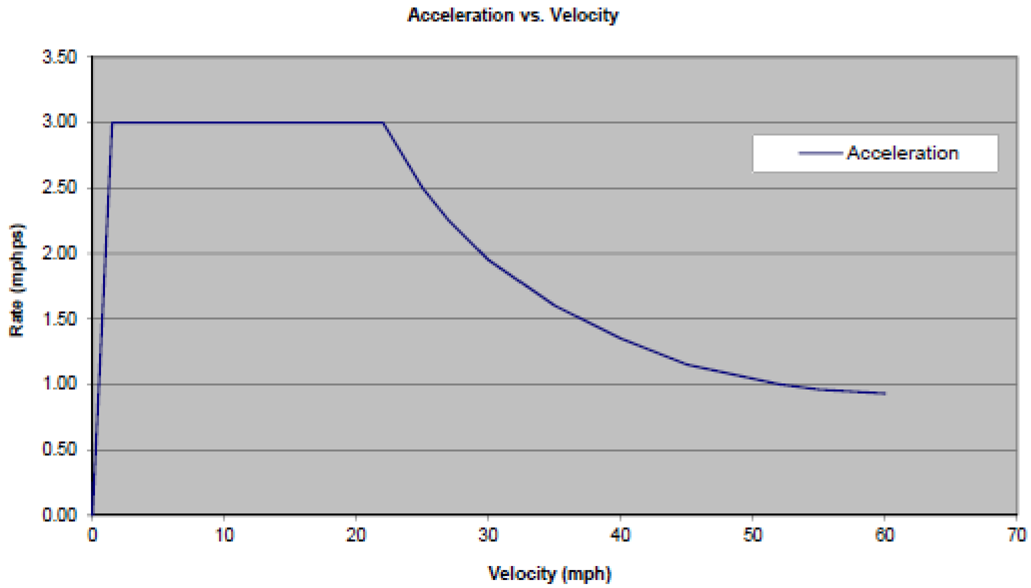


Figure 1 – Acceleration Vs. Velocity

3.1 Speed Commands

The block design will be evaluated with the following seven parameters for MAS and intermediate speeds commands:

- 55 mph
- 45 mph
- 35 mph
- 30 mph
- 20 mph
- 10 mph

The street running command is not part of this contract.

3 Vehicle Specifications

The following specifications will be used for safe braking, runtime and headway analysis. Four consists will be tested in total. Safe braking will be evaluated using one and four car consists using both weights, and the headways and runtime will be evaluated with the four car consists using both weights.

Station Stops:	Assume stops made at all stations for the purpose of calculating runtimes and headways.
Station Dwell:	20 s (includes all aspects of the station stop).
Train Length:	95 ft
Train Weight:	110,000 pounds 158,500 pounds
Curve Speeds:	Posted speed civil speed.
Maximum Speed:	55mph + 4mph over-speed for safe braking 55mph + 0mph over-speed for headway and runtime
Acceleration:	See Figure 1 – Acceleration Vs. Velocity below; [1] Specification Section 34 42 02 2.04 Table 1
Deceleration:	1.95 mph/s for safe braking 2.1mph/s for headway and runtime
Gravity Constant:	32 ft/s^2
Overhang:	7ft (Double overhang of 14ft for following moves)
Jerk Limit:	2.5 mi/hr/sec^2

Safe braking LRV Model Formula:

SBD = (Vos * RTmax * 1.467) + ((Vos^2 – Vf^2) * (0.7333/(0.22G + BReff))) * 1.35 + (2 * 7')

Where:

SBD = safe braking distance in feet.

Vos = Speed of LRV (in mph) as it enters the block, assumed to be cab command speed plus 4 mph overspeed.

RTmax = Sum of worst case reaction times from time LRV passes a cab signal command change point until brakes are applied. This time consists of:

2.0 second to decode new cab command being received
0.5 second to detect lower speed.
0.35 second of propulsion build down time.
0.3 second of LRV propulsion system change time.
0.65 second of brake build-up time.

RTmax is therefore a total of 3.8 seconds. During this time, it shall be assumed that no braking takes place and LRV proceeds into new block at previous Vos.

1.467 and 0.7333 are standard conversion factors to convert from miles/hour to feet/second.

Vf = Final speed of LRV, when calculating SBD, this number will always be zero.

G = Grade (rise/run in percent) over which braking will occur.

0.22 is correction factor used to adjust braking distance for effects of grade.

BReff = De-rated brake rate, 1.95 mphps.

1.35 is the addition of a 35 percent safety factor. Apply only to braking portion of SBD calculation.

Two multiplied by 7 feet accounts for overhang of vehicles and is assumed to be 7 feet at the end of each vehicle.

Nominal Braking Formula:

BD = (Ves * RTnom * 1.467) + ((Ves^2 – Vf^2) * (0.7333/(0.22G + BRnom)))

Where:

BD = Braking distance required to meet civil restriction, typically a spiral to curve point, in feet.

Ves = Velocity at entering speed (assumed to be cab speed)

RTnom = Sum of nominal reaction times from time LRV passes a cab signal change point until brakes are applied and is assumed to be 3.5 seconds. During this time, assume LRV travels at previous cab speed with no braking taking place.

Vf = Civil speed limit of curve LRV is approaching.

BRnom = De-rated brake rate, assumed to be 2.1 mphps

Acceleration due to grade:

$$a = g \times \left(\frac{G}{-1.4667 \times 100} \right)$$

Acceleration:

$$a = \left(\frac{V_f - V_i}{t_f - t_i} \right) \qquad a = \left(\frac{V_f^2 - V_i^2}{-2d} \right)$$

Velocity:

$V = V_i + at$

Distance:

$d = V_i t + 1/2at^2$

Time:

$$t = \frac{V_f - V_i}{a}$$

Where:

A = Acceleration

g = Grade Value

G = Gravitational Constant

V = Velocity – (f-final, i-initial)

t = Time – (f-final, i-initial)

d = Distance

ATP	Automatic Train Protection
Boundary	Insulated joint or other code change point
ft	feet
ft/s	feet per second
ft/s^2	feet per second squared
GE	General Electric Company
GETS-GS	GE Transportation Systems, Global Signaling
MAS	Maximum Authorized Speed
mph	Miles per hour
mphps	Miles per hour per second
s	Second
SBD	Safe Braking Distance
TCL	Track Control Limit
TPC	Train Performance Calculator