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Evaluation Methodology for New Design Switches

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Summary

Transportation Technology Center, Inc. (TTCI), Pueblo, Colorado, has developed a methodology for evaluating the suitability of new switch and turnout designs for heavy axle load (HAL) service. This methodology will assist railroads in evaluating new designs and components prior to installation in track. Facility for Accelerated Service Testing (FAST) will be used as a demonstration of this methodology with its application to current and future switches used on the High Tonnage Loop at FAST.

The methodology TTCI developed consists of the following:

- Failure modes, effects, and criticalities analysis (FMECA)
- Follow-up testing of any potential issues identified by FMECA
- Evaluation of manual operations of switches
- Comparison of operating performance versus baseline switches

A FMECA was conducted on currently used HAL service switches that highlighted the following issues:

- Gapped or chipped switch points
- Dragging equipment derailments
- Track surface and alignment related defects
- Worn switch points
- Split switch due to vertically flexible rods

The evaluation methods proposed will assist track engineers to determine new designs, and their potential effects on track reliability, before implementation is considered. Often, the effects of changes in switch control system components (e.g., switch machine components) on switch failure modes and overall reliability are not readily apparent.

The North American railroad industry is experiencing traffic growth that is expected to continue for the next two decades. Thus, the industry is seeking ways to increase capacity and reliability of track components. This is especially important for special trackwork such as turnouts, crossing diamonds, and insulated joints. These are key elements of the traffic control system and can affect traffic movement on large segments of the railroad.

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INTRODUCTION

The North American railroad industry is seeking ways to increase capacity and reliability of track components to meet increased traffic demand. This is especially important for special trackwork such as turnouts, crossing diamonds, and insulated joints. These are key elements of the traffic control system and can affect traffic movement on large segments of the railroad. Special trackwork related train delay (due to condition-based speed restrictions and track outages for maintenance) is estimated at $600 million to $1 billion annually. Switches are usually one of the top three track causes of Federal Railroad Administration reportable accidents and may contribute greatly to train delay.

The evaluation methods proposed will assist track engineers in evaluating new designs and their potential effects on track reliability, before implementation is considered. Often, the effects of switch control system changes (e.g., switch machine components) on switch failure modes and overall reliability are not readily apparent. FAST will be used as a demonstration of the methodology, applying it to current and future switches used on the High Tonnage Loop (HTL).

The methodology developed consists of the following:

- FMECA
- Follow-up testing of any potential issues identified by FMECA
- Evaluation of manual switch operations
- Comparison of operating performance versus baseline switches

A FMECA was conducted on currently used HAL service switches. The analysis highlighted the following issues:

- Gapped or chipped switch points
- Dragging equipment derailments
- Track surface and alignment related defects
- Worn switch points
- Split switch due to vertically flexible rods

Figure 1 shows a typical freight mainline switch and potential failure locations.

Figure 1. Typical Mainline Switch and Potential Failure Locations

METHODOLOGY

A FMECA will be conducted for the switch following the methods used in previous special trackwork studies.[1,2] This will include a design review with emphasis on any new design elements. The switch will be monitored for long-term performance under FAST/HTL operations. Measures of performance will include wear, dynamic loads, dynamic deflections, and component failures.

Manual switch throw operations will be evaluated for ease of operation. This includes switch throw, switch adjustment, and required periodic maintenance. Furthermore, a trailing point simulated accident run through will be conducted to determine possible failure modes and potential damage that may occur.

The design analysis will be used to develop measurements and tests scenarios specific to each switch design. For example, experience with hollow steel tie switches suggests the transit clips are less stiff than traditional American Railway Engineering and Maintenance-of-Way Association style clips. The additional flexibility may allow this switch to deflect more under loading. This could result in a gapped switch point accident.

Benchmarking measurements (use current standard design):

- Throw effort – measure required throw force at a No. 1 rod with the switch adjusted
- Panel lateral stiffness – measure panel stiffness with TTCI's Track Loading Vehicle (gage restrain measurement system) or individual tie stiffness with a lightweight track loading fixture (for each tie type)
- Switch point roll – apply 40-kips vertical force, 20-kips lateral force and measure switch point movement (vertical and roll)
- Track vertical stiffness – measure track modulus in the switch
- Longitudinal movement – determine allowable longitudinal movement before switch operation is affected

Long-term performance measurements:

- Running surface wear
- Geometry defect occurrence and degradation rate
- Monitor component breakage
- Throw effort, switch point roll, and track vertical stiffness

FAILURE MODES ANALYSIS

A FMECA was conducted for mainline No. 20 switches used in HAL service. The study identified several low-risk issues and a few higher-priority issues. Among the highest priority issues were:

- Gapped or chipped switch points, which are a result of stock rail flow that leads to adverse contact between point and stock rail.

- Dragging equipment derailments are not related to switch performance, as the derailment occurs prior to the switch. Switches provide an immovable obstacle that may cause an upright, but derailed, car to stop.
- Track surface and alignment related defects caused by uneven support due to switch rods in the ballast.
- Worn switch points may allow a worn wheelset or truck to derail by wheel climb.
- Split switch, due to vertically flexible rods, may be split by vertical bending of the rods under load.

An expert panel (TTCI special trackwork experiment managers) developed the failure modes based on experience with mainline switches in HAL service. The panel brainstormed failure scenarios and developed root causes for each. A risk priority number (RPN) was developed for each failure mode based on expert ratings of the severity, frequency, and detectability of each failure mode. Table 1 shows the qualitative rating scales used for each category.

Table 1. Qualitative Rating Scales

Score	Severity	Frequency	Detection
2	Rough ride	Improbable: 1x10^6	Always detected
4	Slow order	Remote: 1/1,000	80 percent
6	Slow order and manual operations	Occasional: 1/year	50 percent
8	Derailment	Probable: 1/month	20 percent
10	Collision	Frequent: 1/week	Rarely or not possible

A failure mode is rated on each factor independently to derive an RPN. Thus, there is no correlation implied between a high score for severity and a high score for frequency or detection in Table 1.

RPN is the product of the severity, frequency, and detectability ratings. The scale of RPN can go from 0 to 1,000 (10 x 10 x 10). The scale is intended to be more sensitive to more severe problems since a midpoint rating of all factors will produce an RPN of 125 (5 x 5 x 5).

Figure 2 shows the RPNs for 43 failure modes developed and rated by the expert panel. Note that most failure modes had an RPN of less than 100, indicating that switch designs are relatively robust, with a wide range of failure modes. Also note that the RPNs are more highly correlated with the detection rating than frequency or severity. This indicates that track maintenance personnel are fixing what they find, but may need additional capabilities to find more types of flaws.

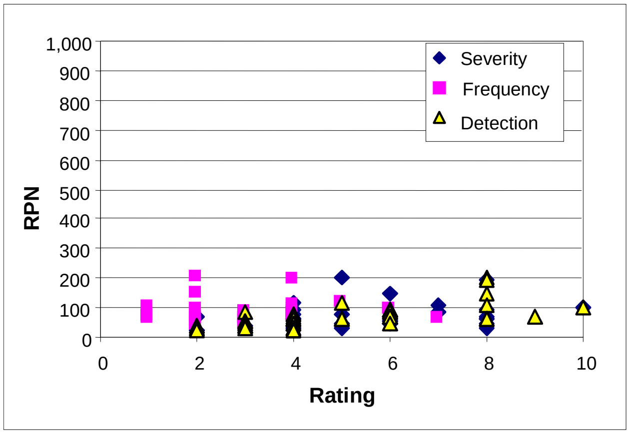

Figure 2. Switch Failure Mode RPN

Failure modes are classified into the following groups:

- Design
- Wear
- Fatigue
- Environment
- Maintenance
- Operations

Table 2 (pg. 4) contains the list of failure modes and RPN ratings (sorted by failure mode category). The major failure modes have not changed considerably since the 2002 study by Davis, Terrill, and Mesnick.[1] Maintenance issues related to wear limits of components are major concerns. Additionally, design issues related to switch operation are important.

FUTURE WORK

The methodology described above will be used to establish the baseline performance of existing switches used in HAL service. It will also be used to evaluate new switch and switch component designs. This will aid the industry in developing improved performance and reliability switches. The HTL turnouts at FAST will provide a demonstration of the methodology by using it to evaluate each mainline switch.

REFERENCES

1. Davis, David, Vincent R. Terrill, and Daniel B. Mesnick. July 2002. "Railroad Switch Design and Failure Mode Analysis." *Technology Digest* TD-02-015. Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado.
2. Davis, David D., Yi-Ren Chen, Frederick V. Lawrence, and Christopher P.L. Barkan. June 2001. "Frog Design Review and Failure Analysis." *Technology Digest* TD-01-013. Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado.

Table 2. List of Failure Modes and RPN Ratings

Line No.	Failure Mode	Result of	Category	Severity (1-10)	Frequency (1-10)	Detection (1-10)	RPN
5	Gapped point	Stock rail flow	Wear	5	5	8	200
12	Derailment	Dragging equipment	Operator	8	3	8	192
42	Gapped point	Rod clip stiffness	Design	6	3	8	144
4	Surface defect	Uneven support	Wear	4	6	5	120
41	Gapped point	Excessive point roll	Design	7	2	8	112
3	Wheel climb	Worn point	Wear	8	2	6	96
40	Out of adjustment	Design tolerances	Design	4	6	4	96
30	Broken rail	TW failure	Fatigue	7	4	3	84
9	Derailment	Sabotage	Operator	10	1	8	80
10	Split switch	Vandals	Operator	8	1	10	80
11	Switch throw	Vertically bent rods	Operator	5	4	4	80
39	Surface defect	Rollers/plates	Design	4	5	4	80
14	Switch throw	Lubrication – lack of	Maintenance	2	6	6	72
15	Switch throw	Longitudinal movement	Maintenance	6	3	4	72
28	Broken stock rail	Rail flaw	Fatigue	8	1	9	72
29	Broken point	Bolt hole/rivet hole	Fatigue	6	2	6	72
2	gapped point	Rod creep	Wear	4	4	4	64
24	Wide gage	Broken hollow steel tie	Fatigue	4	4	4	64
25	Wide gage	Point chipping or RCF	Fatigue	4	4	4	64
26	Alignment defect	Screw spike fatigue	Fatigue	4	4	4	64
27	Chipped point	Excessive point roll	Fatigue	4	2	8	64
23	Alignment defect	Rail brace loose	Fatigue	4	3	5	60
38	Gapped point	Detection rod placement	Design	6	2	5	60
17	Signal failure	Broken wires	Insulation	6	3	3	54
34	Frozen switch	Ice	Environment	6	3	3	54
7	Bent rod	Run thru	Operator	6	2	4	48
8	Gapped point	Improper installation	Operator	6	2	4	48
22	Wheel climb	Casting break	Fatigue	8	1	6	48
33	Frozen switch	Debris	Environment	5	3	3	45
19	Wide gage	Tie/fastener failure	Fatigue	4	3	3	36
20	Surface defect	Tie/fastener failure	Fatigue	4	3	3	36
21	Wide gage	Heel block movement	Fatigue	4	3	3	36
1	Switch throw	Settlement	Wear	4	2	4	32
6	Gapped point	Obstruction	Environment	8	2	2	32
13	Wide gage	Loose components	Maintenance	4	2	4	32
37	Switch throw	Design tolerances	Design	5	2	3	30
32	Switch obstruction	Drainage	Environment	4	3	2	24
35	Surface defect	Fasteners – vibration	Design	2	3	4	24
36	Wide gage	Fasteners – vibration	Design	2	3	4	24
18	Alignment defect	Too few rods	Fatigue	5	2	2	20
16	Signal failure	Heater burns	Insulation	4	2	2	16
31	Animal in switch	Improper closure	Environment	0.01	10	10	1