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Pareto Analysis of the Causes for In-service Brake Failures

Harry M. Tournay, Tom Guins, and Robert Cartwright*

Summary

A Pareto analysis of in-service, brake-related failures reveals that 39 percent of failures are attributable to problems associated with air brake valves, 31 percent of failures are attributable to hose separations, and 11 percent each attributable to brake rigging and air leaks. This digest reports on the process used to conduct the Pareto analysis and the estimated costs associated with each failure mode identified.

Costs associated with these failures, resulting from train delays, are as estimated at $13 million per year.

This Pareto analysis suggests that approximately 62 to 69 percent (depending on analysis method) of air brake failures in the North American rail system are the result of the following:

- Valve failure, which predominates at approximately 35 to 39 percent of all failures
- Air hose separation, the second most predominant failure mode, accounting for approximately 27 to 30 percent of failures

Secondary problems (air leaks and brake rigging) are identified at 10.5 to 13.6 percent each (depending on analysis method).

The remaining failure modes account for approximately 8 percent of failures.

TTCI has initiated investigations into the root causes for, and solutions to:

- Valve failures
- Air hose separations
- Brake beam failures
- Brake rigging failures

The results of these investigations will be reported in subsequent *Technology Digests*. This work was sponsored by the Association of American Railroads as part of its Strategic Research Initiatives Program.

* Manager, Cartwright Consulting LLC

Please contact **Harry Tournay (719) 584-0704** with questions or concerns regarding this *Technology Digest.* E-mail: Harry_Tournay@ttci.aar.com.

INTRODUCTION

Railroads are experiencing capacity constraints that are exacerbated by the in-service failure of brake systems. Transportation Technology Center Inc. (TTCI) was tasked by the Association of American Railroads (AAR), under their Strategic Research Initiatives (SRI) Program to investigate the root causes for in-service failure attributed to the brake system and to recommend solutions.

As a first step to identifying root causes, the six major railroads were approached for statistics on their in-service failures. These statistics were then compared and a Pareto chart was developed for the industry as a whole.

METHOD

Data was obtained from the six major railroads. The data was not exactly comparable as each railroad uses different metrics. For example, four of the railroads reported train stops or delays, one reported car set-out failures, and one reported a mixture of air hose separations and set outs.

The analysis method was thus to look at each railroad's data individually and then attempt to compare the data with the understanding that there are differences in data collection and recordkeeping methods at each railroad.

Discussion of Results for Each Railroad

The railroads are identified as A through F.

Railroad A submitted a summary database for train delays for the six months prior to May 2007. Railroad A reported 26,613 total mechanical failures of which 6,262 were brake related. The largest category is "Other Undetermined Brake".

This railroad's failures are ranked as follows:

- Other Undetermined Brake 2,432
- Valve Failures 2,400
- Air Hose Separation 677
- Rigging 374
- Leaks 292
- Hand Brakes 87

Railroad B reported 9,125 mechanical train delay failures in 2006 of which 6,831 are brake related.

This railroad's failures are ranked as follows:

- Valve Failures 2,956
- Air Hose Separation 1,851
- Hand Brakes 1,006
- Other (Undetermined) 565
- Rigging 453

Railroad C provided data for cars set out on line for air brake problems in 2006. The data includes 777 incidents reduced in the following order:

- Valve Failures 244
- Leaks 232
- Rigging 120
- Air Hose Separation 100
- Hand Brakes 63
- Other 18

Railroad D reported a total of 3,388 mechanical train delay failures in 2006 of which 1,263 are brake related. The Pareto principle ranks the failures as follows:

- Air Hose Separation 417
- Valve Failures 319
- Leaks 275
- Rigging 159
- Hand Brakes 93

Railroad E reported a total of 2,399 mechanical train delay failures in 2006 of which 291 were brake related. The Pareto principle ranks the failures as follows:

Valve Failures	144
Air Hose Separation	89
Rigging	37
Leaks	19
Hand Brakes	2

Railroad F provided data from two databases in 2006: The first database includes all air hose separations as a separate report and the second database contains records of on-line set outs for mechanical reasons.

The first dataset reported a total of 5,568 mechanical set outs of which 1,819 were reported for brake system reasons. *Technology Digest* TD-08-031, devoted to air hose separations, identified 1,877 incidents. In the first dataset the mechanical reporting codes on the railroad combined the set outs for air hose separation, train line leaks and angle cocks (705 incidents) in one code; consequently, these failure modes are not separable.

Because of the combining of the data and the air hose separations being reported as a separate file, the effect of this railroad's data reporting anomaly on the North American railroad system Pareto analysis will be investigated.

This railroad also has a general code for air brake inoperative and reported 680 incidents. It's not clear what this code may cover, but it's not unreasonable to assign this defect to valve failures. The database indicates 343 rigging issues, 72 hand-brake issues, and 6 brake systems overdue test. The latter are presumed to be associated with overdue valve maintenance.

The issues are ranked as:

- Air hose separation 1,877
- Air hose separation & leaks 705
- Valve failure 680
- Rigging issues 374
- Hand-brake issues 72
- Low air hose 13
- Overdue test 6

Summary of Results from Each Railroad

Table 1 summarizes the results from each railroad.

Table 1. Summary of In-Service Brake-Related Failures

Failure	Railroad					
	A	B	C	D	E	F
Valve	2,400	2,956	244	319	144	680
Hose	677	1,851	100	417	89	1,877
Rigging	374	453	120	159	37	343
Leaks	292	0	232	275	19	705
Hand brakes	87	1,006	63	93	2	72
Other	2432	565	18	-	-	N/A
Total	**6,262**	**6,831**	**777**	**1,263**	**291**	**3,677**
Comments	6 months only					Air hose separation data combined with train line & angle cock

Review

Reviewing the above data indicates that although the sources and sizes of the databases are different for each railroad, the basic failures are similar. Combining the data into a single industry result requires a normalizing process that compensates for the differences in the source. In this case, the attempt is made by reducing each data point to a percentage of the total for each category and railroad. The results are averaged over the six railroads and summarized in Tables 2, 3, and 4.

The two items that emerge as prominent are valve failures at approximately 35 percent and air hose separations at approximately 29.4 percent. Rigging and air leaks account for about 10 percent each and all others are negligible (Table 2).

If the data from Railroad F includes the bundled Air Hose Separations/leaks as leaks, the 3rd Pareto item becomes leaks at 13.6 percent, valve failures drop to 34.3 percent, and air hose separations drop to 27.5 percent (Table 3).

If the "Other Undetermined Brake" item from Railroad A is removed from the data, the case for making valves and air hose separations the focus of the root cause analyses becomes more compelling (Table 4).

Table 2. Summary of In-Service Brake-Related Failures as a Percentage

Failures as %	Railroad						Average (%)
	A	B	C	D	E	F	
Valves	38.3	43.3	31.4	25.3	49.5	22.5	**35.1**
Hose	10.8	27.1	12.9	33.0	30.6	62.1	**29.4**
Rigging	6.0	6.6	15.4	12.6	12.7	12.4	**11.0**
Leaks	4.7	0	29.9	21.8	6.5	0	**10.5**
Hand Brakes	1.4	14.7	8.1	7.4	0.7	2.4	**5.8**
All Others	38.8	8.3	2.3	0	0	0.6	**8.3**

Table 3. Summary of In-Service Brake-Related Failures as a Percentage (Railroad F bundled air hose separations and leaks included as leaks)

Failures as %	Railroad						Average (%)
	A	B	C	D	E	F	
Valves	38.3	43.3	31.4	25.3	49.5	18.3	**34.4**
Hose	10.8	27.1	12.9	33.0	30.6	50.4	**27.5**
Rigging	6.0	6.6	15.4	12.6	12.7	10.0	**10.6**
Leaks	4.7	0	29.9	21.8	6.5	18.9	**13.6**
Hand Brakes	1.4	14.7	8.1	7.4	0.7	1.9	**5.7**
All Others	38.8	8.3	2.3	0	0	0.5	**8.3**

Table 4. Summary of In-Service Brake-Related Failures as a Percentage (Railroad A "other undetermined brake" eliminated)

Failures as %	Railroad						Average (%)
	A	B	C	D	E	F	
Valves	62.7	43.3	31.4	25.3	49.5	22.5	**39.1**
Hose	17.7	27.1	12.9	33.0	30.6	62.1	**30.6**
Rigging	9.8	6.6	15.4	12.6	12.7	12.4	**11.6**
Leaks	7.6	0	29.9	21.8	6.5	0	**11.0**
Hand Brakes	2.27	14.7	8.1	7.4	.7	2.4	**5.9**
All Others	0	8.3	2.3	0	0	0.6	**1.9**

This Pareto analysis suggests that approximately 62 to 69 percent (depending on analysis method) of air brake failures in the North American rail system are the result of the following:

- Valve failure which predominates at approximately 35 to 39 percent of all failures

- Air hose separation, the second most predominant failure mode, accounting for approximately 27 to 30 percent of failures

Secondary problems (air leaks and brake rigging) are identified at 10.5 to 13.6 percent each (depending on analysis method).

The remaining failure modes account for approximately 8 percent of failures.

Costs Associated with Brake-Related In-service Failures

Each in-service failure results in a train stop and subsequent train delay. The delay cost is the product of the delay time and the hourly cost of the train equipment, crew, and fuel consumed during the train stop. Cost of line congestion, including delays to following trains and overall line capacity has not been included in this analysis. The delay cost for a typical mainline train is $420 per delay hour.

Table 5 shows the delay cost by failure type. The delay times are taken from a survey conducted in 2006 of five Class I railroads. This table shows the annual delay cost for brake system caused delays to be approximately $13 million.

Table 5. Estimated Annual In-Service Train Delay Costs Per Failure Type

Defect	Delay Time per Delay (minutes)	Number of Delays	Total Time (hours)	Annual Cost
Air Hose	76	5,688	7,238	**$3,100,000**
Valve	78	9,142	11,846	**$5,000,000**
Leaks	54	1,815	1,624	**$700,000**
Rigging	93	1,860	2,868	**$1,200,000**
Hand-Brake	57	1,410	1,334	**$600,000**
Other	62	5,447	5,609	**$2,400,000**
Total:		25,363	30,519	**$13,000,000**

CONCLUSIONS

A Pareto analysis of brake-related, in-service failures suggests that valve failures and air hose separations are the two most prominent failure modes.

These two failure modes result in 66 percent of total in-service failure costs of $13 million per year.

TTCI has initiated investigations into the root causes for, and solutions to:

- Valve failures
- Air hose separations
- Brake beam failures
- Brake rigging failures

The results of these investigations will be reported in subsequent TDs.

Reference

Tournay, Harry M. and Benjamin Madrill. August 2008. "Factors Influencing Unwanted Air Hose Separations." *Technology Digest* TD-08-031, Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado.

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