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Understanding the Effects of Freight Car Component Life with Truck Performance Detector Technology

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Summary

A recent study performed by Transportation Technology Center, Inc. (TTCI) examined Truck Performance Detector (TPD), car repair billing (CRB), and mileage data histories for a homogeneous car fleet operating in unit coal train service. Research was initiated to understand the statistical relationships between TPD performance measures and component wear lives, specifically wheel life for this study. This study explores the use of TPD technology as a tool for developing policies and programs that may improve wheel life.

TPD data was gathered from *InteRRIS*®, a data warehouse query engine developed and maintained by TTCI. This data was queried from a TPD installed on a 3-degree curve for a continuous 5-year period (2003-07). The CRB maintenance data related to wheel wear replacements and mileage history is also used for the same 5-year period in accordance with the Field Manual of the Association of American Railroads Interchange Rules.¹

Only cars with *wear related* wheel replacements during the analysis period are examined. A TPD performance measure, *Truck Gage Spread Force* (TGSF) developed by TTCI is used to group cars by their operating performance. Weibull analysis characteristic life and shape parameters are then used to analyze wheel lives within these TPD performance groups. Therefore, the goal of this study is to understand the correlation of these measures to validate the use of TPD data as a decision making tool.

Key findings of this research include:

- Evidence suggesting that the Weibull characteristic life and scale parameters for wheels can be related to TPD data, although this requires further verification.
- Correlation of time histories of cars experiencing high TGSF with specific wheel maintenance events show a relationship which needs to be explored.
- Further research to verify the results and extend them to other fleets and operating conditions is warranted for wheel related research initiatives.

In an ideal case, TPD data could serve as either an “early indicator” of risk factors that reduce car component life or assist in finding root causes of expensive problems. In addition to TPD data, other wayside technologies, such as wheel profile measurement and truck hunting devices, may be used to identify and validate performance groups with component related wear issues.

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INTRODUCTION

Given the widespread introduction of truck performance detectors (TPD), an important question is whether or not the data they generate can be used to understand and improve vehicle maintenance actions and policies to extend component life. In particular, since TPD’s measure forces on the rail, identical forces must be occurring on the wheel and in the truck.

This may have important economic implications in view of the very high expenditures made by car owners for wheel and track replacements. While excessive truck-generated forces impact the life of track and associated structures, it has not been shown whether or not these forces are associated with reduced car component lives, nor whether correcting the causes of excessive forces will extend component life.

TPDs measure vertical and lateral forces developed at the wheel and rail interface as a car passes across successive measurement points in a curve.² TPDs have the potential to identify cars which may be reducing the life of vehicle and truck components.^{2,3}

Wheel performance is a particularly good place to begin analyzing the effects of component wear, for both engineering and economic reasons. Since the wheel is the point of interface between the vehicle and the rail, the forces can be expected to correspond in a way that reduces wheel life. Economically, wheels are the largest equipment expenditure for North American railways. According to 2007 CRB records, annual costs are in excess of \$800 million.

Study Design

To establish a relationship between TPD measurements and car component life, there are a number of questions that must be answered, including:

- Is there a correlation between TPD events and reduced car component life?
- If the correlations exist, do they vary among and across car fleets in a systematic way?
- If the correlations exist, what are appropriate “triggers” that should be selected to allow maintenance managers to take useful action? (For example, is crossing a particular threshold a better indicator than a trend line?)
- What are the economic implications of using TPD data as a maintenance management tool?

Clearly, these represent a wide range of studies to be carried out, but the first question is central to all the others. This seemingly simple question is subject to a number of potentially confounding factors, including differences in car design, car usage, location where TPD data is collected, uniformity of coding maintenance data or usage data, and time of year when TPD data was collected. To reduce as many of the potentially confounding factors as possible, the study employed car repair and mileage data from a homogeneous car fleet in dedicated service, and related it to TPD data taken from a particular location. Only wear related wheel replacements from the car repair data was used to focus the

study on the wear life of wheels. Table 1 describes the Why Made Code selected to use for wear related wheel replacements. *Wear related* wheel replacements represented approximately 12 percent of all wheels replaced per year for the sample car series.

Table 1. Wear Related Why Made Code

Why Made Code	Description
60	Flange Thin
62	Flange Vertical
63	Thread Worn Hollow
64	Flange High

A number of performance measures have been proposed and have been analyzed, including TGSF and WI.⁴ TGSF is a measure of the load imposed on the track by poorly curving trucks, with values in thousand pounds. WI measures the warp state of the truck, resulting in a measure from 0 percent (unwarped) to 100 percent (fully warped). The TGSF was used as the performance index for further Weibull analysis due to its accepted industry use. The TGSF is also “practical for identifying those cars that induce the highest stresses or wear on themselves and track.”⁵ Lateral forces, acting to place the tie into a state of either tension or compression, are termed gage spread forces (Figure 1).⁶

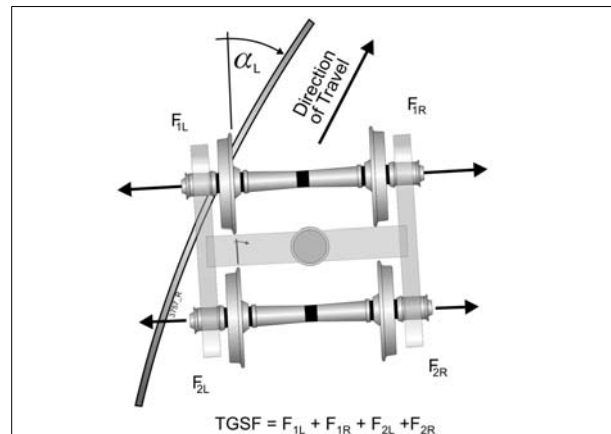


Figure 1. Lateral Wheel/Rail Forces on a Truck in a Curve

Maintenance and mileage data were organized into usable datasets to apply Weibull analysis. Weibull analysis is a tool for statistically estimating the reliability of components and systems and has been used in a number of prior railroad studies.³ The TPD data was then used to create subsets of the overall car fleet with wear related wheel replacements. Those cars with a wear related wheel replacement were grouped into three sets: Cars with TGSF values greater than or equal to 19,000 pounds, car with TGSF values between 13 and 19, and cars with all TGSF values below 13,000 pounds. Each subset was analyzed for Weibull shape and scale parameters using Minitab (in-house software). In addition, an examination was made of TPD histories with relatively high values of TGSF, and attempts were made to identify significant maintenance events linked to them.

Data Sources

TPD data from a 3-degree, right-hand curve over a 5-year time frame (January 1, 2003, to December 31, 2007) was used in the study. Previous studies have shown that there are a number of possible causes for variation in TPD measures, including condition of track, TPD maintenance schedule, vehicle loading characteristics, and weather.² Sampling over a long time frame should help in averaging these factors. After filtering the data, which included removing hits with null values, the TGSF and WI values were calculated.

The cars sampled were AAR classified J311 coal gondolas, all assigned to unit coal train service. CRB and mileage records from January 1998 to December 2007 were available for the car fleet. The fleet averaged over 100,000 miles per year. The CRB records were examined for completeness and consistency, and cars with questionable maintenance records were removed. It should be noted that the car fleet is considered well maintained and used in economically significant service, which not only helps with data consistency, but also reduces the likelihood of finding exceptionally bad cars.

RESULTS

A key issue related to this study was the validation of TPD data used to group the cars by their performance. Therefore, two measures were used in this analysis to understand and validate TPD related performance. The development of the TGSF and Warp Index (WI) performance measures in relation to track curvature indicate that they are “essentially linear with respect to curvatures used for TPD sites.”⁵ This relationship is validated in Figure 2 for the 3-degree TPD site curve used in this study. The figure relates TGSF to WI for cars sampled with a wear related wheel replacement.

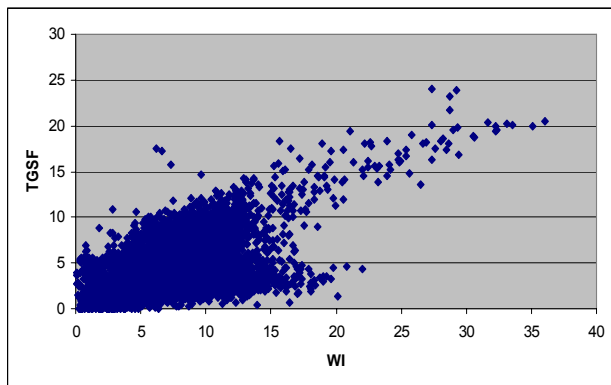


Figure 2. Warp Index vs. TGSF for the A-end of the Railroad Owned Fleet

Table 2 shows the results of the Weibull analysis for the TPD grouping. The results are organized by leading truck across the TPD detector. For each subset of the car fleet, the shape and scale parameters, 95-percent confidence intervals, and measures of central tendency are given. The Weibull shape parameter indicates the pattern by which components fail, with higher values signaling a more predictable pattern of failure. Components with higher values also indicate that preventive maintenance strategies may be developed. The Weibull scale parameter, or characteristic life, is the value at which approximately 63 percent of the components will have failed.

Distinguishing the difference between wheel life of the cars grouped by TGSF values can be shown in the survival plot shown in Figure 3. Approximately 50 percent of the population of wheels with values of the TGSF <13 survive at 500,000 miles unlike those wheels with TGSF >=19,000 pounds at 400,000 miles. This represents a 20 percent reduction in wheel life between the two groups.

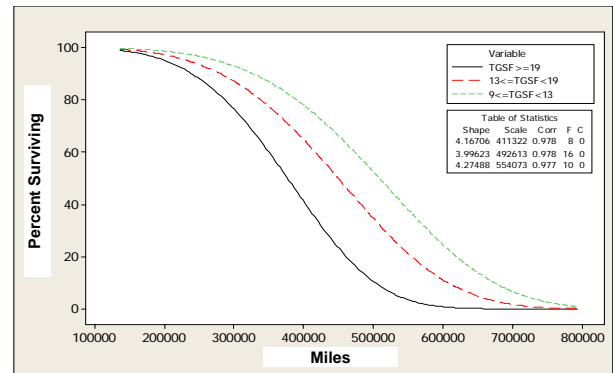


Figure 3. Survival Curve for A-End Sample Fleet

Several points can be noted in the results shown in Figure 3 and Table 2. First, shape parameters describe the pattern of failures relative to life. Shape parameters greater than one indicates components that are good candidates for predictive maintenance. Therefore, in each case shape parameters are significantly greater than one signaling the ability to develop better preventive maintenance policies for this car fleet.

A second result can be seen in looking at the scale parameters in the various subsets. In both cases using TGSF as a performance indicator, there is a dramatic increase in characteristic life from worst to best. With a larger dataset, a statistical hypothesis test can be used to further validate these results. If such a result can be substantiated using additional data (e.g., from higher degree of curvature TPDs), this would be a very promising result.

Table 2. Weibull Analysis Results for Sample Car Series

Performance Measure	Truck Type	Subset	Shape (β)	Scale (α) in miles	95% LCI, Shape	95% UCI, Shape	95% LCI, Scale	95% UCI, Scale	Mean	Median
TGSF	Truck A	TGSF <13	4.27488	554,073	2.79625	6.53538	474,886	646,464	504,131	508,548
		13 <= TGSF < 19	3.99626	492,613	2.23278	7.15246	432,694	560,830	446,482	449,443
		TGSF >=19	4.16706	411,322	1.89705	9.15335	345,160	490,167	373,697	376,690
	Truck B	TGSF <13	4.69563	510,318	3.66652	6.0136	463,971	561,294	466,855	472,000
		13 <= TGSF < 19	5.83564	496,388	2.03183	16.7606	433,179	568,821	459,798	466,171
		TGSF >=19	2.75939	372,015	1.22455	6.21796	266,028	520,227	331,081	325,744

Lastly, we examined the time history of the TGSF for all cars in our sample. The maintenance histories of these cars were examined to look for events that might be related to the TPD measures. In several cases, there was a maintenance event which appeared to correspond to changes in the TPD history. Figure 4 shows an example of such a time history. In this example, there was a wear related wheel change on the second axle represented by the first dotted red line. The second dotted red line represents the next wheel change on the same axle. This wear related wheel replacement was approximately 400,000 miles later or 4 years. Note the increase in TGSF value as the life of the wheel increases up to the point of the second wear related wheel replacement.

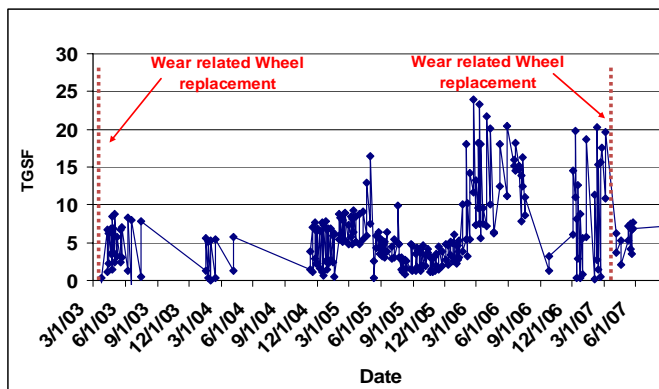


Figure 4. TPD Time History of the A-End of Sample Car

CONCLUSION

This research was initiated to understand the statistical relationships between TPD performance measures and component wear lives, specifically wheel life for this study. This study introduces a methodology to validate the use of TPD data for decision making processes related to maintenance policies, and optimal freight car and component designs.

The sample data used to examine this methodology was developed from a fleet of freight cars operating in unit train service over a 5-year period. TGSF performance measures developed using TPD data, and Weibull characteristic life and scale parameters from CRB data are the key measures used to understand this statistical relationship.

Looking at the Weibull scale parameters in the various subsets, there is a dramatic reduction in characteristic life that corresponds to increased TGSF levels. This implies that operating performance is related to wheel life using this sample data.

Approximately 50 percent of the population of wheels with values of the TGSF <13 survive at 500,000 miles unlike those wheels with TGSF >=19,000 pounds at 400,000 miles. This represents a 20 percent reduction in wheel life between the two groups.

As pointed out in the summary, this analysis was done on a homogeneous car fleet. Therefore, finding consistent differences within the same fleet using TPD performance

groups is a positive implication of this study. Analyzing car fleets with different components and or maintenance policies may also yield valuable information for fleet managers.

Further research to verify the results and extend them to other fleets and operating conditions is warranted for wheel related research initiatives.

FUTURE WORK

The results offer a promising glimpse at the possibility of relating TPD performance measures to car maintenance histories. The limitations of the data and the study, however, preclude any far reaching conclusions. Several topics for future work include:

- Studies using larger datasets having better overlap between the TPD and CRB datasets.
- More systematic examination of the relationship between the TPD time histories and car maintenance events.
- Examination of other car components including truck and suspension system components.
- Evaluation of the economic implications of changes in component design, maintenance policies and practices based on TPD performance measures.

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