

Economic Analysis of High Impact Load Wheels

by
Dharma R. Acharya
and
Thomas S. Guins
TD93-013

Summary

The railroad industry currently spends approximately \$90 million annually for wheels removed due to tread irregularities (about 125,000 wheels). Research by the AAR Research and Test Department suggests that the industry could save anywhere from \$25 million to \$32 million annually in these wheel removal costs by revising the AAR interchange rules. The recommended change would revise the current criteria for wheel tread irregularities in accordance with a performance standard based on wheel impact loads. The estimated economic impact load threshold for removing wheels on a typical railroad car is about 85 kip (thousand pounds). Railroads would, therefore, realize cost savings by removing only wheels imparting 85 kip impact loads or greater. These revisions would have no adverse effect on safety.

The current interchange standards for wheel removal due to tread irregularities contain dimensional criteria based on visual inspection of the wheels. For example, wheels may be removed for flat spots if the flat area is two inches or more in length or if two or more adjoining flat spots are each one and one half inches or more in length. However, there are tread irregularities that cause high impact loads but are not currently removable under the interchange rules. And many of the wheels removed under the current rules do not generate impact loads sufficiently high to economically justify their removal. On an interim basis, until the appropriate economic impact load threshold was determined, the Mechanical Management Committee approved, effective January 1, 1993, the removal of wheels exerting greater than 100 kip impact load when verified by an AAR approved gage as having a minimum radial runout of 0.050 inches.

With wheel impact detectors, it is now possible to measure the impact load resulting from wheel tread irregularities and to specify criteria for wheel removal based on this measure. When devising interchange rules based on impact loads, the issue of auditability and certification of wheel impact detectors should also be addressed. Until the industry has complete coverage by wheel impact detectors, dimensional criteria consistent with the 85 kip threshold will also be needed. A recent AAR research project generated data that could be used to revise such dimensional criteria, based on relationships between tread irregularities and impact loads.



Association of American Railroads
Research and Test Department



INTRODUCTION AND CONCLUSIONS

The existing rule for the maintenance of freight car wheels in interchange service, AAR Car Interchange Rule 41, Section A, is based on dimensional criteria of wheel tread irregularities. Under this rule, some wheels exerting very high impact loads are not condemnable, while other wheels exerting lower impact loads are condemnable. In 1991, the industry spent approximately \$90 million due to wheel removals based on the dimensional criteria in Rule 41-A for shelled treads, built-up-treads, and slid-flats (about 125,000 wheels).

AAR performed a series of tests to understand the speed sensitivity and repeatability of impact detectors and develop a statistical database of measured impact loads from a variety of wheel types (see AAR Report Nos. R-754, R-810 and R-829). This study concluded that a very small percentage of freight car wheels generate high impact loads. Research was then conducted to determine the potential detrimental effects of these high impact loads on track and equipment and their economic and safety impacts.

Results of the follow-on research indicate that high impact loads can lead to more rapid deterioration of track and vehicle components and additional fuel consumption. A car interchange rule based on impact loads, which relate directly to the extent of damage done to the track and vehicle components, would be consistent with the industry move away from dimensional standards to performance standards.

As a result of this research and other work, the Mechanical Management Committee has approved, effective January 1, 1993, the removal of wheels exerting greater than 100 kip impact load when verified by an AAR approved gage as having a minimum radial runout of 0.050 inches. This rule was incorporated on an interim basis until the appropriate economic impact load threshold was determined.

Determining a load threshold for removing high impact wheels is not a safety issue since the tread irregularities at issue do not result

in wheel failures and continued routine inspections will identify wheels with dangerous defects. Instead, this is primarily an economic issue involving trade-offs between the costs of finding and replacing high impact wheels and the cost of operating with them.

Findings from this research suggested that the mid-point of the economic impact load threshold for removing high impact load wheels is 85 kip. By revising the existing Rule 41-A criteria for tread irregularities in accordance with the 85 kip threshold, the industry could realize total net savings between \$25 million and \$32 million annually. This range of numbers result from the variability of the models and data used in estimating these savings. Due to the current low number of wheel impact detectors, dimensional criteria consistent to the 85 kip threshold may also be required. And the estimated annual savings may not be fully achieved.

SYNOPSIS OF APPROACH

The economic threshold for removing high impact load wheels is the impact load level at which the net present value (NPV) of the added cost of wheel removal is equal to the NPV of the benefits. Exhibit 1 displays the mid-point of the NPV of the estimated costs and benefits of removing high impact load wheels. These costs and benefits were estimated using a life-cycle costing approach.

The NPV of the added cost of replacing a high impact load wheel is the lost value of the remaining wheel life if the wheel is replaced at the time of detection instead of at the end of its service life. Because tread irregularities can occur at any time during a wheel's service life, these costs in Exhibit 1 are estimated at the mid-point of its life.

The NPV of the benefit (i.e., the costs avoided by replacing a high impact load wheel) in Exhibit 1 is the sum of the reduced track, vehicle, and fuel costs. These costs were computed using the increment in life-cycle costs from the estimated reductions in component lives.



Exhibit 1 Estimated Costs and Benefits

(Based on 50% of the 250,000 Miles of Wheel Life Remaining, 25,000 miles/yr Usage, and 10% Discount Rate)

Average Impact Load (As Seen by Impact Detector)	NPV of a Wheel Rep. Cost	NPV of Savings (Mid-Point) from Removing a High Impact Load Wheel				Overall Savings
		Track Cost	Veh. Cost	Fuel Cost	Total Cost	
70 Kip	\$632	\$252	\$0	\$143	\$395	(\$237)
80 kip	\$632	\$409	\$0	\$152	\$561	(\$71)
90 kip	\$632	\$603	\$1	\$191	\$795	\$163
100 kip	\$632	\$842	\$1	\$285	\$1,128	\$496

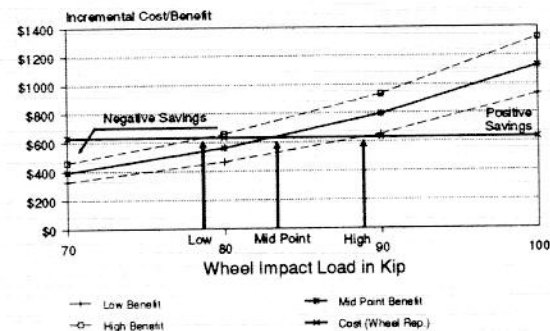
The NPV of the change in track damage cost in Exhibit 1 increases as the average impact load increases since wheels with higher impact loads cause more damage to the track. The AAR's Affiliated Lab at MIT estimated the track damage costs for various cases using results from the AAR's Total Right-of-way Analysis and Costing System (TRACS) and the results generated by the Heavy Axle Load (HAL) Tests performed at the Transportation Test Center.

The damage cost to vehicle components in Exhibit 1 is minimal. The mechanical damage associated with high impact loads is concentrated in the unsprung areas of the freight car trucks. No evidence of significant damage to any unsprung components other than roller bearings was found. Thus, the cost of all other component damage is assumed equal to the increased roller bearing cost.

The reduction in fuel consumption cost in Exhibit 1 was computed using the estimated increase in wheel resistance from the high impact load wheel. Research has shown that an out-of-round or a slid flat wheel increases rolling resistance and therefore increases fuel consumption. The fatigue life reduction in roller bearings and the increase in wheel resistance from high impact load wheels were estimated using the wheel/rail impact model, IMPWHL, developed by Battelle.

Exhibit 2 shows that the impact threshold at which overall cost and benefit of removal are equal lies in the interval from 79 kip to 89 kip. This range of value results from the variability of

the models and data used in estimating these costs and benefits. Therefore, to achieve positive net savings, the wheel removal threshold should be set between 79 kip and 89 kip (with a mid-point of about 85 kip).



50% of 250,000 m. Wheel Life Remaining
25,000 miles/year, 10% Discount Rate

Exhibit 2 Economic Impact Load Threshold

The sensitivity analyses showed that the economic threshold for removing high impact load wheels is sensitive to the car utilization rate. Therefore, where possible, railroads could minimize their costs using even tighter thresholds for removing high impact load wheels in high utilization operations.

OVERALL ECONOMIC IMPLICATION

The industry could realize savings in the following two areas if high impact load wheels are removed in accordance with the 85 kip economic impact load threshold.

Savings from Allowing More Wheels to Remain in Service

In 1991, about 1.3% of the total wheels in the system were removed under Rule 41-A due to tread irregularities (about 125,000 wheels). The 85 kip economic impact load threshold is far above the 50-60 kip level generated by many wheels that are condemnable for tread irregularities under the



current AAR Rule 41-A. Therefore, savings should also come from not replacing wheels imparting less than 85 kip impact loads but condemnable under the existing AAR Rule 41-A. Exhibit 3 shows the estimated net savings by allowing these wheels to remain in service ranges from \$22 million to \$31 million annually.

Exhibit 3 Annual Savings From Revising Rule 41-A

Item Description	Total
Wheels Replaced Due to Rule 41-A	124,800 ¹ (1.3%)
Wheels Exceeding 85 kip Impact Load and Condemnable Under Rule 41-A	11,520 (0.12%) ²
Wheels with < 85 kip Impact Load and Condemnable Under Rule 41-A	113,280 (1.18%)
Savings from Not Replacing Wheels with < 85 kip Impact Load and Currently Condemnable Under Rule 41-A ³	\$51,878,984
Additional Track Damage and Fuel Costs by Allowing Wheels with < 85 kip Impact Load and Condemnable Under Rule 41-A to Remain in Service: Low ⁴	\$21,377,280
High	\$30,083,520
Net Savings in Wheel Replacement Cost by Allowing Wheels with < 85 kip Impact Load and Condemnable Under Rule 41-A to Remain in Service: Low	\$21,795,464
High	\$30,501,704

¹ Includes Codes 75-Shells, 76-B-U-T, 78-Slid-flat from the 1991 Car Maintenance Database. The sum of 77,433 was multiplied by 1.6 to account for the System and Private Cars.

² Based on impact load measurement statistics from a major Western Railroad and on the assumption that there are 1.2 million cars (9.6 million wheels) in the system

³ The estimated NPV of the incremental wheelset replacement cost is \$632/Wheelset (In 1991, 1.38 wheels per wheelset were replaced due to tread irregularities.)

⁴ The two estimates, "Low" and "High", for the track damage and fuel costs are to account for the variability in the models and data used in estimating these values.

Savings from Lowering the Threshold

Savings can also be realized if the current interim impact load threshold of 100 kip for wheel removal is lowered to the 85 kip and if wheels exerting greater than 85 kip and currently not condemnable under Rule 41-A are also removed. Exhibit 4 shows the estimated savings. The estimated net annual savings (\$1.4 million to \$3.3 million per year) in Exhibit 4 is lower than one may expect because many of the high impact load wheels exceeding 85 kip impact loads are already condemnable under the current rules.

Exhibit 4 Savings From Lowering the Threshold

Item Description	Total
Wheels Exceeding 85 kip Impact Load	18,240 (0.19%) ¹
Wheels Exceeding 85 kip Impact Load Level and Not Condemnable Under Rule 41-A	6,720 (0.07%) ²
Replacement Cost of Wheels Exceeding 85 kip Impact Load and Not Condemnable Under Rule 41-A	\$3,077,840
Savings in Track Damage and Fuel Cost from Replacing Wheels Exceeding 85 kip and Not Condemnable Under Rule 41-A: Low	\$4,467,840
High	\$6,369,600
Net Annual Savings (Savings in Track Damage and Fuel Cost Less Wheel Replacement Cost): Low	\$1,390,000
High	\$3,291,760

¹ Based on impact load measurement statistics from a major Western Railroad

² Based on impact load measurement and wheel removal statistics and on the assumption that railroads are already using the 100 kip interim threshold for wheel removal

Note: Contact Thomas S. Guins at (202) 639-2259 with questions or comments about this document.

DISCLAIMER Preliminary results in this document are disseminated by the AAR for informational purposes only and are given to, and are accepted by, the recipient at the recipient's sole risk. The AAR makes no representations or warranties, either express or implied, with respect to this document or its contents. The AAR assumes no liability to anyone for special, collateral, exemplary, indirect, incidental, consequential or any other kind of damage resulting from the use or application of this document or its content. Any attempt to apply the information contained in this document is done at the recipient's own risk. A more detailed report, which may contain revised information, will be available at a later date through the Document Distribution Center, Chicago Technical Center, 3140 South Federal Street, Chicago, Illinois 60616. A report list is available upon request.