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Economic Analysis of High Impact Load Wheels

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Summary

Transportation Technology Center, Inc. has updated the economic analysis of the costs and benefits of removing high impact load wheels. The original analysis was published by the Association of American Railroads (AAR) in 1993 as research report R-855. That report set the economic level for removal of high impact wheels at 85,000 pounds (85 kips) as measured by a wheel impact load detector (WILD).

This digest updates the costs and benefits to year end 2004 values from the original 1992 levels. This has been accomplished by using a combination of AAR price indices, current costs, and new analyses, where appropriate.

The most significant change from the 1993 study is the update of freight car equipment costs to reflect new knowledge gained through analysis of car repair histories and WILD impact measurements. A significant correlation has been established between WILD impact histories and maintenance and delay costs associated with brake beams, brake valves, and roller bearings.

TTCI performed a sensitivity analysis on the model parameters thought most likely to vary across North American freight car fleets. Over a wide range of annual car mileage, wheelset life, and wheelset life remaining at the time of detection, the breakeven impact level varied from 55 kips to 75 kips.

This updated analysis concludes that the breakeven economic level for removing high impact load wheels from service for a North American freight car ranges from 55 kips to 75 kips with an expected value for a composite, average car of 63 kips. This is the level at which the additional cost of early replacement of the wheelset is offset by the benefits gained from:

- Reduced damage to track and equipment
- Reduced fuel consumption
- Reduced train delays caused by high impact wheels, hot roller bearings, inoperative brake valves, and dragging equipment
- Improved safety

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Transportation Technology Center, Inc.

INTRODUCTION

In 1993, the Association of American Railroads' Research and Test Department published "The Economic Analysis of High Impact Load Wheels," research report No. R-855. This report concluded the breakeven economic level for the removal of high impact load wheels was 85 kips. The costs and benefits contained in the 1993 report were based on a series of tests conducted at the Federal Railroad Administration's Transportation Technology Center (TTC), Pueblo, Colorado, and data collected from two wheel impact load detectors (WILD) installed in revenue service.

The general approach in the 1993 study was to find the impact level at which the cost of removal of a wheelset was equal to the expected damage that would have been caused by that wheelset had the wheelset been left in service for the remainder of its normal service life. The same approach has been used for this analysis.

By the end of 2004, 79 WILDs were operational in North America and considerably more data was available to estimate the benefits of removing high impact wheels from service. This *Technology Digest* updates the results of research report R-855.

Cost of Wheelset Replacement

The relevant cost for this analysis is the incremental cost of removing a wheel now, versus the cost of allowing the wheel to remain in service. The net present value (NPV) of the incremental wheel replacement cost is equal to the difference between the NPV of wheel replacements at the normal cycle throughout an infinite time horizon, and the NPV of wheel replacement costs beginning at the time of detection (earlier than the normal cycle), and then following the subsequent wheel replacements throughout an infinite time period.

The average wheelset replacement cost in 2004 was $1001. This includes material plus wheel labor plus the labor charge to jack the car. This results in a NPV cost of replacing the wheelset at the time of detection of $620. This compares to the wheelset cost of $1024 and a NPV incremental cost of $632 used in 1992. This indicates that the cost of replacing a wheelset is actually less in 2004 than it was in 1992. The reduced wheelset cost may be due, in part, to the change to wheelset pricing from individual component pricing and the movement of the material handling additive from the material cost to labor cost.

Track Costs

Track damage costs of operating cars with high impact load wheelsets were estimated in report R-855 using a combination of track deterioration models and impact load factors derived from heavy axle load (HAL) testing at TTC. Ties and ballast were analyzed using the AAR's TRACS (Total Right of Way Analysis and Costing System) model; whereas, rail, turnouts, and welds were analyzed using the damage factor exponent approach.

As with wheelsets, the relevant benefit is the NPV of track maintenance costs from replacing a high impact wheel when detected. When computing the track damage from a high impact load wheel, the analysis assumes that the impact load exerted by the wheel defect remains constant throughout its remaining life. Since recent analyses have shown that impact levels grow over time, this analysis method underestimates the track damage, and thus over estimates the impact level at which wheelset replacement is economical.

The track costs were updated using the AAR's Rail Cost Adjustment Index for Track Material. This resulted in a 13 percent increase in track maintenance costs. Figure 1 shows the track maintenance costs versus impact level.

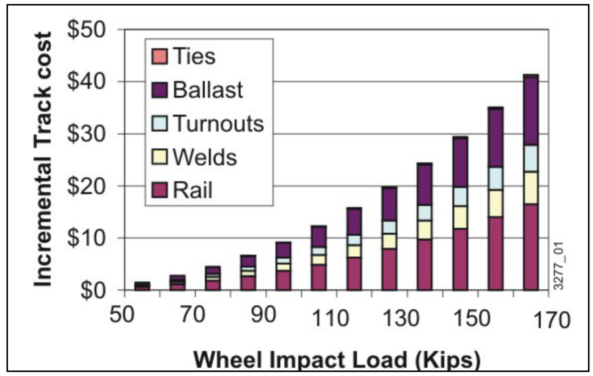

Figure 1. Track Maintenance Cost Per 1000 Wheelset Miles versus Wheel Impact Level

Savings in Freight Car Component Damage Costs

The impact and vibration transferred to the freight car as a result of high impact wheels cause damage to freight car components. Empirical data comparing freight car component damage to wheel impact levels as detected by WILDs has resulted in the ability to estimate the damage to freight car components at various impact levels. This analysis includes damage to roller bearings, brake beams, and brake valves.

Data collected demonstrates an increased probability of component failure as the wheel impact level increases. Table 1 shows the increased probability for roller bearing, brake valve, and brake beam failures for a car with a 55-kip and a car with an 85-kip impact load versus a car without high impact wheels for a car with an impact of 55 kips. The probability of a brake beam failure is 10.64 times higher than it would be for a car selected at random. In this case, the car in the same series with the next higher number was used. For an impact level of 85 kips, the probability of brake beam failure is 31.04 times greater than for a random car without high impact wheels. These increases in probability were used to construct a damage factor exponent model for each component. The resulting incremental equipment benefit is shown in Figure 2.

This chart shows a range of costs from $1 per 1000 wheelset miles for a wheelset generating an impact level of 50 kips to $35 per 1000 wheelset miles for a wheelset generating an impact level of 160 kips.

Table 1. Percent of Cars with Failed Components versus Wheel Impact Load Level

Component	Cause for Replacement	Wheel Impact Level (kip)	Increased Probability of Occurrence (%)
Brake Beam	Broken	55	1064
		85	3104
Roller Bearing	Defective Internal Parts	55	296
		85	691
Roller Bearing	Overheated	55	540
		85	1482
Brake Valve Portion	Inoperative	55	609
		85	1148

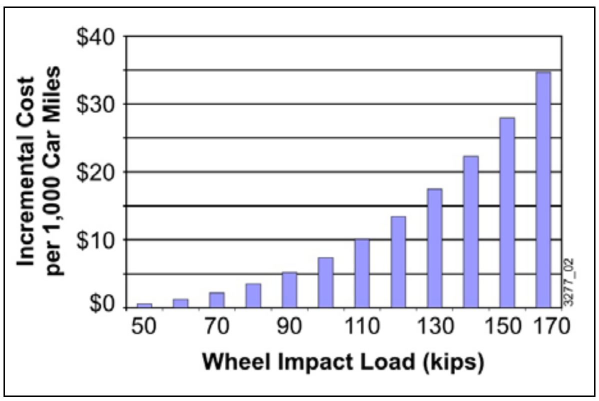

Figure 2. Net Present Value of Equipment Damage resulting from Operating with High Impact Load Wheels versus Impact Level

SAVINGS IN FUEL COSTS

The increase in fuel consumption associated with high impact load wheels is the result of the increased energy required to raise the wheel/car out of the tread discontinuity. The increased energy associated with a number of wheels representing a range of impact loads was estimated by Battelle Columbus Laboratories using its IMPWHL model (AAR report R-851). The incremental energy was converted to gallons of fuel per 1000 wheelset miles and then to cost per 1000 wheelset miles using the current cost of fuel.

The fuel cost has been updated using the AAR Railroad Cost Index, diesel fuel index, from the known point in 1992 to the 2004 level to be consistent with the other costs used in this analysis. This use of the index resulted in a fuel cost of $1.16 per gallon. Although this number may appear to be low in the current environment, this may be a viable estimate of the long run fuel cost. Further, to the extent the fuel cost is underestimated, the resulting breakeven economic level for removal of high impact wheels will be overestimated.

ECONOMIC IMPACT LOAD THRESHOLD

The breakeven economic impact load is the impact level at which the increased cost of removing a high impact wheel is equal to the benefits derived from removing that wheel. As an example, Figure 3 shows the cost and benefit versus impact load for a composite, average North American freight car (25,000 miles/year, 250,000 mile wheel life, 50% life remaining at the time of wheel removal). As the figure shows, the breakeven point is 63 kips. Thus, the impact load at which it becomes economical to remove the high-impact wheel is 63 kips. The range of potential modeling error in the benefit calculations is shown as blue and yellow in Figure 3. The potential error creates a range of 61 kips to 65 kips for economic high impact load wheel removal.

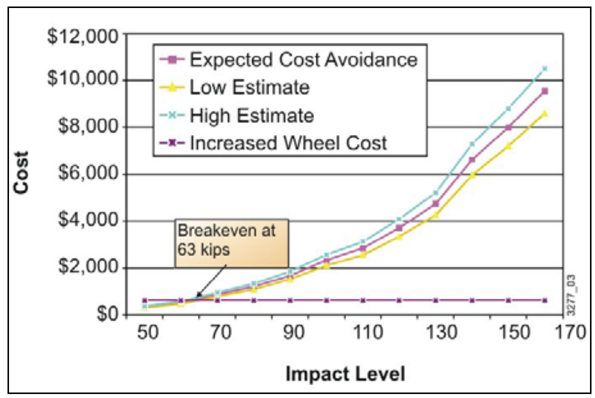

Figure 3. Cost Removing a High Impact Wheel at the Time of Detection and the Benefits of Removing the Wheel versus Impact Load

SENSITIVITY ANALYSIS

TTCI has performed a sensitivity analysis for those model parameters thought most likely to vary across industry fleets or fluctuate in the future. The composite, average North American freight car was used in sensitivity analyses of fuel price, wheel life, and remaining wheel life. Annual car mileages from 10,000 miles to 120,000 miles were used to assess the impact of mileage.

Fuel Price

The fuel price was varied from the base price of $1.16 per gallon, the year end 2004 price, upward to $1.50 per gallon and as low as $0.90 per gallon. Figure 4 shows the results of this analysis. Increases in the fuel price affect only the cost avoidance and result in decreases in the breakeven impact level. The price of fuel has very little effect on the breakeven wheel impact removal level.

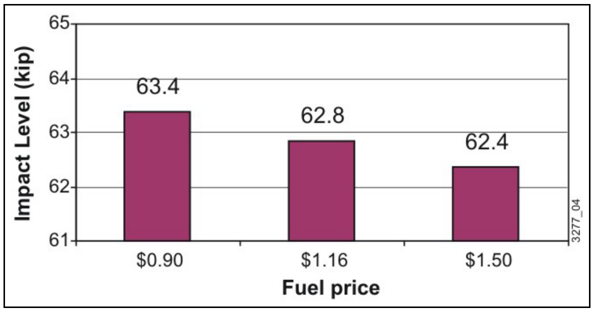

Figure 4. Sensitivity Analysis Change in Breakeven Impact Level (Price of Fuel for the Composite), Ave. Car

Wheel Life

Wheelset life is highly variable based primarily on the cause of removal. The average for the North American fleet is approximately 250,000 between replacements (Figure 5). As wheelset life increases, the cost of removing the wheelset at the time of detection also increases due to increased time the wheelset would have otherwise remained in service. Further, the cost avoidance also increases as the cost avoidances are proportional to the length of time the wheelset remains in service. Because both factors vary together (increasing or decreasing), the effect on the breakeven impact level is small. The breakeven impact level varied from 66 to 58 as the wheel life was changed from 200,000 miles to 400,000 miles.

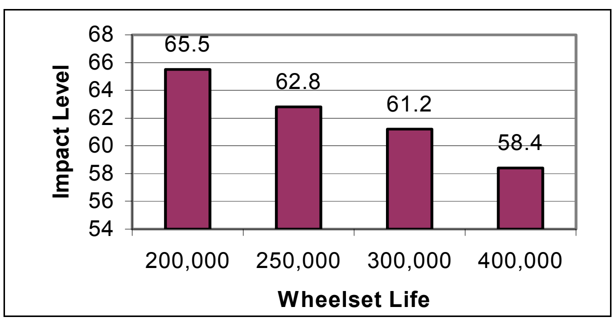

Figure 5. Sensitivity Analysis Change in Breakeven Impact Level with the Wheel Life

Remaining Wheel life

Wheels causing high impact levels are assumed to have 50 percent of their life remaining at the time of detection. This assumption is based on the expectation that a causative event can happen at any point in the wheel's life. The remaining wheel life varies from 25 percent to 75 percent. Figure 6 shows the sensitivity of the breakeven impact level to remaining wheel life. There is very little change in the breakeven impact level with changes in the remaining wheel life. Both the NPV cost of removing the wheelset at the time of detection and the benefits derived from removing the wheelset are affected equally by the remaining life of the wheel. As remaining wheelset life increases, the NPV cost of removing the wheelset at detection increases, but the NPV derived from the benefits of removal at detection increases in proportion to the increase in remaining wheel life.

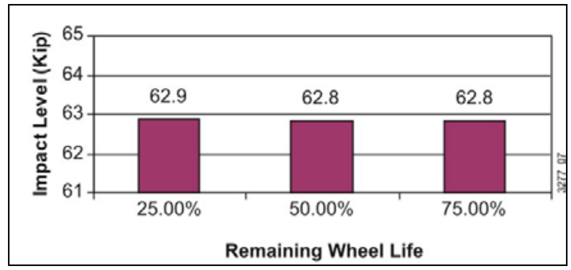

Figure 6. Sensitivity Analysis Change in Breakeven Impact Level with Remaining Wheel Life

Annual Car Miles

The average annual car miles were varied from the industry average of 25,000 miles per year upward to 120,000 miles and down to 10,000 miles. This covers the annual mileage of a wide range of freight cars. Figure 7 shows the results. As annual car miles decrease, the cost of removing the wheelset at the time of detection increases and the cost avoidance decreases. This results from discounting future cash flows. Both the future wheelset replacement and the cost avoidance will occur further into the future, and thus the discounting reduces the present value. Because the two vary in opposite directions, the effect on the breakeven impact level is significant. The range of breakeven impact levels varies from 75 kips down to 55 kips as the annual car mileage increases.

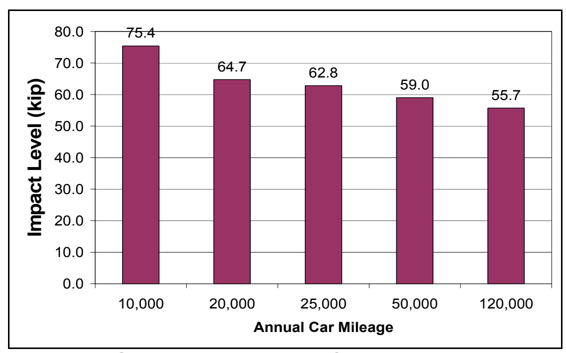

Figure 7. Sensitivity Analysis Change in Breakeven Impact Level with the Annual Car Mileage

CONCLUSION

The economic analysis presented in this TD shows that the breakeven economic impact load level for removing high impact wheels is between 55 and 75 kips (with an expected value of 63 kips). Changes in costs of wheelsets, fuel, track components, and freight car equipment have lowered this threshold from the 85 kips reported in AAR R-855. Sensitivity analyses show that for specific car types and services, this threshold may vary considerably from the mid-point value for the average car in North American freight service.