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Cost Analysis of Using Thicker Wheel Rims in Freight Operation

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Summary

Due to the increased availability of turned wheelsets, using wheels with thicker rims would result in a steady state projected economic outcome ranging from a net annual cost of $9 million to a net annual benefit of $108 million. This analysis was performed by Transportation Technology Center, Inc. (TTCI) as part of the Association of American Railroads (AAR) Strategic Research Initiatives program under the Wheel/Rail Profile Design and Maintenance project.

The majority of new wheels currently produced in North America are of single-wear (1-W) design because they have the lowest initial cost. The analysis described here involves the specific case of eliminating the single-wear wheel design and using only two-wear (2-W) wheels with 1/2 inch more rim material. The 15-year Net Present Value (NPV) is estimated between -$92 million and +$186 million. The breakeven point is calculated to occur no earlier than the seventh year due to increased costs beginning immediately; but the benefits are phased in as more and more turned wheelsets become available. These benefits are calculated assuming a $100 price premium per wheelset for two-wear wheels.

The resulting range of estimated benefits is quite broad because of the differences between the percentage of wheelsets with turned wheels that would be available for reapplication under current maintenance practices (31.6 percent) and the best case percentage of wheelsets with turned wheels that could potentially be available (53.1 percent). This difference is thought to be due, in large part, to the practice by some wheel shops of scrapping wheel plates when the axle needs maintenance regardless of remaining rim thickness. Various AAR groups are currently considering ways to address any unintended financial disincentives that may be affecting the reapplication of wheels.

For some car types, an industry-wide transition to thicker rim wheels could present some issues with clearances above the top of rail due to the larger potential range of wheel diameter. At least a portion of the double-stack fleet is designed with the intention that only 1-W wheels be used in order to maximize the available clearances. Fortunately, most double-stack cars make use of 33-inch and 38-inch nominal diameter wheels, so any change in wheel design could be implemented on the far more common 36-inch nominal diameter wheels.

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INTRODUCTION

TTCI is analyzing options for increasing the life of wheels in a cost-beneficial way for the industry. It is important to discern between the total life of a wheel from manufacture to scrap, and the application life of a wheel from the time it is placed in service until it is removed for cause. In some cases, wheels can be applied multiple times throughout their life.

BACKGROUND

AAR specifications[1] allow different wheel rim thicknesses; including single-wear (1-W), two-wear (2-W), and multi-wear (M-W). Table 1 shows critical dimensional differences between these wheel designs. Reprofiled wheels must have rim thickness greater than or equal to the reapplication limit when they are placed back into service.

Table 1. Wheel Dimensional Parameters

Design	1-W	2-W	M-W
New Rim Thickness at Gage Line	1.5 in.	2.0 in.	2.5 in.
Net Rim Material to Reapplication Limit	0.5 in.	1.0 in.	1.5 in.
Net Rim Material to Condemning Limit *	0.625 in.	1.125 in.	1.625 in.

** For 28-, 36-, and 38-inch diameter wheels*

The majority of new wheels produced in North America are 1-W design because they have the lowest initial cost. They are also the lightest option; resulting in a weight savings per wheel of about 80 pounds compared to a 2-W wheel of the same nominal diameter.[2] The potential range of wheel diameter of a 1-W wheel is less than that of other wheel designs, and many double-stack cars are designed with the intention that only 1-W wheels be used in order to maximize the available clearances.

RIM MATERIAL LOST DURING REPROFILING

At a wheel shop, the lathe operator makes successive cutting passes across the wheel tread and flange until the remaining surface of the wheel is free of shells and cracks and has a profile that meets acceptable standards. In this analysis, we segregated the amount of material removed during the reprofiling process into the following three categories based on the Why Made Code (WMC)[3] associated with the wheelset removal:

- Heavy cut (0.6250 inch) for thin flange removals (WMC 60).
- Medium cut (0.4659 inch) for tread damage removals (WMC 61, 65, 75, 76, and 78).
- Light cut (0.1250 inch) for other causes including non-wheel related removals, hollow wheels, and high flange (WMC 11, 63, 64).

New wheels are produced with AAR-1B wide flange profiles that have a nominal flange thickness of 1.3750 inches.[1] Reprofiled wheels can be cut to the AAR-1B wide flange or AAR-1B narrow flange (nominal flange thickness 1.1563 inches).[1] Commonly, wheels are cut with a flange thickness in between the wide and narrow flange limits to preserve rim material while ensuring that the flange thickness will not be less than the nominal AAR-1B narrow flange. A worn flange becomes condemnable at 15/16 inch (0.9375 in.).[3] In this condition, a standard wheel gauge[4] will indicate that the lathe must cut into the rim by 11/16 inch (0.6875 in.) to restore a wide flange profile and 9/16 inch (0.5625 in.) to restore a narrow flange profile. In this analysis, we have assumed a compromise of 0.6250-inch rim material loss for a heavy cut when reprofiling a wheel condemned for thin flange.

The amount of rim material removed for a medium cut on wheelsets condemned for tread damage causes was derived by analyzing data from two different wheel shops: 2,774 wheel records were obtained from one shop and 3,906 wheel records from another shop. Each record contained the rim thickness readings before and after the reprofiling operation and the original design of the wheel (1-W or 2-W). Unfortunately, the WMC for each wheel or wheelset was not available. Instead, more general data showing the distribution of WMCs processed by each shop was used. Average cut depth at each shop for 1-W and 2-W wheels were calculated separately. The averages were adjusted to account for the percentage of wheelsets condemned for WMC 60 and the associated heavy cut depth described previously. Figure 1 plots the resulting average cut depth values for 1-W and 2-W wheels at the two different shops as a function of the percentage of tread damaged wheelsets needing a medium cut versus the percentage of wheelsets needing a light cut.

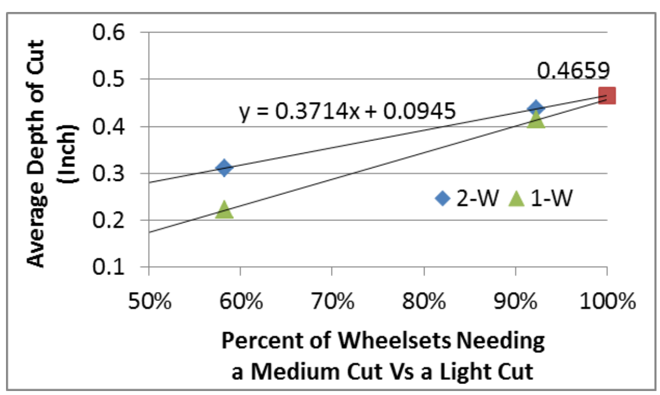

Figure 1. Cut Depth to Remove Tread Damage

This plot shows that one of the wheel shops processed a larger percentage of tread damaged wheels compared to the other shop. It also shows that 1-W wheels have less material removed, on average, during the reprofiling process than 2-W wheels because deep cuts are not possible on most 1-W wheels without a resulting rim thickness that is below the minimum reapplication limit. Thus, for this study, the 2-W data is more useful. Least squares regression lines for the 1-W and 2-W series nearly converge at a value of 0.4659 inch for the case of 100 percent medium cut. Accordingly, this value was used in the analysis for medium cuts.

The light cut category encompasses a wide variety of removal causes. All of these wheelsets would require at least a “skim cut” before reapplication. It is assumed that 2/16 inch (0.1250 in.) is removed on average for a light cut. Small, non-condemnable shells can be found on many wheelsets removed from service for causes other than tread damage and would need to be removed by the lathe.

RIM MATERIAL LOST DURING SERVICE

Wheel data reported to the AAR Car Repair Billing (CRB) database contain rim thickness side scale readings for both the removed wheels and the applied wheels. The database was queried to determine the rim material loss while in service and segregated by WMC. The query was written so that it only returned records where the wheel manufacturer and wheel manufacture date were identical on the applied wheelset and the subsequently removed wheelset from the same car in the same axle position. While this does not guarantee that the same wheelset remained in the car during the query period, it does substantially improve the confidence that the majority of the records are valid examples of the change in rim thickness during the service life of that wheelset. A total of 383,184 wheel records were analyzed for wheels that were new when applied. Because the rim material loss was not necessarily normally distributed, the median values were selected to represent the associated WMCs.

ANALYSIS OF EXPECTED LIFE

Table 2 shows a breakdown of the percentages of wheelsets removed for common WMCs for the calendar year 2014. The “Other” category includes causes such as thin rim, obsolete, shattered, and broken wheels. Table 2 also contains the median rim thickness loss from wear during service, the material loss during reprofiling, and the total rim material loss per application.

The number of applications was calculated by looking at all possible permutations of removal causes for up to five applications per wheelset. For example, if a wheelset was first removed for WMC 65, then reapplied to a different car and removed for WMC 11, then reapplied and removed for WMC 76, the calculated tread loss would be 0.5909 inch during the first application, 0.2500 inch during the second application, and 0.5284 inch in the third application. The probability of occurrence for this permutation of removal causes is calculated as 0.380*0.148*0.005=0.000281, or 0.0281 percent. Sequentially subtracting the tread loss in each application from the initial rim thickness shows that a 1-W wheel would be scrapped after only one application in this scenario because the rim thickness would be less than the reapplication limit. Similarly, a 2-W wheel could be used for three applications with this permutation of removal causes. This process is repeated for each of the 10,000 possible permutations. The number of applications is multiplied by the probability of occurrence and these results are summed for each wheel design.

Table 2. Rim Material Loss

WMC	Percent Cause for Wheelset Removal	Rim Material Loss in Service	Rim Material Loss in Reprofiling	Total Rim Material Loss per Application
11	14.8%	0.1250	0.1250	0. 2500
60	5.5%	0.3125	0.6250	0.9375
61	9.3%	0.0625	0.4659	0.5284
63	0.5%	0.3750	0.1250	0.5000
64	15.1%	0.3750	0.1250	0.5000
65	38.0%	0.1250	0.4659	0.5909
75	5.2%	0.1250	0.4659	0.5909
76	0.5%	0.0625	0.4659	0.5284
78	1.4%	0.0625	0.4659	0.5284
Other	9.7%	Assume wheels are scrap when removed		

Table 3 shows these results and also includes the expected steady state percentage of applied wheelsets with turned wheels based on the other values in the table. This value can be calculated iteratively by starting with 100 percent new wheels and multiplying the percentage of wheels with two, three, four, and five applications by the percentage of wheels with one fewer application from the previous iteration.

Table 3. Analysis Per Wheel Design

Design	Expected Applications	Number of Applications (Percent of Wheels)					Expected Percent Turned
		1	2	3	4	5	
1-W	1.33	69.6	28.2	2.2	0	0	23.7
2-W	2.17	9.7	64.9	24.0	1.3	0	53.1
M-W	2.95	9.7	13.8	49.0	26.2	1.3	64.1

ANALYSIS OF COSTS AND BENEFITS

Railinc's component registry system and the CRB database can be used to evaluate the percentages of new and turned wheelsets being applied under current practice. The component registry shows that 21.9 percent of all wheelsets applied in 2015 had turned wheel plates; including 20.3 percent of 1-W wheelsets and 31.6 percent of 2-W wheelsets. The CRB database shows similar values. The component registry and CRB data values are a bit lower than the expected steady state percentage of 1-W turned wheels shown in Table 3: 20.3 percent compared to 23.7 percent. However, the values diverge substantially for 2-W wheels: 31.6 percent compared to 53.1 percent. This indicates that there may be factors other than remaining wheel rim thickness that cause wheels to be scrapped at the wheel shop. For example, in some wheel shops, if the axle needs maintenance, the wheels will be pressed off and scrapped regardless of remaining rim thickness due to complications of re-boring the wheels and mounting them on an axle with larger wheel seats. Some wheel shops report scrap rates as high as 25 percent for certain types of axles.

Because of the discrepancy between the expected value and the component registry value, the economics will be considered for both values of the steady state percentage of applied wheelsets with turned wheels. The economic benefit of 2-W wheels results from the increase in the number of turned wheelsets available for application to freight cars. It is believed the price premium is in the range of approximately $100 per wheelset as reflected in the *AAR Office Manual of the Interchange Rules*.[5] Benefit is realized by moving from the current state of 21.9 percent of wheelsets applied with turned wheels to either 53.1 percent or 31.6 percent of wheelsets applied with turned wheels at full implementation of 2-W wheelsets. Depending on the price premium for 2-W wheelsets as compared to 1-W wheelsets (estimated premium in the range of $90-$110 per wheelset), the potential annual net benefit at full implementation is in the range of $106 million to $110 million for the case of 53.1 percent wheelsets with turned wheels, and an annual cost (negative benefit) of $6 million to $12 million for the case of 31.6 percent wheelsets with turned wheels.

There is cost due to the increased tare weight of cars equipped with 2-W wheels. The increase in weight is 640-pounds for a four-axle car. This results in an increase in the number of trains required of 0.26 percent. The cost to the industry of the increased number of required trains is expected to be approximately $23 million per year at full implementation.

However, to reach full implementation, a significant period of increased costs will be experienced before benefits will occur. This is a result of the price premium starting in the first year of implementation, but the benefits not starting to accrue until the wheelsets are removed for cause over the service life of the wheelsets. This analysis assumes that wheelsets are removed from service uniformly over a 12-year period. Thus, significant benefits do not begin accrue immediately, but phase in slowly to full implementation in approximately 12 years.

Table 4 shows the assumed price premium and resulting 15-year NPVs, internal rates of return, and break even points associated the implementation of 2-W wheels only for the best case scenario and the current practice (53.1 percent and 31.6 percent applied wheelsets with turned wheels, respectively). The breakeven point occurs no earlier than the seventh year.

Table 4. Net Benefit (Loss) of Requiring 2-W Wheels

Case	Percent Turned Wheelsets	2-W Price Premium per Wheelset	15 Year NPV (Millions)	Internal Rate of Return	Break Even (Years)
Best case	53.1%	$100	$186	35%	7
Current practice	31.6%	$100	($92)	N/A	N/A

CONCLUSION

An analysis of using wheels with thicker rims shows a potential net benefit due to the availability of more turned wheelsets for application to freight cars. The increased wheel rim thickness of 2-W wheels could potentially allow for 53.1 percent of applied wheelsets to have turned wheels, but with current maintenance practices, this is limited to 31.6 percent for 2-W wheels. Various AAR groups are currently considering ways to address any unintended financial disincentives that may be affecting the reapplication of wheels.

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