TECHNOLOGY DIGEST
Timely Technology Transfer

EFFECTS OF HEAVY AXLE LOADS ON RELIABILITY OF TRAIN OPERATIONS

by Thomas S. Guins and
William E. Robert and Carl D. Martland
Massachusetts Institute of Technology (MIT)

TD 97-030

Summary

The results of a study recently conducted by the Association of American Railroads show that operations with 36-ton or 39-ton axle loads result in additional track maintenance, but require fewer trains for the equivalent net traffic under 33-ton axle loads. The benefits of heavy axle load (HAL) operations are highly route-specific, with the benefits being most important on lines that are operating close to capacity.

Other key findings, using state-of-the-art computer models, include:

- For the high-tonnage route (annual traffic of 80 million gross tons) examined in this study, HAL traffic resulted in a slight reduction in train delay and an increase in reliability, as the additional delay caused by additional track maintenance is more than offset by the reduction in delay related to train meets.
- Heavy axle loads on the high-tonnage route resulted in a reduction in trip time of 2 to 3 percent, and a reduction in standard deviation of trip time of 5 to 9 percent. However, for the medium-tonnage route (annual traffic of 30 million gross tons) examined in this study, heavy axle loads resulted in an increase of under 1 percent in annual average trip time, and an increase of approximately 18 percent in standard deviation of trip time.
- For both routes the analysis indicates more favorable results for 36-ton than for 39-ton axle loads in terms of train delay, trip time and reliability. For higher-tonnage lines the capacity benefits could be more important, which would favor 39-ton axle loads.

Suggested Distribution:
☐ Equipment/Rolling Stock
☐ Research & Development
☐ Maintenance Planning
☐ Planning & Analysis

Association of American Railroads
Railway Technology Department
August 1997

TECHNOLOGY DIGEST
August 1997

INTRODUCTION AND CONCLUSIONS

Train delay and reliability are critical factors in the efficient operation of freight railroads. Train delay may be defined as excess time required for a train to reach its destination beyond the scheduled time. Reliability may be defined as the ability to meet a particular train schedule, variability in train arrival times or variability in train travel times. As the traffic on a line increases, delays tend to increase and reliability drops. Ultimately, track capacity is limited by the maximum acceptable delay to trains.

The Association of American Railroads (AAR) Heavy Axle Load (HAL) Phase I Economic Analysis recognized, but did not investigate, track-capacity or train-delay issues. Subsequent to the analysis the AAR sponsored several relevant studies on line performance. The first Massachusetts Institute of Technology (MIT) study simulated train performance on a single-track line as a function of siding spacing, speed limits and other factors, including the probability of delays related to engineering or mechanical problems. The study demonstrated that engineering and mechanical problems could reduce the capacity of a single-track line by 5 to 10 percent.

A follow-up study at MIT focused on the interaction between track-maintenance requirements and train performance. The track windows required for track maintenance, based upon the results of the Phase I HAL Economic Analysis, were estimated. Then the effects of the maintenance windows on train performance were simulated, demonstrating that track maintenance has significant, negative effects on train delay and reliability.

The extra maintenance required for HAL operations (defined here as operating at 36- or 39-ton axle loads) is not expected to cause serious line problems. Indeed, on high-tonnage routes, HAL operations can lead to improvements in train performance and track capacity. Although heavy axle loads tend to lead to increased track maintenance, the delay and loss of reliability from increased maintenance is generally offset by the reduction in the number of trains. For the high-tonnage route examined, heavy axle loads are expected to result in improvements in trip time, reliability, and train delay relative to the base case. For this route the reduction in number of trains for HAL operations more than offsets the effects of increased track maintenance. These results indicate that HAL operations are likely to increase line capacity. The results are of course highly route-specific.

For the medium-tonnage route, heavy axle loads are expected to result in slight increases in trip time and train delay, and a reduction in reliability. This is not a serious effect, however, as performance on the medium-tonnage route is, under all axle loads, much better than on the high-tonnage route.

For both the high- and medium-tonnage routes, the trip time, train delay and trip time standard deviation results are more favorable for 36-ton axle loads than for 39-ton axle loads. For higher-tonnage lines, the capacity benefits could be more important, which would favor 39-ton axle loads.

Further work is underway at the MIT Affiliated Lab to address capacity issues by examining the full range of maintenance and operating costs on an entire coal-distribution network, rather than on an individual route.

ANALYSIS

MIT updated the previous studies, taking into account the Phase II HAL Results. The analysis approach and results are described below.

Route

The routes were based on the two prototypical coal routes used in the HAL Analysis: an 80 MGT high-tonnage western route and a 30 MGT medium-tonnage eastern route. Both routes were 292 miles long with 2-mile sidings separated by 12 miles of single track, i.e., the same assumptions used in the earlier study.

Maintenance

Track maintenance requirements were based on the HAL Phase II Economic Analysis, in turn developed based on TRACS and other state-of-the-art maintenance models. Maintenance requirements were estimated for rail relaying, track inspection and defect repair, production and spot tie replacement, ballast resurfacing and renewal, and turnouts. Exhibit 1 summarizes the annual maintenance requirements determined for each of the six cases, expressed in terms of hours of track closure time. The results indicate that track maintenance tends to increase with heavier axle loads. The 36-ton axle load case for the 30 MGT route is an exception; maintenance hours are slightly lower for this case than for the base case, reflecting in part a reduction in annual gross MGT and in part differing assumptions concerning grinding, defect rates, and work windows.

The maintenance requirements were used to determine for each case how many weeks of the summer and winter months involve no maintenance, how many weeks involve 8-hour work windows, how many involve 6-hour work windows, and how many involve 4-hour work windows. Activities that are performed in 2-hour work windows, including spot tie replacement and some turnout work, were assumed to occur between trains without causing significant additional delay.

Since nearly all maintenance occurs in the summer, different maintenance activities must be scheduled concurrently or there will not be enough hours to complete the required maintenance. Simultaneous maintenance activities can occur either when two activities are performed by the same crew at the same time, such as through the use of a P811 supermachine, or when there are two maintenance crews on different parts of the line at the same time. Exhibit 2 shows the distribution of weeks in the summer and winter months with different levels of maintenance activities, assuming a fair amount of overlapping activity. Note that for the 80 MGT route there is very little time during the summer without some level of track maintenance activity.

Simulation

The line-haul simulation model dispatches trains over a specified route based on the train schedule, defect rates and maintenance scenario. The model calculates the average trip time per train, average train delay per train, and standard deviation of trip time. Separate runs were performed for each of the six cases for different levels of unscheduled maintenance (resulting from train or infrastructure failure) and scheduled maintenance. For unscheduled maintenance, runs were performed to explore the effects of zero failures, train failures only (no infrastructure failures), average rail-defect rates, summer (low) defect rates, and winter (high) defect rates. For scheduled maintenance, runs were performed to explore the effects of 4-hour, 6-hour and 8-hour maintenance windows.

Results for summer and winter months were combined to obtain delay per train, trip

Maintenance Activity	**80 MGT**			**30 MGT**		
Axle Load	**33-ton**	**36-ton**	**39-ton**	**33-ton**	**36-ton**	**39-ton**
Rail Relaying	262	262	284	98	109	115
Rail Defect Repair (through inspection)	84	140	136	53	66	68
Rail Defect Repair (service failures)	84	140	136	53	66	68
Ties — Production	181	188	190	144	152	153
Ties — Spot	1,255	1,279	1,273	1,134	1,153	1,176
Ballast Renewa	98	97	103	37	37	39
Ballast Resurfacing	274	282	290	105	108	111
Turnouts 2-hr Window (Ties, Grinding)	292	223	263	219	168	198
4-hr Window (Points, Surfacing)	210	179	229	158	134	172
8-hr Window (install, frogs, undercutting)	298	285	337	223	214	254
Total Hours	**3,038**	**3,075**	**3,241**	**2,224**	**2,207**	**2,354**

Exhibit 1. Annual Hours of Track Maintenance by Route and Axle Load

Window	Percentage of Weeks in Year with Windows (5/days/wk)					
	80 MGT			30 MGT		
	33 ton	36 ton	39 ton	33 ton	36 ton	39 ton
Summer						
None	5%	6%	0%	23%	24%	20%
4 hours	10%	9%	11%	8%	6%	8%
6 hours	12%	12%	13%	5%	5%	5%
8 hours	23%	23%	26%	14%	14%	17%
Winter						
None	48%	47%	47%	49%	48%	48%
4 hours	0%	0%	0%	0%	0%	0%
6 hours	0%	0%	0%	0%	0%	0%
8 hours	2%	3%	3%	1%	2%	2%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Exhibit 2. Distribution of Maintenance Windows by Route and Axle Load

time per train and standard deviation of trip time. Assumptions were developed concerning the maintenance windows for each type of activity, the percentage of work occurring in summer months, and the percentage of work occurring in the "shadow" of other maintenance. The results are summarized below in Exhibit 3. The results for train delay and trip time standard deviation are shown graphically in Exhibit 4 and Exhibit 5.

For the 80 MGT route, the annual average trip time, average delay per train, and standard deviation of trip time are lower for heavy axle loads than for the base case of 33-ton axle loads. The average trip time is 2 to 3 percent lower for heavy axle loads; the average train delay is 8 percent lower and the standard deviation of trip time is 5 to 9 percent lower.

Description	Annual Average Results (hours per train)			Percentage Change to Base Case	
	33-ton	36-ton	39-ton	36-ton	39-ton
High-Tonnage Route (80 MGT)					
Total Delay	2.5	2.3	2.3	-8%	-8%
Trip Time	9.8	9.5	9.6	-3%	-2%
Trip Time Standard Deviation	2.2	2.0	2.1	-9%	-5%
Medium-Tonnage Route (30 MGT)					
Total Delay	1.1	1.1	1.2	0%	9%
Trip Time	8.4	8.4	8.5	0%	1%
Trip Time Standard Deviation	1.1	1.3	1.3	18%	18%

Exhibit 3. Annual Average Train Performance Results by Route and Axle Load

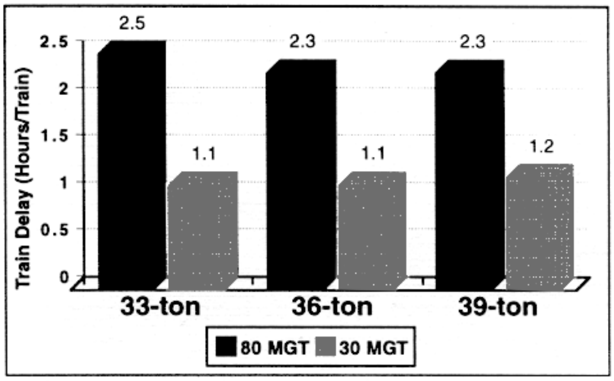

Exhibit 4. Annual Average Train Delay by Route and Axle Load

For the 30 MGT route, which has many fewer meet delays, the results are a bit different. The annual average trip time, average delay per train and standard deviation of trip time are the same or higher for heavy axle loads than for the base case. The annual average trip time is essentially the same, the average train delay is up to 9 percent higher, and the standard deviation of trip time increases approximately 18 percent.

Note: Contact Tom Guins at (202) 639-2259 with questions or comments about this document.
E-mail: tom_guins@aar.com

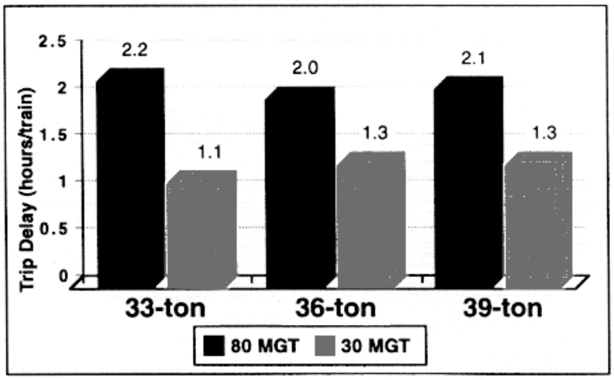

Exhibit 5. Annual Standard Deviation of Trip Time by Route and Axle Load

A MORE DETAILED REPORT, WHICH MAY CONTAIN REVISED INFORMATION, MAY BE AVAILABLE AT A LATER DATE THROUGH THE AAR, PUBLICATION ORDER PROCESSING, 50 F STREET, NW, 5TH FLOOR, COG, WASHINGTON D.C., 20001