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The Economic Effects of Train Speed on Steel Railway Bridges

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Summary

As part of the Association of American Railroad's Strategic Research Initiative on Railway Bridges, Transportation Technology Center, Inc. (TTCI) has recently conducted a study on the economic effects of train speed on steel railway bridges.

TTCI developed an economic model based upon the Heavy Axle Load (HAL) Phase 2 Economic Study and used this model to evaluate the effects of train speed on key component replacement costs for steel railway bridges. The model uses the same bridges, train types, and routes that were used in the original HAL Phase 2 Economic Study.[1]

Key effects based on model:

- A train speed increase of 10 mph increases annual steel bridge costs about 8 to 11 percent.
- An annual traffic density increase of 10 percent leads to a 10 percent increase in annual steel bridge costs.
- Marginal increases in traffic density can be offset by a decrease in train speeds in order to keep annual steel bridge costs constant.
- An increase in gross car load from 286 to 315 kips leads to 30 to 40 percent increases in steel bridge costs. Significant train speed reductions would be needed to offset gross carload increases in order to maintain constant steel bridge costs.

Actual steel bridge costs for a particular route can be sensitive to the number and types of steel bridges on the route.

The conclusions from this analysis show that speed effects can be significant, especially for bridges with floor systems. Although the degradation from impact due to train speed is exponential in behavior, it is somewhat linear within the range of freight train operating speeds. Bridge degradation is highly sensitive to axle load and the effects of speed and annual tonnage amplify this sensitivity.

Costs are highly route dependent, and this is affected by bridge type and bridge density. Costs of foundations and train delays for maintenance windows or due to slow orders placed on bridges are not included. Costs of timber and concrete bridges are not included in this study.

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Introduction

As a part of the Association of American Railroad’s Strategic Research Initiative on Railway Bridges, TTCI has recently conducted a study on the economic effects of train speed on steel railway bridges.

TTCI developed an economic model based upon the HAL Phase 2 Economic Study and used this model to evaluate the effects of train speed on key component replacement costs for steel railway bridges. The model uses the same bridges, train types, and routes that were used in the original HAL Phase 2 Economic Study[1] and is briefly described later.

Figure 1 shows the results for bridge costs on six different routes normalized to 40 mph train speed. Results vary slightly depending on the number and type of bridges on the route. A train speed increase of 10 mph leads to an increase of 8 to 11 percent in steel bridge costs.

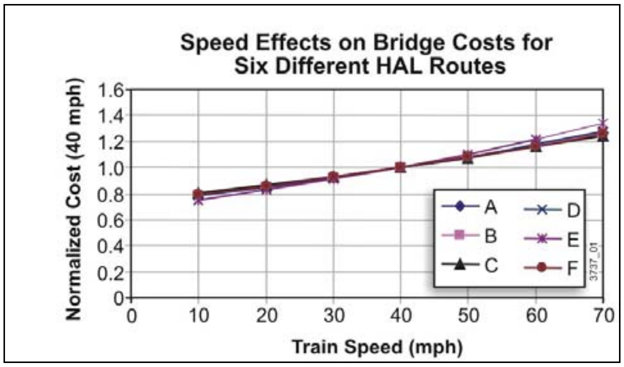

Figure 1. Train Speed Effects on Bridge Costs, Normalized to 40 mph

Figure 2 uses Level Route A to illustrate the sensitivity of bridge costs to changes in annual traffic density and train speed for 286-kip unit coal trains. Level Route A was selected as a representative route with costs falling near the middle of those for the six routes studied. Costs in Figure 2 are normalized to 40 MGT and 40 mph. This shows that as annual tonnage is doubled, so is the cost factor. As annual traffic density increases, the cost effects of increasing train speed can also be seen in the steeper upward sloping cost factor lines. This analysis does not consider the increased cost due to train delays that result from maintenance work performed on lines with increased traffic density, nor added train operating costs if slower speeds are imposed.

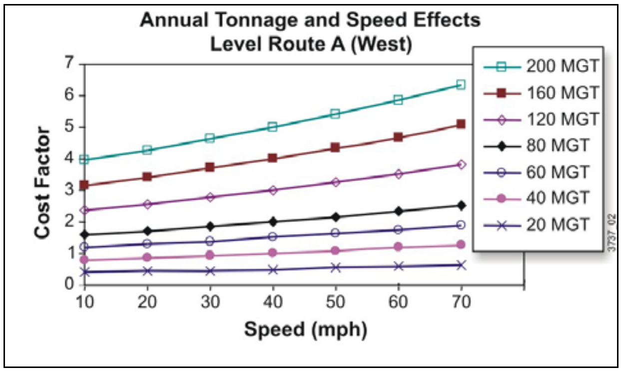

Figure 2. Sensitivity to Changes in Annual Traffic Density – Level Route A (West)

Figure 3 shows constant cost curves illustrating the relationship between traffic density (in MGT) and train speed. In this example, constant cost curves are built around a baseline condition of 40 mph and multiples of 40 MGT.

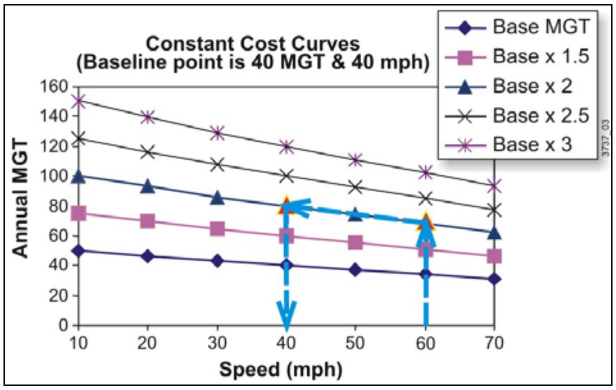

Figure 3. Constant Cost Curves – Level Route A (West)

The dotted lines in Figure 3 show that for lines hauling 70 MGT per year at 60 mph, increasing annual density to 80 MGT would require dropping the speed to 40 mph, if the same bridge costs were desired.

Figure 4 shows the cost effects on Level Route A of changes to axle load and train speed at traffic density of 40 MGT per year. Costs are normalized to 40 mph and 286-kip unit coal traffic.

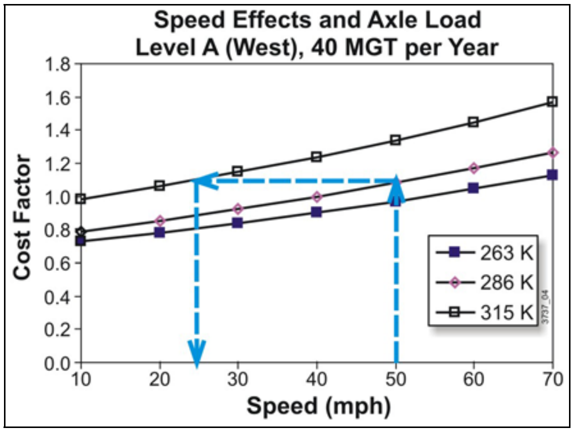

Figure 4. Sensitivity to Speed and Axle Load

The dotted lines in Figure 4 illustrate that to maintain the same bridge cost incurred by 286-kip unit coal trains traveling at 50 mph, 315-kip unit coal trains would need to drop their speed to approximately 25 mph; a decrease of 50 percent.

The Economic Model

TTCI developed an economic model to evaluate the effects of train speed on key component replacement costs for steel railway bridges. The model is built upon the platform of bridges, train types, and coal haul routes that were developed for the HAL Phase 2 Economic Study.

The model uses a menu of 34 bridges for which fatigue degradation rates were estimated for key components such as stringers, floor beams, girders, and hangers.

Six different train types are available and include 263-kip, 286-kip, and 315-kip unit coal trains, a typical double-stack container train, a typical trailer-on-flat-car/container-on-flat-car (TOFC/COFC) train, and a mixed freight train.

There are six actual coal haul routes that represent both eastern and western Class 1 railroads.

AREMA Chapter 15 guidelines were used to estimate impact-related fatigue degradation rates for key components such as stringers, floor beams, girders, and hangers. The model estimates costs by assuming steady-state replacement of members, due to loading fatigue. Component costs from the earlier HAL Phase 2 study were updated using the Railroad Cost Recovery Index. Foundation costs are not included in the analysis.

The impacts were applied to the bridge fatigue data developed in the HAL Phase 2 Economic Study to define relationships for speed versus fatigue life for each member of each bridge. Rating guidelines for impact as opposed to design impact were used. To simplify the analysis, harmonic rocking was excluded, and a linearized speed versus impact relationship was applied.

Although the model is designed to perform long-term analyses, the results presented here are based on single-year results that do not require discounting.

The results presented here are also based solely on unit coal train traffic. The car length used for all car weights in this analysis was 53 feet. For the 263-kip and 286-kip cars, axle spacing was 70 inches and truck spacing was 40.5 feet. For the 315-kip cars, axle spacing was 72 inches and truck spacing was 40.33 feet. Results might be considerably different for cars of different lengths and axle configurations.

The HAL Routes

There are four level routes and two mountain routes. Table 1 shows designation, type, and length of these routes.

Table 1. HAL Routes

Routes	Type	Length (miles)
Route A	Level	386
Route B	Level	1,115
Route C	Level	938
Route D	Level	1,043
Route E	Mountain	816
Route F	Mountain	323

An analysis was conducted for the types of bridges on these routes. Each of the bridges was matched as closely as possible to one of the bridges in the inventory of 34 HAL bridges for which fatigue analysis was performed. On the basis of this analysis and allocation, Figure 5 shows the bridge density in feet of bridge per mile of route. As is expected and seen in the analysis, route costs are sensitive to bridge density.

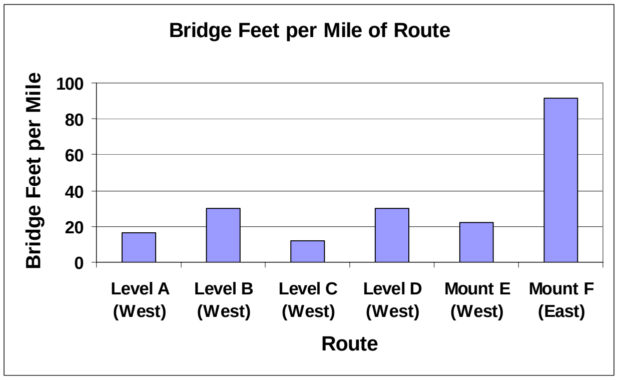

Figure 5. Bridge Density on the Six Routes

Figure 6 shows the distribution of bridge feet by type of bridge for the collective routes. Deck plate girders (DPG) in the open deck (OD) and ballasted deck (BD) configurations are the most prevalent bridge types used on the study routes, followed by open deck steel beam spans (SBS). Steel pile trestles (SPT), through plate girders (TPG), deck trusses (DTR), and through trusses (TTR) are less common.

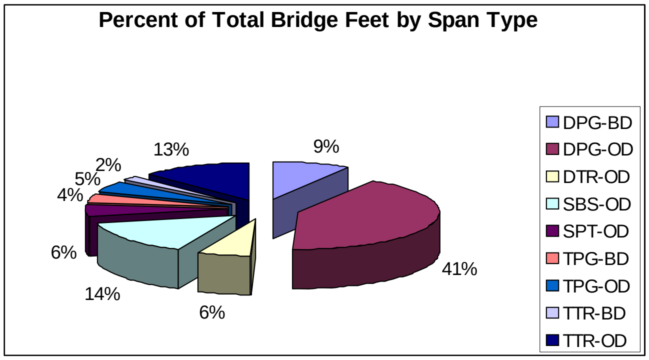

Figure 6. Percent of Bridge Feet by Span Type

The Economic Analysis

Several cases were conducted to evaluate the effects of changing train speed. The first case considered the effect of bridge costs on a route-by-route basis for 100 MGT per year of 286-kip unit coal traffic. Figure 7 shows the results of this, in costs, are route specific and sensitive to the density of bridge feet per mile of track.

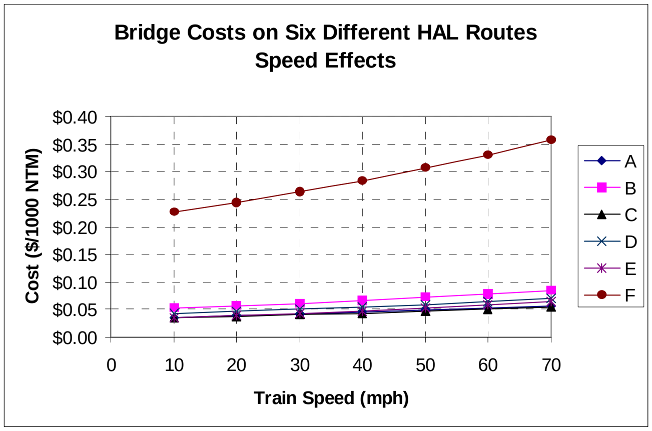

Figure 7. Route-by-Route Bridge Costs versus Train Speed

Figure 8 shows the cost effects of speed versus span type for the bridges used in this analysis. Sensitivity is shown in terms of cost increase per 10 mph of speed increase for 286-kip cars. The sample size of each bridge type is shown in parentheses in the legend of the chart. As can be expected, more complex bridges with floor systems, such as trusses and through-plate girders, are more sensitive to the impacts of train speed than simpler bridges such as deck-plate girders.

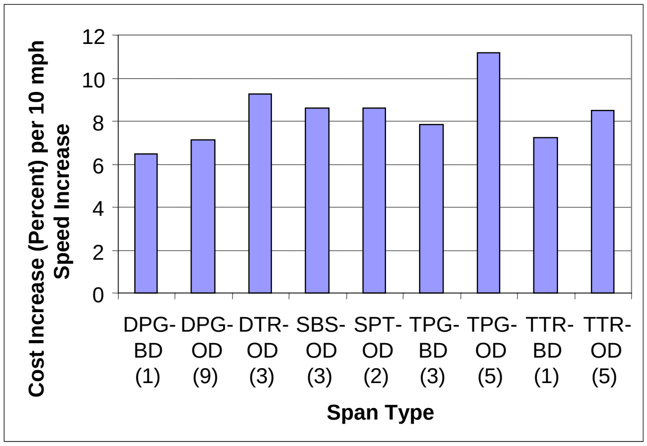

Figure 8. Sensitivity to Speed for Various Span Types

Conclusions

- Speed effects can be significant, especially for bridges with floor systems. Although the degradation due to train speed is exponential in behavior, it is somewhat linear within the range of freight train operating speeds.
- Costs are highly route dependent, and this is affected by bridge type and bridge density.
- Bridge degradation can be highly sensitive to axle load; the effects of speed amplify this sensitivity.

Reference

1. Hargrove, M. B., T. S. Guins, D. E. Otter, S. Clark, C. D. Martland. November 1995. "Economics of Increased Axle Loads: FAST/HAL Phase 2 Results," Proceedings, A World of Change – 1st Annual Association of American Railroads Research Review, Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado.