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Legacy Train Loading Estimation for Bridge Fatigue

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Summary

Transportation Technology Center, Inc. (TTCI) has undertaken a comprehensive project under the direction of the Association of American Railroads' (AAR) Bridge Technical Advisory Group for determination of Fitness for Service (FFS) for steel deck girder bridges on the North American railway system. Deck girders have been chosen initially for study given their substantial portion of the bridge inventory. Their age and replacement cost are such that addressing those concerns is important for budgetary consideration. The primary issue at the beginning of this effort is to refine modeling for bridge fatigue. The current steel bridge inventory on the railroad system has demonstrated that fatigue is currently not an issue, especially with riveted girders, some of which have been in the inventory for over a century.

A method has been developed to estimate the number of cars and trains that may have passed over a bridge where extensive data is not available. The method uses publicly available data from the AAR for the rail system as a whole, while still needing some specific data at the particular location. Current steel bridge design recommendations include assumptions for train traffic that are appropriate for new designs, but generally overestimate previous traffic over an existing bridge — especially an older bridge in place for many years.

The method described herein makes some broad assumptions that can be refined if information available for the particular location provides more guidance. For a rail line where a specific commodity is being shipped, specific data may be available that can reduce uncertainty and provide a more comprehensive and accurate estimate.

This initial FFS evaluation made use of nationwide data. Regional data is available, but the methods for reporting that data have changed over the years. The data used for this report was consistent in its presentation in AAR publications through the life of reporting for the types of results that were available at the time. Results for regions can also be presented in a similar fashion to what is displayed in this report with manipulation of certain data segments. A search for additional historical data to augment that currently available will be ongoing. The details of car and locomotive lengths, axle spacing and weights, and changes over time are very important in the overall fatigue analysis, as are types of locomotive. These and other items will be included in additional reports providing details for a bridge fatigue model proposed to simulate the effects of rail traffic prior to present day.

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INTRODUCTION

TTCI has undertaken a comprehensive project under the direction of the AAR Bridge Technical Advisory Group for determination of fitness for service (FFS) for steel deck girder bridges on the North American railway system. Deck girders have been chosen initially for study given their substantial portion of the bridge inventory. Further, their age and replacement cost are such that addressing the concerns with them is important for budgetary consideration.

Fatigue of steel railroad bridges is a concern, but results of fatigue life evaluation using adaptation of current design methods have produced disappointing results. Calculations on many bridges indicate that fatigue failure should have occurred in the past while the bridge itself displays no sign of fatigue accumulation. Refinements in analysis modeling for fatigue are warranted. The major factors for fatigue analysis are the number of cycles, the associated stress range with each cycle, and the category of the fatigue detail under investigation. Each category defines cycle life based on applied stress range. Category of fatigue detail is relatively easy to determine as many types of details have been tested and catalogued.

For cycle counting, design assumes a certain number of cycles; while for analysis of an existing bridge the number of cycles needs to be determined. In design, AREMA Chapter 15 [1] assumes 60 trains per day with 110 cars per train over an 80-year life. For many lines, that number of trains may be quite high on a historical basis, providing a life well beyond the 80-year assumption.

No formal method has been adopted to determine the past cycles for existing railroad structures. This work discusses the information needed to make a transition from available historical tonnage data to an estimate of the number of trains traversing a bridge at a particular location.

The method described herein is not precise in its application for the determination of either cycles or stresses. At the same time, fatigue calculations involve cycle counting into the hundreds of millions of cycles such that an estimate of the final life must be considered an estimate without benefit of precision. Along with that, stresses display variability which affects the fatigue calculations especially when considering actual versus calculated stresses.

This method provides a more nuanced starting point and can be used for future development of a more comprehensive model. Discussion of potential error is included. If the location is on a line where a specific commodity is shipped, (e.g., coal) information for that line is easier to define. For main line routes, more variability will often be in play. This method is intended for freight traffic only. Passenger traffic can also produce accumulative cycling and will be addressed in the future.

DATA SOURCES

The first step is determining the number of trains that may have crossed a particular bridge. This requires a knowledge of the traffic for the particular location; including overall tonnage, number of trains, number of cars in a train, a determination of loaded and empty car ratios, and method of handling the loaded and empty cars in trains. Current traffic density reports for a particular section of railroad are quite detailed given the use of computers. Older records, however, are often not detailed or no longer exist. Thus, when past records are not available, an estimate must be developed.

A current assessment of the required data for the location being evaluated is necessary. Operating practice, current tonnage levels, and traffic mix can guide decisions on train size and makeup, including the handling of empty cars. Multiple main line track also creates complications determining the portions of loaded and empty cars on each track. This information is available from discussions with operating personnel and observation of operations, equipment types, etc.

For the main route or other lines where general traffic is the norm, AAR data can be applied. The AAR's annual *Railroad Facts* annual publication[2] provides data that can provide a general sense of the amount of traffic that may be on a particular line. The following figures display data taken from the AAR publication. The available annual data was from 1916 through 2013. Full data used to perform the calculations shown here were found for years 1929 to 2013. The search for full data for earlier years continues.

The data is provided for United States operations (including Canadian railroad operations in the U.S.). While strictly Canadian operations are excluded, many times those operations follow the same trends as U.S. operations. If this type of data becomes available for Canadian (or Mexican) operations, similar charts can be developed.

APPLICABLE DATA AND ANALYSIS

Figure 1 displays originated tonnage data. Originated tonnage is the amount of freight loaded into empty freight cars in the U.S. only. A caveat is that it doesn't include traffic that may be been loaded in either Canada or Mexico and interchanged at the U.S. border, which is equivalent to originated tonnage. It still provides a trend line of how much traffic has been transported.

As can be seen in the figure, tonnage has ebbed and flowed over the years; including the significant drop in traffic that occurred in the early 1930s marking the Great Depression. For a general freight line, the chart allows indexing for a year of known traffic against past years. As an example: a bridge has been in place since 1926 and a traffic density report for a specific rail line in 1978 shows that overall tonnage was 41.5 million tons. We can determine tonnage for a specific year; say 1947, for example.

Originated tonnage in 1978 was 1,690,175,000 tons. The same figure for 1947 was 1,537,546,000 tons. Traffic density in 1947 can be estimated at 37.8 million tons by using the ratio of the two numbers.

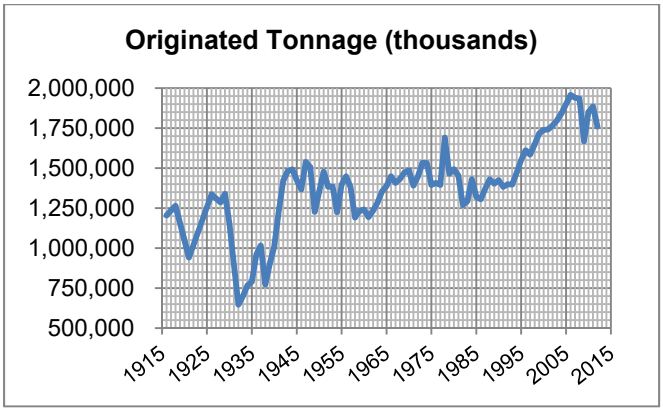

Figure 1. Originated Tonnage (US, 1916 – 2013)

The traffic density figures also include train tare weight and empty cars. The comparison of originated tonnage provides an overall revenue business but any model needs to account for backhaul of empty cars, along with an increase in car capacity. Average car capacity is tabulated in the AAR's annual publication but the report also provides average tons per carload, which provides more meaningful information. Figure 2 charts average tons per carload for years 1925 to 2013.

The data in Figure 2 is that which is currently available. Pre-1945 data was not completely available, but a trend can be seen in the data points such that the user could make an interpolation to determine the value. For the year 1947, the average tons per carload was 41.0 tons for the entire United States. An interesting note about Figure 2 is that since approximately 1980 average ton per carload has steadily decreased. This seems counterintuitive given the increase in coal shipments and tailoring of the railcar fleet to maximize load weights. This may indicate that while bulk commodity car loads have increased, shipment of intermodal with general merchandise has also increased offsetting the bulk shipments in terms of average car weight.

Given this value for commodity weight, the tare weight of car needs to be added to determine an estimate of car weight for the fatigue train. For determination of tare weights, average car capacity informs on the anticipated tare weight. Table 1 shows the percentage of the net (commodity) that would be tare weight in terms of nominal capacity of equipment through the years.

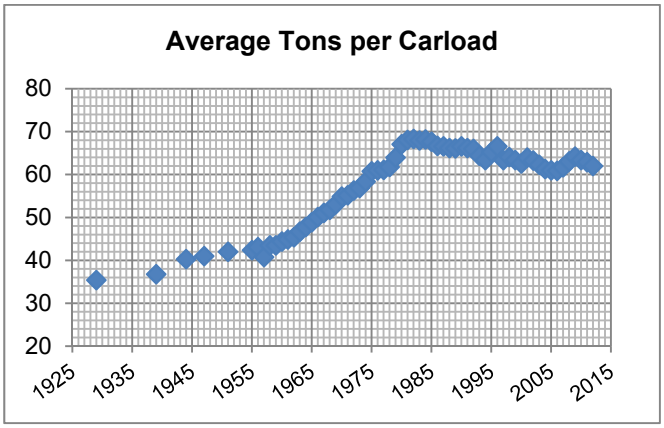

Figure 2. Average Tons per Carload (US, 1925-2013)

The total car weight can be calculated by adding the percentage of net weight representing the tare weight to the net weight. Given that the average tons per carload were 41.0 tons, the tare weight in this example is assumed to be 70 percent of the 41.0 tons; or 28.7 tons per car. This brings the total car weight to 69.7 tons for the average car.

At this point, a decision must be made regarding the number of empty cars that are being hauled across the bridge. Assuming that all cars will encounter an empty backhaul, or for each loaded car there will be an empty car at the same time, this assumption may or may not be correct given the nature of the traffic on a line. For a coal branch, this is a valid assumption. However, for main line routes this may be less accurate. For the purposes of this exercise, the assumption of 100 percent empty backhaul is used. A total weight of two cars is calculated by adding the weight of one loaded and one empty car, or a total of 98.4 tons.

With the weights of cars calculated, the total number of cars across the bridge can be estimated. With 37.8 million tons for the year 1947, the estimated number of cars is 768,293, or an average of 2,105 cars per day with the assumption that half of those cars are empties. At this point, determination of the number of trains is required. Figure 3 displays the reported number of average cars per train for the period of 1916 to 2013.

Table 1. Tare Weight to Net Weight Ratios

	40-Ton Car	50-Ton Car	70-ton car	100-ton car	110-ton car
Nominal Car Capacity (lbs)	80,000	100,000	140,000	200,000	220,000
Tare Weight (lbs)	56,000	69,000	80,000	63,000	66,000
Total Weight (lbs)	136,000	169,000	220,000	263,000	286,000
Tare Wt to Net Wt Ratio	70.0%	69.0%	57.1%	31.5%	30.0%

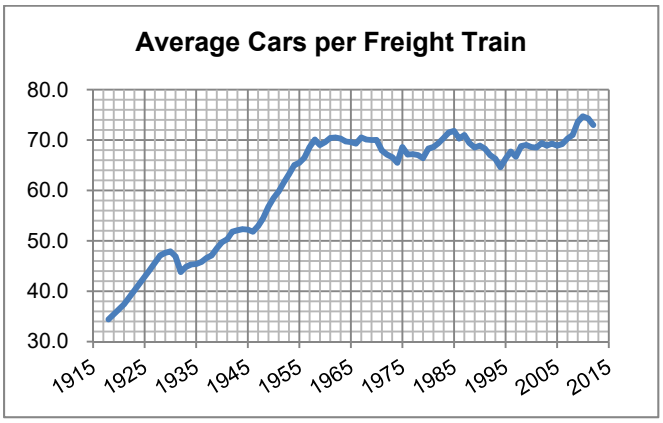

Figure 3. Average Cars per Train (US, 1916 – 2013)

For the year 1947, the average train length in cars is 52.9. Using this information, the estimated number of trains for this bridge location is 39.8, or 40 trains per day with a rounding to 53 cars per train. The rounding of the train and car counts brings the total number of empty and loaded cars to 2,112 versus the 2,105 originally calculated. The makeup of the train with empty and loaded cars still must be considered. This is a substantial change from the design assumptions of sixty 110-car loaded trains, or 6,600 loaded cars per day.[2]

Table 2 provides additional time periods showing the same calculation for a variety of years from 1929 through the present day using 1978 as the reference year.

Table 2. Average Train Count, Size for Various Years

YEAR	Calculated MGT	Trains Per Day	Cars Per Train	Tons Per Loaded Car
1929	40.1	47	48	35.4
1932	19.3	25	44	35.8
1940	30.2	31	50	37.5
1944	44.6	42	53	40.3
1960	37.1	26	70	44.4
1980	44.6	28	69	67.1
2000	52.0	32	69	62.6
2010	55.4	31	75	63.4

POTENTIAL ERROR

The method given herein provides a "broad brush" in trying to determine a typical train for a given location. It depends heavily on average data if local conditions are not known, and traffic mix for that location is not taken into account. Also, the originated tonnage data shown encompasses all of the United States.

The addition of traffic base at a specific location at an arbitrary time point can skew the data. Examples include Powder River Basin coal from the late 1970s and west coast port intermodal traffic from the 1990s; especially if that traffic is not over the location in question. Train size is also a critical factor that depends upon locale and can be variable.

Assumptions for certain items like empty backhaul and tare weight ratios can skew the results to a certain degree. Further work will address this and other issues to refine a train model that provides an appropriate number of cycles in use as a fatigue model.

CONCLUSION

A method has been described for attempting to determine the number of cars and trains that may have passed over a bridge where extensive data is not available. The method uses publicly available data from the AAR for the rail system as a whole while still needing some specific data at the particular location. Current steel bridge design includes an assumption for train traffic that generally overestimates what was probable traffic over an existing bridge, especially an older bridge in place for many years.

The method described in this report makes some broad assumptions that can be refined if information available for the particular location contraindicates what may be assumed. For a rail line where a specific commodity is being shipped, more specific data may be available that removes uncertainty for necessary data and provides a more comprehensive and accurate estimate.

This initial effort made use of nationwide data. Regional data is available in the reports, but how that data is displayed has changed through the years. The data used for this report was consistent in its presentation in AAR publications through time. In addition, the details of car length, axle spacing, weights, and those changes over time are very important in the overall fatigue analysis. Locomotive characteristics are also very important in fatigue analysis. These and other items will be included in additional reports.

REFERENCES

1. American Railway Engineering and Maintenance of Way Association. *Manual of Railway Engineering*, Chapter 15, "Steel Structures." Lanham, MD. 2015.
2. Association of American Railroads. "Railroad Facts 2014 Edition." Washington, DC. 2014.