TECHNOLOGY DIGEST

TD-18-019

©AUGUST 2018

TIMELY TECHNOLOGY TRANSFER

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Current Loading Spectra for Evaluation of Railway Bridges

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Summary

Transportation Technology Center, Inc. (TTCI) conducted a research effort to quantify the current loading environment on railway bridges. This report presents a load model developed using wayside data from 28 locations in five regions across North America under revenue service train traffic. The data was analyzed and statistical parameters were calculated. This load model can be utilized to evaluate the fitness for service of railway bridges using probabilistic methods. The findings from the study are as follows:

- The mean value of car weight for loaded railcars was generally less than or close to the nominal weight of 286 kips; however, the data shows some cars were found to exceed the nominal value, especially mixed freight cars.
- The car weights were distributed consistently around the mean value with small fluctuations, as indicated by small coefficients of variation (COV), which ranged from 1 to 4 percent, and for axle loads from 3 to 7 percent. Despite the significant number of overloaded railcars, the amount of overloading is relatively small.
- The difference between the leading axles and trailing axles for 53-foot unit train cars and mixed freight cars suggests imbalanced weight distribution between the leading and trailing trucks. The leading trucks tended to be heavier.
- The car weight and axle loads for each car type at each location exhibited approximately normal weight distributions.

This study focuses on conventional four-axle cars. A recent study covered intermodal equipment.[1] This research was conducted as part of the AAR's Strategic Research Initiative on bridge life extension.

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INTRODUCTION

TTCI performed this study to update the current loading environment data for North American railway bridges. This *Technology Digest* presents a statistical load model that consists of load spectra derived from wayside data from 28 different revenue service locations in five regions across North America. The data was analyzed and statistical parameters were calculated. This load model can be utilized to evaluate fatigue life using probabilistic methods that estimate fatigue life in terms of probability of crack initiation. It can also be used with the current AREMA minimum fatigue life estimation methods as found in Chapter 15 of the *Manual for Railway Engineering*.

Bridge fitness for service estimates are usually made using theoretical calculations. The loading spectra to which railway bridges are currently being subjected, rather than the design load, is essential to perform a fitness evaluation of a bridge. More detailed calculations taking full advantage of the AREMA rating provisions and measured stress can provide a better estimate. However, stresses estimated from measurements are not always available and often are not easy to obtain. Therefore, a statistical load model is a useful alternative for estimating stress cycles.

LITERATURE REVIEW

The latest load spectra for railway bridges was developed based on the data collected over 20 years ago by Tobias et al. (1996).[1] Load data from 508 trains was recorded at five riveted steel bridges located in Illinois, Virginia, and Tennessee. The data collected include the speed of each train, the distance between each axle, and dynamic wheel loads. The measured axle spacing was compared to known railcar dimensions to determine general car types.

The data collected was analyzed and five probability distribution functions were chosen as the best fit to the measurements. The determination of statistically-admissible distributions was performed using various goodness-of-fit tests.[2] The mean values of car weight were reported to be above the nominal maximum value at that time of 263 kips, and the coefficients of variation (COV) were from 3 to 23 percent. Similar statistics were noted for axle loads.

The load spectra presented by Tobias, et al. (1996) provides good information; however, the dynamic effect included in the data can be affected by span type, length, and other bridge parameters. The data was collected from various bridge types including: open deck double plate girders, ballasted deck double plate girders, Warren through trusses, and through-double plate girders. The span lengths varied from 40 feet to 156 feet. Also, while loading was site specific, the data included in the report was limited to three states: Illinois, Virginia, and Tennessee.[2]

WAYSIDE DATA

For TTCI's study, wayside data was collected from 28 revenue service wheel impact load detectors (WILD) in five regions (East, South, West, North, and Central) across North America from January 2017 to April 2017.

Wayside systems can gather data from a large number of passing trains including different types of equipment, and are currently in use at many locations on several railroads throughout North America. This study used measured net truck vertical forces from WILDs on tangent track from unit trains and mixed freight trains. The dataset was reduced to a selection of trains that can cause fatigue cycles on a bridge. The initial dataset of WILD wheels between Jan. 1, 2017 and Apr. 30, 2017, was 248 million wheel passes for all load conditions. Then, the dataset was reduced to 29 million wheel passes, using only Salient WILD sites and 100+ four-axle loaded cars. Next, the output train summaries by car length and maximum weight was created, and the dataset was reduced to train passes of only 286 kip cars on trains, reduced from 27,053 train passes to 12,642.The analysis was carried out for 50 trains for each of the four train types for the five regions.

Only 286-kip gross weight cars were studied in this project.[3] The wayside data collected included dynamic car weight, truck weight, axle load, and wheel load for traffic in both directions. The traffic included in the data consisted of: (1) unit trains of 42-foot long, four-axle short cars carrying cement or sand, (2) unit trains of 53-foot long, four-axle coal cars, (3) unit trains of ~60-foot long, four-axle grain cars, and (4) four-axle cars in mixed freight trains. Over 72,000 railcars were analyzed. Wayside data was sorted by region and car type. Partially loaded cars (less than 230 kips) were excluded from the analysis. Table 1 shows a summary of the sample sizes for each type of train in each region.

Table 1. Sample sizes of each type of car at each region

Region	42' Unit (kips)	53' Unit (kips)	60' Unit (kips)	Mixed Freight (kips)	Total (kips)
Central	5,207	6,582	3,345	NA	15,134
East	NA	5,148	762	8,476	14,386
North	4,987	5,712	5,280	5,403	21,382
South	5,130	6,154	824	1,442	13,550
West	NA	405	1,945	5,543	7,893
Total	15,324	24,001	12,156	20,864	72,345

LOAD SPECTRA

Load statistics describe the most probable range of loading for a specific train type and are important for fatigue evaluations. The load model comprises statistical parameters for each of the four train types listed above and for measurements from each of the five regions. Figure 1 presents a comparison of car weights for all car types from each region considered in this study.

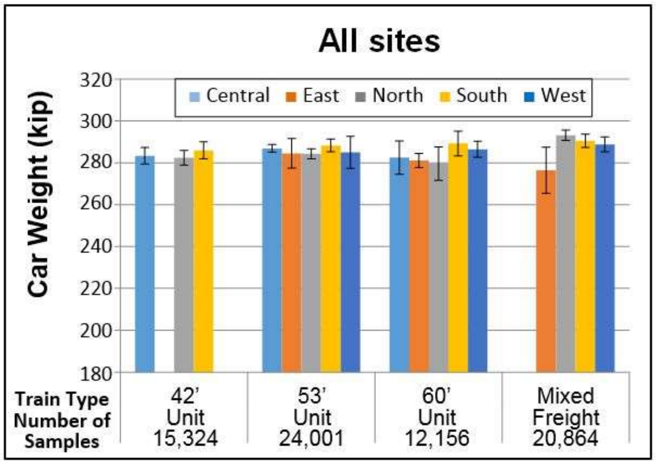

Figure 1. Summary of car loadings

The car weight data and truck weight data were plotted on a normal probability plot (y-axis shows standard deviation) for unit train types and mixed freight trains to confirm the type of distribution. The cumulative distribution functions (CDFs) of car weight are close to straight lines when plotted on the normal probability plot, which permits a normal distribution to be considered for the model. As an example, the distribution of 42-foot car weights is plotted on a normal probability plot and presented on Figure 2.

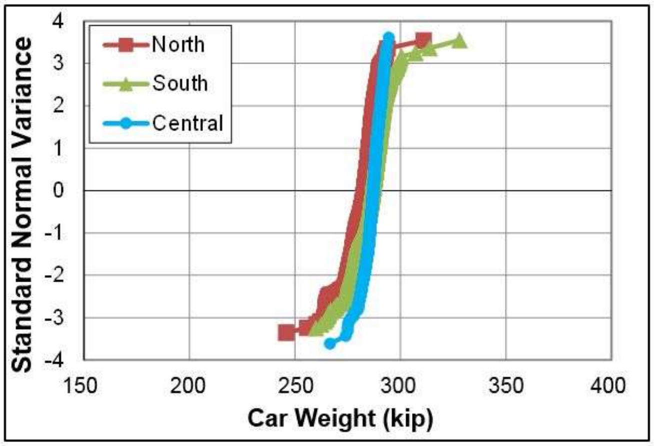

Figure 2. CDF of 42-foot car weight

The summary of mean value, COV, and maximum value of car load and axle load are presented in Tables 2 and 3, respectively. The mean and standard deviation of the car weight, truck weight, and axle weight were also analyzed to characterize the normal distribution and are presented in a companion research R-1028.[4]

Table 2. Basic statistics for current car loadings

Car Type	Mean (kips)	COV (%)	Maximum Load (kips)	Percent of Cars over Nominal Values
42′ unit	283.9	1.5	327.9	30.2
53′ unit	286.1	1.6	325.3	57.6
60′ unit	282.1	3.1	312.6	29.2
Mixed Freight	285.1	3.6	325.8	62.1

Mean values of car weight were usually below the nominal maximum value of 286 kips. COVs were very small for all car types: for 42-foot unit train cars and 53-foot cars, the COV was less than 2 percent; for 60-foot cars and mixed freight cars, the COV was between 3 and 4 percent. It should be noted that a high percentage of cars exceeded the nominal maximum value of car weight (Table 2, last column), and 62 percent of mixed freight cars exceeded the nominal maximum value. However, the small COVs suggest that although the number of overloaded cars was high, the overloaded weight was not significant.

The mean values of axle loads were mostly below the nominal maximum value of 71.5 kips, except for the leading axles of 53-foot unit train cars and of mixed freight cars. For the 53-foot unit train cars and mixed freight cars, the mean values of axles in a lead truck were heavier than the axles in a trailing truck, indicating imbalanced load distributions.

Table 3. Basic statistics for current axle loadings

Car Type	Axle Type	Mean (kip)	COV (%)	Maximum Load (kip)
42′ Unit	Leading	71.0	3.1	84.6
	Trailing	70.9	2.9	80.9
53′ Unit	Leading	73.7	3.5	84.5
	Trailing	69.4	4.0	86.6
60′ Unit	Leading	70.6	4.4	83.7
	Trailing	70.5	4.2	82.0
Mixed Freight	Leading	72.8	4.5	87.1
	Trailing	70.9	4.3	83.2

Figures 3-5 illustrate mean values and standard deviations of car, truck, and axle loads for each type of train in the North Region. These figures provide detailed information on load distributions from car weights to axle loads. For example, the mean value of car loads for 53-foot unit train cars (284.3 kips) was below the nominal value of 286 kips; however, the mean value for the leading truck was 144.1 kips, which exceeded the nominal maximum truck load of 143 kips. Following that trend, the leading axles were 72.1 kips and 72.0 kips, which are greater than the nominal maximum axle load of 71.5 kips.

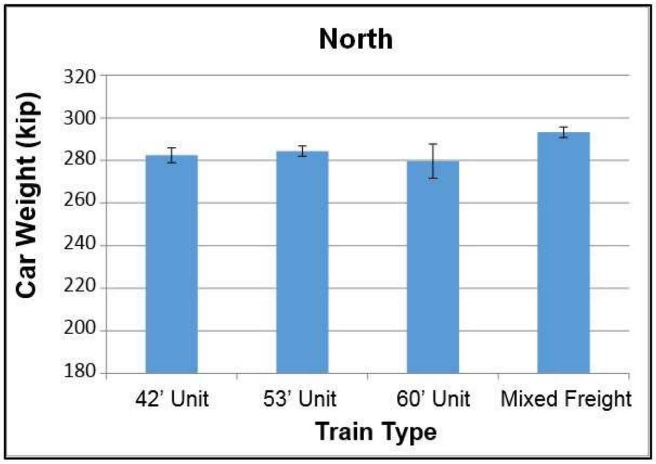

Figure 3. Car load spectra in North Region

CONCLUSION

This study presents an updated load model comprising statistical parameters that characterize the current load spectra on railway bridges for use in fitness for service calculations. The results showed that distributions of car weight and axle load were close to normal distributions. Mean values of car weights and axle loads were generally close to the nominal maximum value. However, some cars were found to exceed the nominal value, especially mixed freight cars. Also, imbalanced load distribution caused one truck to be overloaded even if the total car weight was close to the nominal maximum value. These events should be considered when bridge stresses are calculated.

The presented statistical load model can be valuable for evaluating the fitness for service of railway bridges.

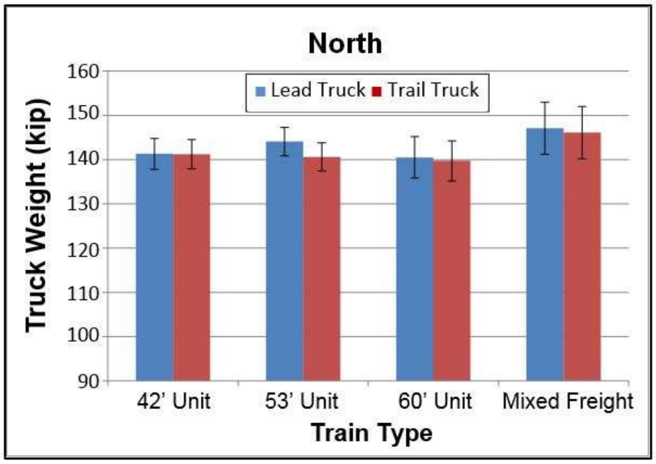

Figure 4. Truck load spectra in North Region

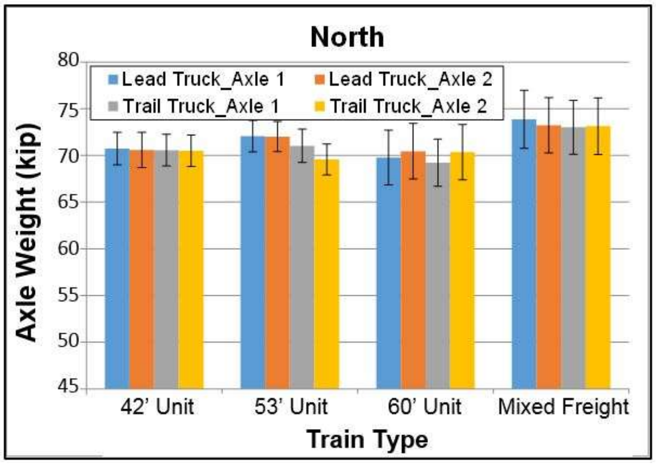

Figure 5. Axle load spectra in North Region

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