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Load Rating Choice and Longer Combination Vehicle Impacts On The Rural Interstate Bridge Network

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ABSTRACT

The paper describes the results of a survey of U.S. State Highway Departments in which 60 percent of the 47 responding states recommended using the Inventory Bridge Rating for the operation of longer-combination vehicles. Calculations for double 48 ft. and triple 28 ft. vehicle configurations show that the choice of bridge rating criterion dramatically affects predicted longer-combination vehicle impacts on the rural Interstate network. Employing these vehicle types and the Inventory rather than Operating Rating on the rural Interstate network produces 309 percent more deficient bridges, 531 percent higher affected traffic volumes, and 335 percent higher replacement costs. The replacement cost rating differential exceeds $6 billion, excluding user delay costs.

BACKGROUND

The desirability of allowing longer combination vehicles (LCVs) to operate regularly on the national highway system is an issue that has received much attention from highway professionals, trucking associations, railroad interests, and safety advocates in recent years. While highway research on this issue -- often federally sponsored -- has focused on pavement damage,[1] geometric design issues,[2] and on safety impacts,[3] LCV operations from the trucking perspective have addressed performance,[4] configurations[5] and productivity issues.[6] At the same time, policy analysis on this issue has been driven by cost benefit arguments that compare the estimated savings in LCV ton-mile trucking costs to the increased direct infrastructure costs imposed on federal and state highway budgets.

Two recent Transportation Research Board (TRB) studies are especially germane to LCVs, the first study dealing with the issues and options of allowing truck weight increases,[7] and the other related to Turner Trucks, which are configured to reduce pavement damage while allowing significant increases in gross vehicle weights.[8] Previous to these TRB studies, bridge impacts had been relatively neglected, due partly to the complexity of measuring stress, and partly to the lack of a comprehensive, system-wide structural data base. Both of the TRB studies relied almost entirely on a contracted study[9] that estimated bridge impact costs calculated on the basis of National Bridge Inventory (NBI) analyses supplemented with survey information. While the NBI is the single most important (some would argue, only) source of bridge data for the national highway system, it was not devised for truck impact evaluation. Nonetheless, it permits analyses to be made for the determination of broad policy issues. Because the validity of the conclusions of both studies was so heavily dependent upon this single common source, and because of other questions which arose in reviewing both studies, it seemed essential to re-examine the NBI data.

The Texas Research and Development Foundation (TRDF), under the sponsorship of the Association of American Railroads (AAR), undertook an evaluation of the methodology adopted in the TRB studies so as to determine further the full range of bridge impacts.[10] The LCV debate now underway centers on two of the truck/trailer configurations most favored by many in the trucking industry -- namely double 48-foot trailers and triple 28-foot trailers. The initial objective of LCV proponents is to gain legal access to the rural Interstate highway system. Accordingly, the TRDF study has been limited to determining agency and additional user costs that might reasonably be expected to occur due to rural bridge replacements on Interstate highways (outside cities of 50,000 population or more) in the event that LCV usage is made legal.

DETERMINING THE APPROPRIATE RATING FACTOR

The decision whether to use the Operating Rating or the Inventory Rating,[11] to identify bridges incapable of accommodating LCV operations is critical in determining valid bridge replacement cost estimates. The Operating Rating (75 percent of yield stress)

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is customarily used for the infrequent permitting of special heavy loads and for the posting of load-limited deficient bridges. The more conservative Inventory Rating (55 percent of yield stress) is most often used for the issuance of multiple-trip permits on a continuing-use basis. To use the higher stress limit of the Operating Rating for continuous truck operations would accelerate fatigue by an unknown (but possibly large) factor (which is inconsistent with current state and federal concerns regarding the protection of existing capital investments) and would further strain extremely tight highway maintenance and replacement budgets. On the other hand, since the intent of legalizing LCVs would be to promote the regular, wide-spread and continuous operation of those vehicles, the lower Inventory Rating would allow those loads to be applied repeatedly throughout the design life of a structure without appreciable structural deterioration. The TRB studies, incidentally, did not explore the implications of the Inventory Rating versus the Operating Rating, nor did they discuss how dramatically the cost conclusions might be affected by the choice of ratings.

TRB RATING SURVEY

As stated earlier, the bridge cost components of both of the TRB studies were based on a single TRB sponsored research project, which determined in a nation-wide survey that 50 percent of the states (25 of the 50 State Highway Departments) used the Operating Rating to post or limit bridge use. As a consequence, the Operating Rating then became the criterion to determine the number of bridges that would have to be replaced in order to safely accommodate LCVs on the highway system. After reviewing the TRB studies, it occurred to the authors that state officials might have misconstrued the purpose of the question when they were asked to specify the rating factor they employed for the posting of bridges. They might not have understood that factor would be used to analyze bridges for LCV continuous usage. If that assumption were correct, then the subsequent conclusions would be, at best, unintentionally misleading, if not invalid.

TRDF RATING SURVEY

The TRDF authors were therefore keenly interested in determining how state highway officials would respond to a question specifically directed towards LCV operations. Accordingly, a short questionnaire was developed and mailed to every State Highway Department in the United States. A cover letter accompanying the questionnaire referred to the use of the NBI database, stating that there was a desire to analyze bridge impacts using the Inventory and Operating Ratings contained therein (and as defined by AASHTO). The questionnaire asked highway officials which rating – Inventory, Operating, or other -- would they recommend for regular, continuous LCV operations on highway bridges (assuming the gross weights of triples and doubles were limited only by the federal bridge formula, with no 80 kip cap). Thus highway officials were asked to identify specifically the Inventory Rating or the Operating Rating as their choice, or to detail any other rating employed or recommended for LCV operations if they considered either of the other two ratings inappropriate. Ninety-four percent of the states responded. Table 1 shows the responses to the TRDF survey compared with those given in the TRB contract report, state by state. The responses were then aggregated by survey as shown in Figure 1.

Comparing the results of the TRB survey with the TRDF survey is difficult, principally because of the questions asked: TRB referred to the posting of bridges, whereas TRDF specifically directed its question to the regular operation of LCVs. Clearly, however, the results of both polls were used in comparable manners to develop LCV policy and fiscal information. It is unquestionably correct that 50 percent of the states used the Operating Rating in 1988 for the posting of bridges (TRB). It is likewise true that only 20 percent in 1990 would recommend the Operating Rating as the basis for LCV analysis, while 58 percent recommended the Inventory Rating (TRDF). These seemingly contradictory surveys may in fact not be in conflict, but probably simply reflect the differences in focus of the questions asked. Additionally, the TRDF survey was conducted in recent months, while the TRB-sponsored survey is now two years old. During the interim since the TRB work, state officials have become increasingly aware of LCVs, are looking more critically at the potential problems posed by LCV operations, and are more than ever before aware of the importance of selecting the proper rating factor.

A number of states made additional comments on rating issues when replying to the TRDF survey, and these are summarized in Table 2. Most of the state officials recommending a rating other than Inventory or Operating chose a value lying somewhere around the mid-range between these values. Such responses include Vermont (67 percent of yield), Virginia (65 percent of yield), and Idaho (70 percent of yield). Two respondents recommended the use of both ratings because of existing permitting methods. One state, Oregon, responded that while staff would prefer to use the Inventory Rating for LCV

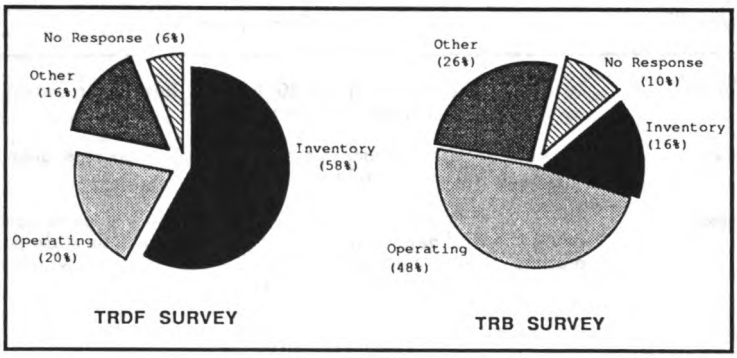
TABLE 1

Comparison of TRDF (1991) and TRB (1990) Rating Surveys

State	TRDF	TRB
Alabama	Operating	Operating
Alaska	Inventory	Operating
Arizona	Inventory	Operating
Arkansas	Operating	Operating
California	Inventory	Operating (LF)
Colorado	Inventory	Operating
Connecticut	Inventory	Inventory
Delaware	Inventory	NA
Florida	Inventory	Other
Georgia	Operating	NA
Hawaii	Other	Other
Idaho	Other	Other
Illinois	Inventory	Operating
Indiana	Inventory	Inventory
Iowa	Inventory	Operating
Kansas	Other	Varies
Kentucky	Operating	Varies
Louisiana	Inventory	NA
Maine	Inventory	Varies
Maryland	Inventory	Operating
Massachusetts	NR	Inventory
Michigan	Other	Operating
Minnesota	Operating	Operating
Mississippi	Inventory	Operating
Missouri	NR	Other
Montana	NR	Inventory
Nebraska	Inventory	Other
Nevada	Inventory	Operating
New Hampshire	Inventory	Operating
New Jersey	Inventory	NA
New Mexico	Inventory	Operating
New York	Inventory	Varies
North Carolina	Operating	Operating
North Dakota	Operating	Operating
Ohio	Operating	Operating
Oklahoma	Inventory	Operating
Oregon	Other	Operating
Pennsylvania	Operating	Varies
Rhode Island	Inventory	Inventory
South Carolina	Other	Varies
South Dakota	Operating	Operating
Tennessee	Inventory	Inventory
Texas	Inventory	Inventory
Utah	Inventory	Operating
Vermont	Other	Other
Virginia	Other	NA
Washington	Inventory	Operating
West Virginia	Inventory	Inventory
Wisconsin	Inventory	Operating
Wyoming	Inventory	Varies

FIGURE 1

Rating Survey Comparison



operations, triples are already operating by permit based on an evaluation using H15 bridges at the Operating Rating. If they were to re-evaluate these vehicles they would probably limit them to weights that produce Operating stresses in H15 bridges and Inventory stresses in HS 20 bridges, whichever is less. For the purposes of a rural Interstate network analysis (where HS20 designs predominate), the Inventory Rating would be used. Growing sensitivity to the problem of accommodating larger vehicles is also shown by Iowa's decision to set up a Task Force to determine an LCV policy and, within that, an appropriate LCV bridge rating procedure.

Kansas recommended that the NBI data not be used as a basis for the LCV study. Staff there stated that the policies and methods used to rate loads could vary considerably on a state-by-state basis, resulting in erroneous or misleading results. While this recognizes the probability that errors will occur in such a massive data base as represented by the NBI, researchers are resigned to live with these deficiencies, which after all are present in all large data bases. Finally, and most importantly, there is no alternative data source to the NBI, and any national policy study must therefore work within any constraints affecting the NBI structure and integrity. It may be that Kansas officials were concerned that the NBI might be used to determine the suitability of structures on actual LCV routes. It should be emphasized that the NBI data are used to determine national LCV policy issues and not specific LCV routes. Bridge information more detailed than that contained in the NBI data base is needed to study LCV impacts for specific Interstate route purposes.

The main conclusion from the rating survey is that a majority of states recommend using the Inventory value to rate bridges for LCV operations.

TRDF METHODOLOGY FOR INVENTORY AND OPERATING RATING COMPARISONS

As previously stated, the TRB studies do not report the impact that the rating selection has on the evaluation of LCV operations. Consequently, TRDF researchers decided to analyze the impact of two LCV configurations on the rural Interstate network using both Inventory and Operating Ratings. The latest NBI data base (1988/9) was obtained from the Federal Highway Administration (FHWA), together with the coding guide.[12] All of the Interstate bridges on the system (excluding those located within cities having more than 50,000 inhabitants) were then identified. This produced a rural Interstate data base containing around 29,700 structures (excluding culverts), which compares with 155,000 Interstate and primary bridges evaluated in the TRB studies. Data from each NBI structural record were then categorized into simple and continuous spans so that bending moments for the selected truck types and loads could be applied to each bridge category identified on the rural network. This method accords with recommendations made by previous researchers on NBI analyses[13] but differs from that adopted by the TRB studies, inasmuch as Moses did not calculate bending

TABLE 2

Additional State Comments on TRDF Bridge Survey

State	Comments
California	Inventory adequate for HS20 bridges but lower rating may be necessary for bridges less than HS20.
Georgia	Opposes proposal to increase weight limit > 80 kips; does not allow triples or turnpike doubles.
Kansas	The Bridge Section of Kansas DOT definitely does not recommend using the NBI data as a basis for a study. Various state policies and methods used to load rate could differ considerably, which could lead to erroneous and misleading results.
Michigan	Recommends both inventory and operating rating.
Minnesota	Selection of operating rating conditioned on numbers of LCVs. Fatigue concerns may require a review and adjustment of policies.
North Carolina	Opposes LCVs.
Ohio	Uses inventory rating for HS20 analysis.
Oklahoma	Studies showed that LCVs will produce bridge stresses higher than existing legal trucks.
Oregon	Oregon would prefer to limit continuous operating vehicles to the inventory stress level. However, they already allow triples by permit, and made their evaluation using H15 bridges at the operating stress level. If they re-evaluated these vehicles, they might limit them to weights that produce operating stresses in H15 bridges and inventory stresses in HS20 bridges, whichever is less.
Pennsylvania	Requires permit >80K lbs.
Rhode Island	Triples and turnpike doubles prohibited.
South Dakota	All bridges posted at 75% allowable stress.
Texas	Why bother to ask? Operating rating only to be used for infrequent permit type vehicles.
Vermont	Recommends 67% of allowable stress.
Virginia	Recommends 65% of allowable stress.
Washington	Limit all vehicles to inventory rating for each structure.
Wisconsin	Would not allow daily operation of vehicles >80 kip.

moments for each bridge in the data set. Rather, he obtained data on various categories and groups of bridges from the NBI data base and used summary statistical techniques to determine LCV impacts. This, though adequate for determining broad policy issues, is not as accurate as TRDF's approach, which calculates bending moments on an individual bridge-by-bridge basis.

Loading configurations were developed for twin 48-foot trailer and triple 28-foot trailer trucks, based on uncapped federal bridge formula constraints. Figure 2 gives the dimensions and loads associated with each truck type. A program to predict the moments induced by such vehicles was then written and applied to all rural Interstate structures, and the results were then compared using both Inventory and Operating rating live load moments for each bridge. In this study, structures that failed to meet the Inventory Rating and Operating Rating loads (plus a 5 percent allowance) were identified, and their deck areas and traffic noted to forecast replacement costs.

Table 3 shows the LCV impacts using the Inventory and Operating Ratings and reports the results for each of the three vehicle categories (triple 28s, double 48s, and both types) by bridge categories, defined in terms of simple spans, continuous spans, and both types together. Results for these vehicles/bridge categories are reported in terms of numbers of bridges failed, deck areas for these bridges, and finally the average daily traffic volumes for these bridges as reported on the NBI data base. The traffic data were used to examine the impacts of various replacement strategies on the highway users. Data were then reorganized to include a cost comparison for both ratings, with the results shown in Table 4 and Figure 3. Deck areas have been used to calculate a replacement program based on an average value of $81.00 per square foot. This figure was calculated from weighted 1986 federal unit replacement cost data, adjusted to 1990 prices. Figure 3 shows a significant difference between the two rating methods, both in terms of costs, bridge deficiencies, and traffic using the deficient structures.

Clearly, LCV policy implications are highly sensitive to the choice of the rating method. It can be seen that using the Inventory Rating dramatically increases the number of deficient bridges, the consequent replacement costs, and the affected traffic levels, when compared to the Operating Rating used by TRB. In addition, the TRB researchers compared the projected gains that would accrue to the trucking industry by switching to LCV operations, with the agency costs associated with bridge replacement, increased bridge maintenance, and higher design criteria for new bridge construction. An important omission in the TRB study, in our view, was its failure to include the negative impact on users affected by bridge replacement programs. The impact of this omission can clearly be seen by comparing the amount of traffic affected by the deficient bridges following the permitting of both double 48 and triple 28 trucks on the rural highway system. Employing the Inventory Rating suggests that around 89 million vehicles per day would be affected – in some way – by the replacement program, while employing the TRB Operating Rating gives a prediction of only 14 million vehicles per day.

Recent research on the impact of longer combination vehicles on the rural Interstate network explored the consequences of bridge replacement on highway user time and vehicle costs, using a work zone delay model.[14] Fuel and passenger delay costs reported for a set of approximately 1,200 bridges exceeding 20,000 ADT – rendered deficient by exactly the same methodology as reported in this paper and using the Inventory Rating – were calculated to be approximately $6 billion. This figure is of the same order of magnitude as the calculated replacement costs for all deficient bridges (see Table 4). What this suggests is that each dollar of replacement cost is approximately matched by an additional dollar of user expense incurred during the reconstruction activities.

CONCLUSIONS

This paper demonstrates three important points. First, the methodology for calculating bridge deficiencies attendant on LCV operations is highly sensitive to the choice of rating method. Second, the Inventory Rating is the method most often recommended by state officials for assessing LCV bridge impacts. Finally, in addition to bridge deficiencies, and therefore replacement costs, the choice of rating method is critical in determining traffic volumes adversely affected by reconstruction activities. User-delay costs are a function of traffic volumes and, as noted above, are likely to match the reconstruction costs.

Many reports dealing with this issue conclude that significant gains would accrue from the use of heavier trucks, or that productivity benefits will exceed additional costs. This study suggests that the economic impacts may not be clear-cut in every case, and that they are highly sensitive to the choice of rating method. The rating choice not only directly affects the size of the bridge replacement program, but also the user-cost impacts associated with increased fuel consumption and time delays caused by bridge reconstruction work.

FIGURE 2

Gross Load, Axle Weights, and Dimensions for Double 48 and Triple 28 Trucks (uncapped federal bridge formula)

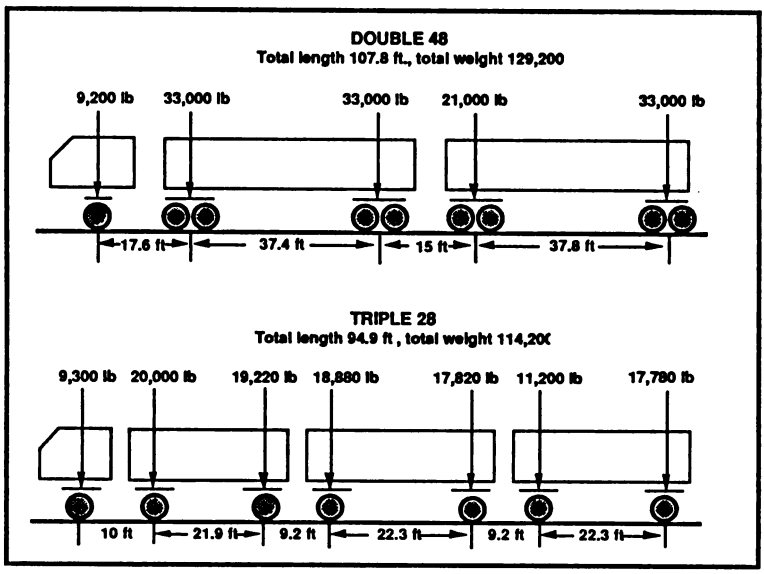


TABLE 3

LCV Impacts Using Inventory and Operating Ratings For Interstate Rural Bridges

Veh./Bridge Categories	Rating					
	Inventory			Operating		
	Count	Area (000)	ADT (000)	Count	Area (000)	ADT (000)
Triple 28s						
Simple	1,184	24,537	24,773	232	4,271	2,338
Continuous	1,687	36,955	20,578	501	10,536	5,311
Both	2,871	61,493	45,351	733	14,806	7,649
Double 48s						
Simple	2,033	35,693	38,491	463	6,238	4,671
Continuous	4,017	59,211	47,105	1,036	15,844	8,977
Both	6,050	94,904	85,596	1,499	22,082	13,648
28s/48s						
Simple	2,061	36,051	38,807	463	6,238	4,671
Continuous	4,237	61,610	49,962	1,076	16,231	9,393
Both	6,298	97,660	88,770	1,539	22,469	14,064

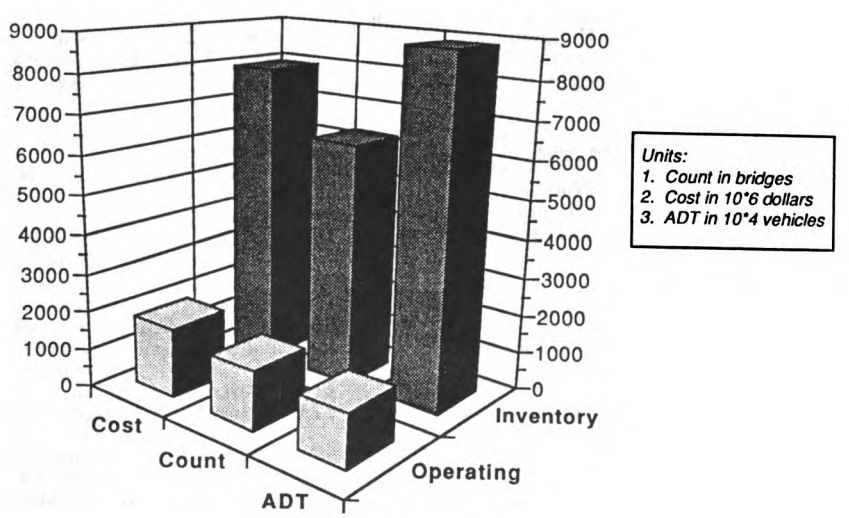
TABLE 4

Comparison Between Inventory and Operating Rating Impacts on Rural Interstate Bridges: Double 48 and Triple 28

Bridge Type	Rating	Count	Replacement (000$)	ADT (000)
Simple	Inventory	2,061	2,920,131	38,807
	Operating	463	505,278	4,671
Continuous	Inventory	4,237	4,990,410	49,962
	Operating	1,076	1,314,711	9,393
Both	Inventory	6,298	7,910,460	88,770
	Operating	1,539	1,819,989	14,064

FIGURE 3

Rural Interstate Bridge Inventory and Operating Rating Impacts for Double 48s and Triple 28s



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