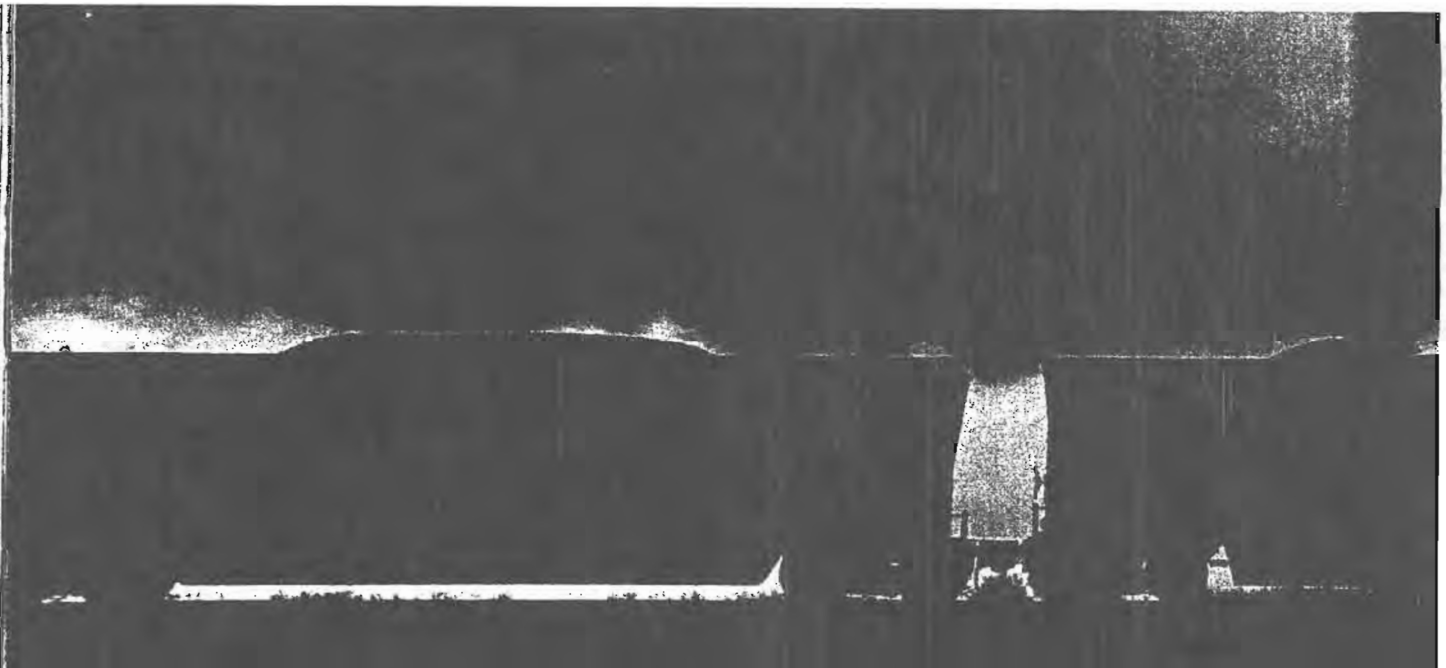

The implications of the 100-ton car

There are serious questions about the 100-ton, four-axle car that should be answered before we allow it to become the predominant vehicle for rail bulk freight

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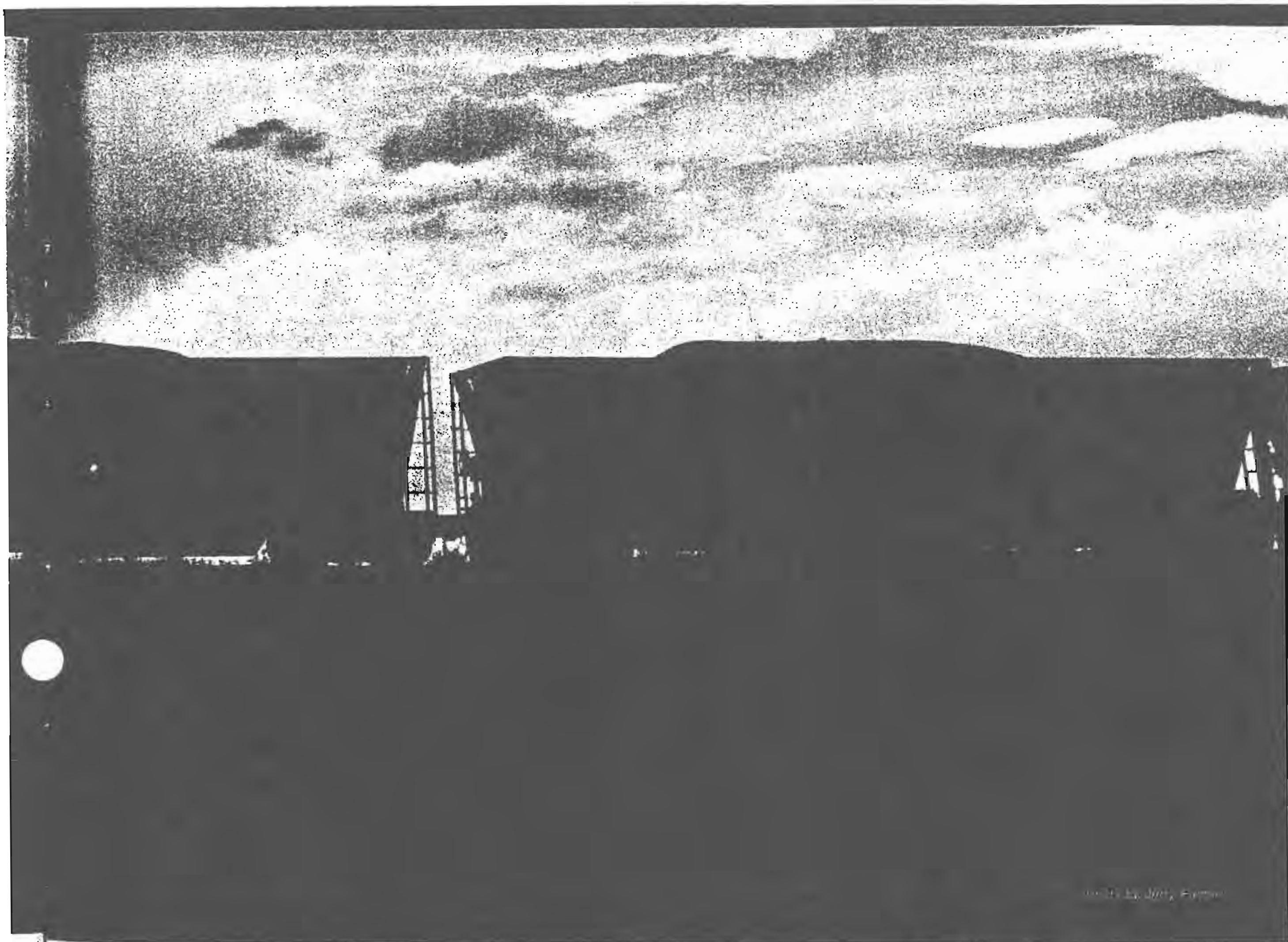
The 100-ton, four-axle freight car, weighing 263,000 lbs. fully loaded, has descended upon the rail industry in a big way. Nearly all new open-top hoppers, covered hoppers, most of the gons, and many of the tanks presently on delivery are 100-ton cars. These car types represent the areas of greatest growth in rail traffic and, if the present trend continues, it will not be too long before the predominant vehicle for carrying bulk rail freight will be the 100-ton car.

There are some serious questions that should have been answered before the industry ever allowed the 100-ton car to become widespread. To continue the present course could be extremely harmful to the rail industry, as well as to shippers and others who depend on it.

At the time of the 100-ton car's introduction a number of research and track engineers warned that it would be highly detrimental to the track structure. At the same time marketing people, under the influence of costs expressed on a "per carload basis" were clamoring for the 100-ton cars as a way of achieving competitive advantage. Further influencing the decision-making was the fact that car purchase costs were rapidly increasing, and the 100-ton car afforded an opportunity to reduce these costs on a "per net ton basis." Without fully analyzing the economic implications of the 100-ton car, the industry essentially adopted it by default. The car investment advantages of the 100-ton car were easily figured—they were apparent in every car purchase cost quotation. The detrimental effects of these cars on the track were generally accepted but, because of the time and difficulty in quantifying them, they were largely regarded as negative intang-



bles we would eventually have to live with. At that time, "eventually" seemed a long way off; car investment savings were "now."

Today, more than ten years later, the chickens are coming home to roost and "eventually" has become "today." The question that should have been answered then is begging to be answered today, and the answer is growing more obvious and more alarming.

Prior to the widespread use of continuous welded rail, rail life generally was determined by end batter at the joints and by the amount of head wear that would result in flanges contacting the tops of joint bars. With welded rail, chief engineers could look forward to greater allowable head-wear for there were no ends to batter and no joint bars for flanges to contact. With the heavier rail sections, rail lives of roughly a billion gross tons were anticipated. The 100-ton cars have squelched any hopes of achieving that kind of rail life. Fatigue-induced defects, accelerated wear rates, shelling, and metal flow are cutting rail life to roughly half what otherwise would be expected.

Line and surface are more difficult to maintain under 100-ton cars, and require more costly, more frequent cycle maintenance. Even more costly, however, is the increased need for spot maintenance where specific areas of instability rapidly deteriorate. Ballast degradation is intensified, adding to the muddy ballast problem. In the long run, this will require much greater reliance on ballast shoulder cleaning, complete undercutting, and sledding periodically to restore resiliency to the ballast.

Subgrades are, to a much greater extent, overstressed with the 100-ton cars. Settlement problems, and uneven line, surface, and cross-level are the costly result. Timber bridges must be rebuilt more frequently as a result of the crushing and shearing stresses imposed on the timber by these heavier axle loads. This is particularly true of pile caps, which, in many cases, are being replaced with prestressed concrete.

The problem is not traffic volume, not the gross tons per year; the problem is the axle-loading of the nominal vehicle size which is carrying the traffic. The driving question which must be answered is simply, *"What nominal car will provide the most economical transportation per net tonmile, all costs considered?"* Regardless of how we have chosen to *allocate* costs in the past, if it is more costly to move net tonmiles in 100-ton cars than in lighter cars, we should be emphasizing lighter cars.

The answer to this question is entangled in many factors, of which track cost is but one. To adequately assess the problem, it must be simplified to the extent that it can be visualized and assessed. For this purpose, an economic comparison was drawn between an 80 and 100-ton car, detailed in Table 1.

To compare the variable costs of moving freight in the two car sizes, it is necessary to analyze in detail only those variable cost elements that differ with car size. The two cost categories which have the greatest impact on this analysis are *maintenance of way and structures* and *car investment.* Other costs which have a minor impact are *locomotive fuel, investment, and maintenance.*

Car maintenance is generally believed to be a "wash;" the lower cost of maintaining an 80-ton car is offset by the larger number of cars needed. Train and switching labor vary only slightly with car size. Accident and derailment costs, while probably higher for the 100-ton car, are difficult to quantify. Thus only MW&S, car investment, and locomotive fuel, investment and maintenance were considered in this analysis.

Subgrades are overstressed

Robert E. Ahlf began his railroad career in 1965 as a rodman on the Seaboard Air Line. He joined the Illinois Central as a junior engineer in 1968, and moved through successive engineering, marketing, and operating positions on the IC/ICG, becoming chief operations planning officer in 1977. He received his BS degree in Civil Engineering from the University of Florida in 1966 and an MS in Transportation from the University of Tennessee in 1968, including a minor in Railway Civil Engineering at the University of Illinois.

Mr. Ahlf, a member of AREA Committee 16, has already published several other articles on various aspects of M/W. He is currently serving on an ad hoc AAR committee for the economic evaluation of bulk-commodity cars with respect to dynamic improvements. Although some of the material has already been utilized by the committee, this article represents the findings of the author and does not necessarily represent any findings or views that may be developed by the committee.

Because of space limitations it has been necessary to omit most of the details of Mr. Ahlf's analysis. However, those details are in an expanded version of the article that may be had for the asking by writing *Modern Railroads* or the author.

Space limitations prevent any detailed description of the methodology used in the analysis; but more information is in an expanded version of this article available from *Modern Railroads* or from the author.

Maintenance of way cost

For purposes of this analysis, there are three categories of total maintenance of way and structures costs:

1. Costs which are fixed and do not vary with tonnage or with axle-load.
2. Tonmile variable costs which vary in direct relation to the mechanical action of the track under load.
3. Tonmile variable costs which vary in direct relation to the service life of rail.

To establish the relationships of these costs with axle-load, it is first necessary to determine the amount of the costs at current normalized levels, then to break down the costs into the above three categories, and lastly to assess how each of the last two categories varies with axle-load.

To establish current, normalized MW&S spending, data from the 1978 R-1 reports of 28 Class I railroads were added up and treated as one huge road. (These 28 railroads included all those that were not bankrupt and which had shown a positive net railway operating income for the past five years.) Their total MW&S spending was $4,082,754,000 (1980 dollars).

Tonmile variable costs were then broken out of these accounts and applied to the 1,586,502 million gross ton-miles of these 28 roads, with the results shown in Table 2.

The analysis then sought to answer the question: how do these two variable cost categories vary with the axle loadings of the 80-and 100-ton cars?

The first category, costs which vary with track action, includes the variable portion of ties, as well as ballast, surfacing and maintenance, bridges, road property damaged, highway grade crossings, and the respective portions of roadway machines, small tools and supplies, and fringes. Here the work of the late Prof. Talbot of the University of Illinois was utilized.

The Talbot relationships can be used to determine the amount of rail deflection (a measure of the mechanical action of the track) under differing axle loads and under different conditions of track support (track modulus).

Because the rail deflection is an indicator of the mechanical action of the track, it is assumed that it is also an indicator of the wear of the track components below the rail (ties and ballast), and an indicator of the deterioration of the track with usage—the cause of the need for lining and surfacing. Used in this fashion, the amounts of deflection are not the central object; they are merely used as indicators of cost variability.

As for the costs which vary with rail life, it has been common practice to speak of rail life in terms of first-position life. There is great diversity of practice among railroads in secondhand use of rail.

From the R-1 reports we see that more secondhand rail was laid in 1978 than new rail, indicating that, on the average, rail is being extensively "cascaded." Thus, any meaningful comparison of rail lives must look at total rail life, not merely at first position.

As a result of the 100-ton car, not only is rail life being reduced but also the most limiting factor which determines rail life is shifting from wear to fatigue-related defects. Under the lighter cars, the contact stresses in the head of the rail were below the elastic limit. Likewise, rail resistance to bending was generally adequate, provided rail support was kept sufficiently strong. Under these conditions, rail wear and end batter were the major determinants of rail life.

Now, the 100-ton car is changing that. Rail head contact stresses, previously of minor importance in determining rail life, are now a dominant factor. These stresses beyond the elastic limit are resulting in the rapid propagation of fatigue-related defects which are becoming the primary limitation on rail life in tangent track. Depending upon the defect rate which a railroad is willing to live with, tangent rail life is being reduced to less than one-half of what it would otherwise be with the lighter cars. Rail life in curves continues to be limited by abrasive wear heavily aggravated by roller bearings, even with the larger car size; however even this determinant of rail life is greatly reduced by the heavier cars.

It is concluded that with the 100-ton car, the industry is in for a drastic reduction in rail life. Considering the first and following rail positions, a 50 percent reduction in rail life as a result of using 100-ton vs 80-ton cars appears to be a sound conclusion.

The results of this analysis of track action and rail service life are summarized in Table 3.

Car ownership

The method of determining this cost has been to use comparative quotes for a purchase of 80-ton cars which occurred at the approximate time of another purchase of 100-ton cars, and to obtain their cost ratio. This has then been applied to a 1979 quote, inflated to 1980 dollars, resulting in a cost of $45,100 for a 100-ton car and a cost of $41,808 for an 80-ton car. Conversion to daily cost is based on a capital recovery factor of 0.13147 for a 15-year life and a nominal car finance cost of 10 percent. To apply these time costs to a summation which includes the mileage costs of MW&S requires that a productivity rate be assumed. This table of costs (abbreviated to save space) was prepared for several productivity rates as shown in Table 4.

Table 4 shows not only how car ownership costs vary with respect to car size; it also shows how sensitive these costs are with respect to productivity, or car utilization.

Locomotive costs

Locomotive fuel, ownership, and maintenance costs vary with axle load, but only to a small extent. Generally, these costs vary on the average with the drawbar force required to move the traffic. To obtain basic locomotive-related costs with as small as possible a component for grade and curve resistance, nine unit-rain operations were examined on a railroad which is relatively flat and straight but which has fairly typical amounts of starting, stopping, and speed changing. These costs, including loaded and empty trains of nominal 100-ton cars, ranged from 206.8¢ to 437.8¢ per 1000 ntm., and averaged 328.0¢ per 1000 ntm. in 1979. At the estimated 1980 level, this would be 382.0¢.

The relationship of these costs to car size, as indexed by train resistance, can be determined by the Davis Equation. Using it, the resistance for both loaded and empty cars, and for both 80-ton and 100-ton cars were computed. Again omitting details and summing up, within the speed range of 0 to 50 the penalty for using 80-ton cars instead of

Table 1. Comparison of Cars

	80-Ton Car	100-Ton Car
Gross Wt.	220,000 lbs.	263,000 lbs.
Tare Wt.	54,000 lbs.	63,000 lbs.
Lading Wt.	166,000 lbs.	200,000 lbs.
Net/Tare Ratio	3.07	3.17
Type:	Open-top, three pocket, hopper four-axle, roller bearing 33-inch wheels.	Open-top, four pocket, hopper four-axle, roller bearing 36-inch wheels.

Table 2—Elements of MW&S Cost

	Total $	¢/1000 GTM	%
Cost that vary with track action	$1,609,618,000	101.5	39.4
Costs that vary with rail life	677,242,000	42.7	16.6
Remaining fixed costs	1,795,894,000		44.0

Table 3—Variable MW&S costs, ¢ per 1000 GTM, 1980 $

	80-ton car	100-ton car
Poor track	269.6	355.4
Average track	172.5	240.1
Good track	118.3	175.4

Table 4. Variation of Ownership Cost with Productivity.

	80-ton car	100-ton Car
1980 Purchase Cost	$41,808	$45,100
Annual Cost	$ 5,496	$ 5,929
Daily Cost	$ 15.05	$ 16.24
Cost Per Net Ton Mile @ 1 loaded mile per car day	$18.133¢	$16.240¢
Cost Per Net Ton Mile @ 50 loaded miles per car day	363¢	325¢
Cost Per Net Ton Mile @ 100 loaded miles per car day	181¢	162¢
Cost Per Net Ton Mile @ 200 loaded miles per car day	91¢	81¢

100-ton cars ranges between a 10 and a 12.8 percent increase in locomotive-related costs. For the purposes of this analysis, we used 11.1, giving the following average locomotive-related costs in 1980 ¢ per 1000 ntm:

80-ton cars—364¢
100-ton cars—328¢

Summary and conclusions

Table 5 summarizes the above three significant cost categories which vary with axle-load. It should be noted that this is not a table of variable costs (costs which vary with traffic volume); it is a table of *that portion of variable costs which varies with axle-load.*

This analysis is conservative in that it throws the benefit of doubt to the favor of the 100-ton car. If, for example, the effect of inelasticity of rail support is considered, there is good reason to believe that the above economic penalties would increase by an additional uniform 8¢ per 1000 ntm. This represents a 20 percent increase in the cost differential related to the mechanical action of the track.

Although difficult to isolate from the R-1 accounts, there are two rail-related costs, not specifically addressed in this analysis, which will increase very substantially if the trend toward using 100-ton cars continues. These are the costs associated with rail detector services and inspections, and the costs associated with non-programmed change-outs of defective rails often under emergency conditions.

Effect of track condition

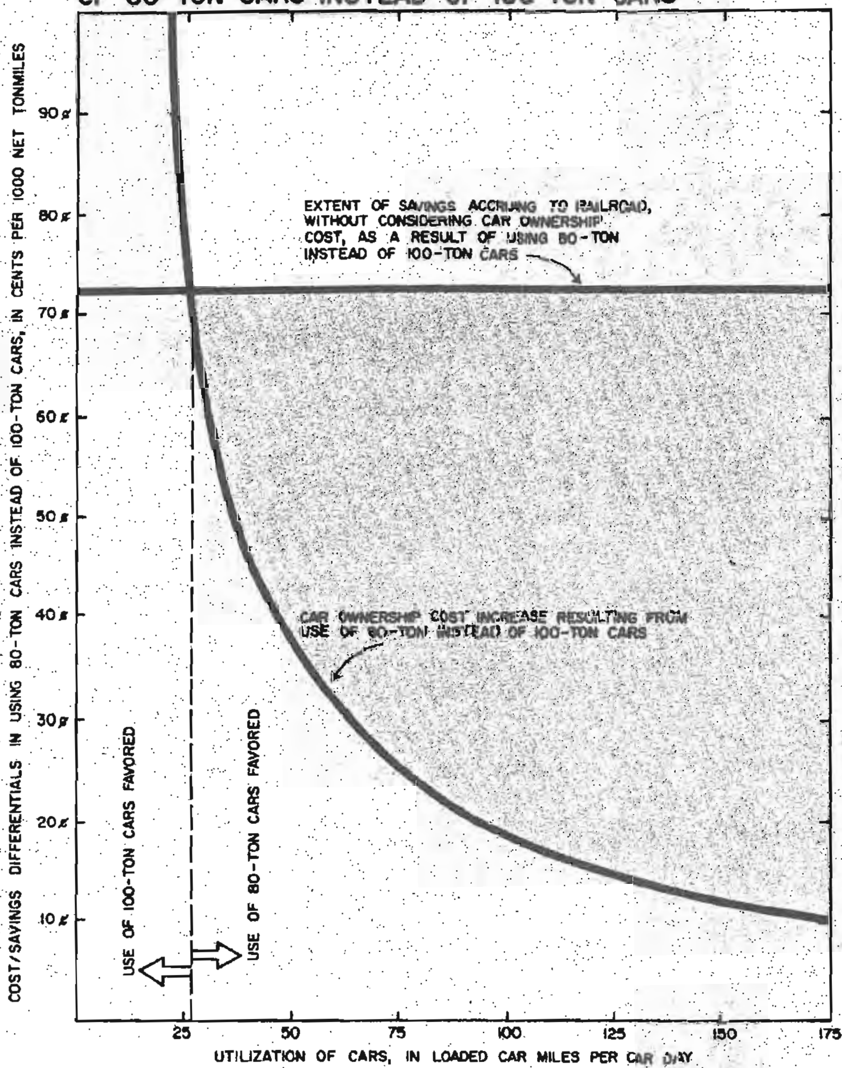
The above penalties have been put together on the basis of average track. As used in this analysis, average track refers to the kind of track over which the average gross tonmile moves. This is considerably better track than the average of all track miles. Thus, "average" as used herein, is really pretty good track in the common sense of the word. "Good track" as used in the MW&S cost analysis is really superior track. The costs related to the mechanical action of the track are quite sensitive to track quality as well as to axle loading, thus poor track exhibits a much greater differential between 80-ton and 100-ton cars than does good track (Table 6). Thus, the penalties in Table 6 would increase by an additional 28¢ per 1000 ntm. If track were poor instead of average. Conversely, it would decrease by 16¢ per 1000 ntm. if track were good instead of average.

M/W priorities

The implications of rail life being determined by fatigue-related defects as a result of

Rail renewal increases

CHART I: SAVINGS DIFFERENTIALS WITH USE OF 80-TON CARS INSTEAD OF 100-TON CARS



Shaded area represents range of economic incentive for use of 80-ton cars instead of 100-ton cars. For example, at 75 loaded car miles per car day, the net incentive is 71¢ – 26¢ = 45¢ per 1000 net tonmiles.

100-ton cars are staggering. If the proliferation of 100-ton cars continues, no longer can main lines be inspected ultrasonically or magnetically two or three times a year. This will have to be done bimonthly, perhaps even monthly on the heaviest-density lines, and accompanied by very well-organized and meticulous record keeping. Non-programmed rail change-outs, once a feature primarily of decrepit branch lines, will become increasingly prevalent on the main lines. Even the programmed rail renewals will have to be managed more stringently, with rigid financial implications. When rail wear was a primary criterion for rail renewal, postponing the relay of rail for a few years because of budget constraints could be tolerated. Such will not be the case when rail life is governed by the incidence of defect propagation. With defects on a given rail installation rapidly increasing, the postponement of relaying that rail will be considerably more dangerous.

The problems of increased subgrade consolidation (often differential), increased ballast abrasion, degradation, mudding, and cementation, and the resulting increase in the need for lining and surfacing are beginning to be felt already. Basic structural remedial work, such as complete undercutting, plowing, sledding, cribbing, and ballast shoulder cleaning will be much more extensively required. The same is true of subgrade stabilization to attempt to provide a stronger track-bed support in areas of weak soil. Roadbed drainage, of fundamental importance anyway, will become more critical, especially in areas of weaker, more moisture-sensitive soils.

Car utilization

The 100-ton car was an attempt by the rail industry to gain additional productivity out of its heavy investment in freight cars. Table 6 indicates the futility of this, relative to the more difficult, but much more rewarding, alternative of increasing the productivity of freight cars by producing more loaded car miles per car day. The way to improve utilization of cars is to move them; we have exceeded the point of diminishing returns in trying to cram more freight into bigger and better ones!

Recommendations

Referring again to the cost penalty chart, it is a logical conclusion to recommend that the railroad industry stop building and ordering 100-ton cars, and direct its purchases to 80-ton cars. The advantages of doing this are greatest in the services where cars are well utilized, such as unitrains and trainload operations. About the only economic use for the 100-ton car is in operations involving short hauls and lengthy idle times, especially if high-cost specialty cars are involved. Ironically, for the past decade, the industry has followed the reverse course.

It would be too great a shock to the industry to quickly limit the allowable axle-load of existing cars; however, it would be very sensible to set an upper limit on the axle-load of new cars yet to be constructed which would correspond to the 220,000-lb. car, or a maximum of 55,000 lbs. per axle.

A very large percentage of 100-ton cars is owned by shippers or car-leasing companies. All indications are that this trend will not change abruptly. Therefore, shippers must be motivated to build, purchase, or lease the smaller cars. A practical means of doing this is to insert a differential in each shipper-car freight tariff that would adequately encourage the shippers to gradually adopt lighter cars. This differential should fit within the range of negotiability illustrated on Graph 1. The horizontal line represents the maximum amount of differential a railroad could afford to offer, and the curved lines represent the minimum amount of differential necessary to offset the shippers' higher car ownership costs. The area below the horizontal line and above the curved line is the "range of latitude". Note how the effect of car utilization drives the relationships.

For example, with average track, with car prices of $41,808 and $45,100, and with car utilization of 100 loaded car miles per car day, it would cost a shipper 19¢ per thousand net tonmiles to provide 80-ton instead of 100-ton cars. The railroad will obtain savings of 71¢ per thousand net tonmiles if the shipper can be induced to convert. The difference (52¢) is the latitude of negotiability. Notice how this latitude of negotiability narrows if cars are utilized less. At 75 loaded car miles per car day, it becomes 45¢; and at 50, it becomes 33¢.

Summarizing the recommendations derived from the graph for general conditions:

1. A railroad should purchase 80-ton cars rather than 100-ton cars for operations that will average in excess of 25 loaded car miles per car day.

2. To provide adequate monetary incentive for shippers to furnish 80-ton, instead of 100-ton cars, railroads will have to write economic differentials into tariffs, no less than 38¢ per mntm at 50 loaded car miles per car day; 19¢ at 100 miles, 13¢ at 150 miles, 11¢ at 200 miles; and no greater than 71¢ per thousand net tonmiles.

3. As quickly as possible, railroads should restrict their new car purchases to a maximum axle load of 55,000 lbs. on 33-inch wheels, and should encourage shippers to do likewise by use of the appropriate tariff differentials.

4. During the remaining life of 100-ton cars, they should be used in low-mileage service where their detrimental physical and economic effects are minimized.

Table 6. Added MW&S Cost of 100-Ton vs. 80-Ton Cars

Poor Track. .	.135¢/1000NTM
Av. Track . . .	.107¢/1000NTM
Good Track . .	.91¢/1000NTM

5. The industry should, as quickly as possible, perfect the four-axle, 220,000 lbs. capacity car. Several items include:

A. Use of lighter materials to further improve net-to-tare ratios.

B. Careful design to improve the track-train dynamic characteristics of the cars.

C. Use of roller-bearing adaptors to permit greater lateral freedom of the axles which would greatly reduce abrasive wear of curve rail, and wheel flanges.

There should be a sense of urgency in adopting the 55,000 lb. maximum axle load for new cars. It is uneconomical to light-load conventional 100-ton cars because of the resulting significant reduction in the net-to-tare ratio. Thus, it is likely that every new 100-ton car will continue to carry 100 tons for the remainder of its life, at a considerable economic loss to the railroad, as compared with purchase of 80-ton cars at the outset.

Also, the problem remains largely an economic one today, except on those lines where 100-ton cars are unusually numerous. There is a time-lag in the detrimental consequences of the 100-ton car, and those consequences have not yet caught up with the industry as a whole.

The time to correct the 100-ton car problem is *now*—before rail-defect incidence and other track problems become so intense and widespread that they produce, not just an economic problem but an operating and maintenance crisis. ■

Table 5. Cost categories that vary with axle-load

Loaded Car Miles Per Car Day	*MW&S*		*Car Ownership*		*Loco.Fuel, Ownership & Mtce.*		*Total of Costs Varying w/Axle Loading*	
	80T	*100T*	*80T*	*100T*	*80T*	*100*	*80T*	*100T*
25	285	392	725	649	364	328	1374	1369
50	285	392	363	325	364	328	1012	1045
75	285	392	242	216	364	328	891	936
100	285	392	181	162	364	328	830	882
150	285	392	121	108	364	328	770	828
200	285	392	91	81	364	328	740	801

Summarizing the cost differences, we have:

Car Utilization Rate, in Loaded Car Miles Per Car Day	*Economic Penalty From Use of 100-Ton Cars vs. 80-Ton Cars, ¢/1000 NTM. (1980 $)*
25	(5¢)
50	.33¢
75	.45¢
100	.52¢
150	.58¢
200	.61¢