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Meeting the need for accurate m/w costing

Costing models enable railroads to determine incremental costs. Is one model better than another?

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Accurately determining maintenance-of-way costs has become increasingly important within recent years. As tonnages and traffic densities have increased, so has the need to isolate, and establish a cost for, the incremental cost incurred by each train (freight or passenger) operated over a given line. Since a single line may carry many different kinds of traffic, it is essential that railroads understand cost relationships, so that appropriate transportation costs can be established. But how can one determine, with a reasonable degree of accuracy, how much damage a single train may have inflicted on the track structure? And assuming that the damage can be quantified, what is the cost of the repair?

One frequently-used costing methodology for determining the incremental track-maintenance costs for both freight and passenger trains is the Speed Factored Gross Tonnage (SFGT) model. SFGT was originally developed in the mid-1970s for the Interstate Commerce Commission's Rail Services Planning Office (RSPO). RSPO, created by Congress after the passage of the Amtrak Act in late 1970, was intended to act as an ombudsman and consumer advocate for rail passengers. RSPO was also charged with determining a fair compensation to freight railroads for operating passenger trains. SFGT was developed to provide a methodology for allocating track maintenance costs between passenger and freight trains. As originally specified, the model considered only operating speed and amount of annual traffic (gross tons) moving over the line. Other variables that might significantly affect cost, such as axle load, were not included in the model.

SFGT was based on work conducted by an AREA committee in 1956. This work, essentially a cross-sectional analysis of a number of Class 1 railroads, attempted to construct curves relating traffic density and m/w costs for groups of railroads sharing similar weights of rail in track and (to the extent possible) traffic types. Traffic densities varied, but most were in the 7-to-15-mgt range, very low by today's standards. Only a few data points were obtained at the 25-mgt-and-greater levels that characterize most of today's mainlines. From this work, it was hypothesized that maintenance-of-way costs increased, in general, as the square root of traffic density. This assumption was included in the 1975 SFGT model.

SFGT has been "fine tuned" several times since 1975 to better suit it for estimating the incremental cost of heavy freight traffic as well as passenger traffic. A separate category for heavy-axle-load traffic has been established, an improved tie-life equation introduced and the rail/OTM and ballast/surfacing equations modified to increase the model's sensitivity to differences in axle loads between traffic types. However, the coefficients and constants in the equation remain those developed from railroad data now more than 30 years old, and the basic square-root-of-density relationship remains unchanged.

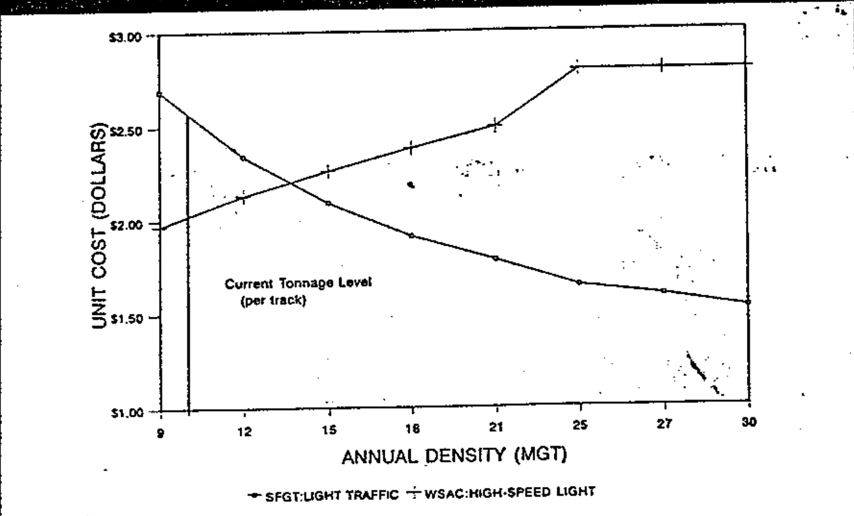
The current SFGT model structure is based on a regression of costs against traffic for some 1977 Burlington Northern data. Especially in the tie model, these regressions produced large constant terms. This means that most tie costs were assigned, not to traffic, but only to miles of track in service. The most critical assumption in the SFGT model, however, is the square-root-of-density relationship. In practice, this relationship means that the *incremental* cost of all traffic on lines with average annual tonnage of about 25 mgt or more will be assigned a cost lower than the railroad's system average m/w cost for all traffic. As railroads continue to concentrate traffic on fewer and fewer lines, this has frequently resulted in substantially more than half a railroad's traffic moving at below system average cost, a *prima facie* impossibility.

Equally disturbing are the economic implications of a continuously declining marginal cost. The least of these implications is that if a railroad can lower its marginal cost by continually increasing output (ton miles for track mile), then the optimal traffic level is infinite.

SFGT was not challenged by railroads in the 1970s for two reasons. The first was that average traffic densities were in most cases low enough that SFGT produced approximately correct cost estimates. The second reason was that the rail industry was focused on branchline abandonments. Prior to deregulation, railroads had to demonstrate losses on branchlines. The SFGT model had the effect of making branchline track maintenance very costly.

The concept of scale economies has been accepted in most human endeavors, however. Could SFGT be at least partially

Figure 1
Comparison of Incremental M/W Costs SFGT and WSAC, Moderate-Tonnage Line



correct? Are there economics of density in track maintenance?

Re-thinking cost relationships

While SFGT may have its flaws, its outputs did, for some time, track well with observed cost behavior. This should not be surprising. After all, the original formulation was based on empirical data, and even a mis-specified function may track well with reality over a limited range of observations. However, once outside that limited range, a mis-specified model will fail. Indeed, the railroad industry has changed significantly in the past decade, moving far from the limited range over which SFGT produces plausible results. For example:

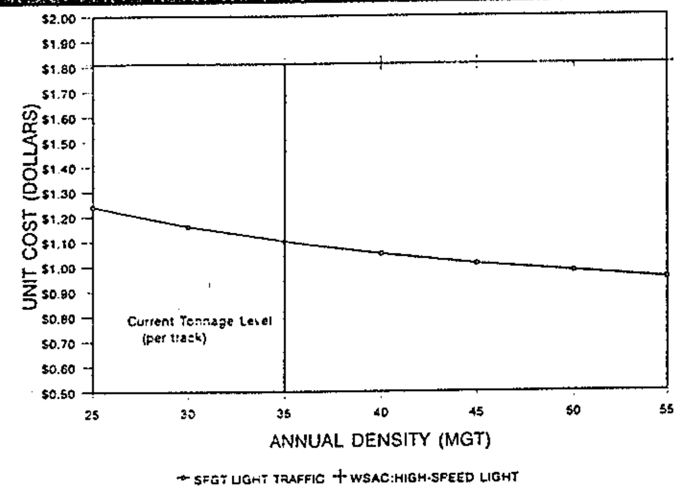
- The average car capacity is near 100 tons today; three decades ago it was closer to 50 tons.
- Welded rail is now widespread. The elimination of joints, along with the trend toward heavier cars, has completely changed the mechanisms that result in condemnation of rail and its removal from track.
- In the years since deregulation, there has been a trend toward concentrating rail traffic on fewer and fewer mainlines. This trend is partially a result of mergers and the contraction of the rail network, but it also reflects a deliberate effort by railroads to make maximum use of their investment in physical plant. The result is an increase in per-track annual tonnages to levels never before reached in the U.S., or anywhere else for that matter.

The consequences of these changes for maintenance-of-way costs have been great. Huge annual volumes of traffic are now being regularly and safely operated over thousands of single-track route miles. Much has been learned about the effects of heavy cars on rail, ties and roadbed. This increased knowledge has been reflected in changed maintenance practices. Larger tie plates and better grades of ballast have extended tie life and surfacing cycles. Widespread use of welded rail, high-hardness steels and profile grinding have extended rail life (in terms of total tonnage carried) far beyond historic levels.

These advances in maintenance technology have led some observers to conclude that the unit cost of track maintenance has in fact declined as tonnage has increased, just as had been predicted by the AREA and later by the SFGT model. However, what has in fact happened is that the ratio between maintenance spending (which is expensed) and major track reconstruction (which is capitalized) has changed. Track components are lasting longer but costing more. In short, the railroad industry is spending more per ton mile of traffic to maintain track, not less. Heavier cars and more intensive use of tracks have produced economies, but not in the maintenance-of-way accounts. The square-root-of-density relationship does not appear to be supported by the data.

If it is assumed that m/w costs are in fact related to the square root of traffic density, then it is also necessary to assume that track component lives—measured in mgt—increase continuously as traffic increases. At relatively low traffic levels (below 25 mgt) there may in fact be an effect of this kind (since some component degradation may be due to environmental factors, depending on traffic volume). However, at higher tonnages (25 mgt and above) environmental degradation is supplanted by mechanical wear resulting from the passage of traffic. At these typical mainline tonnages, there is a substantial body of knowledge to suggest that the relationship between traffic, and the degradation of major track components (rail, ties and ballast) becomes linear. That is, for each additional unit of traffic there is an equiva-

Figure 2
Comparison of Incremental M/W Costs SFGT and WSAC, Heavy-Tonnage Line



lent unit of component degradation (and therefore cost).

The development of a full understanding of the relationship between component lives and traffic is relatively recent. The SFGT square-root-of-density assumption, as previously mentioned, is taken from work by the AREA during the 1950s, where cross-sectional analysis of a number of Class 1 railroads did produce an approximate square root relationship between traffic and costs. However, the analysis was confined largely to lines with moderate traffic densities (by 1991 standards), bolted rail and relatively light axle loads (100-ton cars were still a decade away from wide use). It also did not adequately address differences in maintenance practices between railroads (e.g., heavier densities were found mostly on larger, wealthier railroads with a higher degree of mechanization in maintenance). However, the square-root relationship became embedded in railway costing practice, with far-reaching consequences for both railroad rates and railroad policies.

Recent engineering research has suggested cost relationships very different from the square root of density. The shift from wear to fatigue as the primary determinant of rail life has increased the importance of the strongly non-linear effects of axle load. Increases in tonnage per track mile have moved much of the North American rail system to traffic levels where the effect of environment is negligible. Maintenance-of-way activities have been almost fully mechanized on all Class 1 railroads, meaning that there is no longer a significant difference in production rates (and therefore costs) between low-tonnage and high-tonnage lines.

Rail wear has been determined to be linear with tonnage, as has the degradation of track geometry and ballast under traffic. However, rail fatigue is a function of the square (or more) of axle load, resulting in a rapid deterioration as axle loads have increased. Ties are more affected by environmental factors than rail or ballast, but when traffic reaches the level where mechanical, traffic-induced factors supplant environmentally-caused decay, tie deterioration also becomes linear with traffic.

The accepted engineering finding is that track component deterioration is linearly related to traffic at typical mainline traffic densities. The economies of density, so often predicted, appear to apply only to activities not directly related to the passage of trains, such as track inspection, snow clearing and the maintenance of the signal system. However, these costs are small compared to the costs incurred for maintenance and replacement of rails, ties and turnouts, and to the costs of maintaining track to proper geometric standards.

An alternative model

As indicated in the previous review of engineering research, rail life is linearly related to traffic density at all but the very lowest annual traffic volumes. That is, the life of rail, in mgt, can be expected to remain the same as traffic increases (while the life in years will decrease). The situation for ties and ballast is more complex. It is undeniable that environmental damage plays a part in determining the life of these components. It was almost certainly environmental decay that produced the cost relationships first plotted by the AREA in 1956 and later included in the SFGT model. However, at some traffic level, mechanical wear and crushing must become the dominant life-determining factors.

One alternative to SFGT is known as the Weighted System Average Cost (WSAC) model, and was originally developed for the Association of American Railroads. WSAC uses engineering equations to produce "engineering adjustment factors." These EAFs reflect the relative track damage caused by different types of rail traffic. Traffic types are defined by axle load and speed. Track characteristics, such as curvature, grade and weight of rail, are also considered in the model.

The EAFs are applied directly to a unit cost (e.g., system average cost), increasing or decreasing it in accordance with the characteristics of each traffic type and each track segment. While the original AAR formulation of the model worked only with system average cost, it is possible to extend the model to take account of both costs and track characteristics on specific line segments. While WSAC does require significant amounts of data on track characteristics and traffic types, the weighted costs it generates are based on known engineering relationships and therefore can be expected to reflect actual track damage done by each traffic type using a railroad line.

The most critical difference between WSAC and other common costing methodologies such as the SFGT model, however, is that WSAC assumes a linear relationship between costs and traffic at typical mainline traffic densities. Therefore, when the aim is to determine incremental cost (as opposed to allocating common costs), WSAC will produce dramatically different results than SFGT and similar models. At lower tonnages, where SFGT produces high marginal costs, WSAC indicates that the actual marginal cost is low, and at high tonnages (where cost relationships are linear) the WSAC marginal cost will be high and constant where an SFGT-determined cost declines with increasing traffic. These relationships are shown for SFGT and WSAC in Figures 1 and 2.

The reason for this behavior of the marginal cost curve in WSAC has to do with the relationship between environmentally-caused damage and traffic-caused damage to track components. As an illustration, consider a segment of track with 100 ties, 10 of which have been weakened by environmental factors and will fail in a year's time—even in the absence of any rail traffic. Assume that operation of a single train over these ties will destroy one weakened tie and will also cause one sound tie to fail (due to mechanical damage). In addition, it is reasonable to assume that some number of the remaining nine weak ties will be pushed close to failure by the first train. Assume for the moment that two of the nine ties are now near failure.

Now, when a second train runs over the track, it will probably destroy the two weakened ties. In addition, the second train may also cause one of the otherwise sound ties to fail (as did the first train). So the first train destroys two ties and the second train three. This increase in marginal cost will continue until all the weakened ties fail and are replaced. At this point, the relationship between traffic and track damage will become linear.

The preceding scenario, while hypothetical, serves to show the interrelationship between environmental decay and mechanical damage to track components. This is the mechanism that accounts for increasing marginal costs at low traffic densities.

WSAC is an engineering model, and does not address such factors as difficulty of maintenance access or reductions in gang productivity due to traffic on busy mainlines. Costs are assumed to be linear with traffic at levels above 25 mgt per mile per year. Because of this, WSAC