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16. Abstracts

This study examines various operating and economic aspects of short train operation. It includes a summary of studies conducted by several railroads plus original research by the author. Changes in freight train labor productivity and costs are discussed and related to changes in capital invested in freight cars. Parameters relevant to train size include identified operating, economic and marketing factors. Since no comprehensive analytical procedures exist upon which to formulate conclusive answers, the study documents the need for the railroad industry to develop such a methodology.

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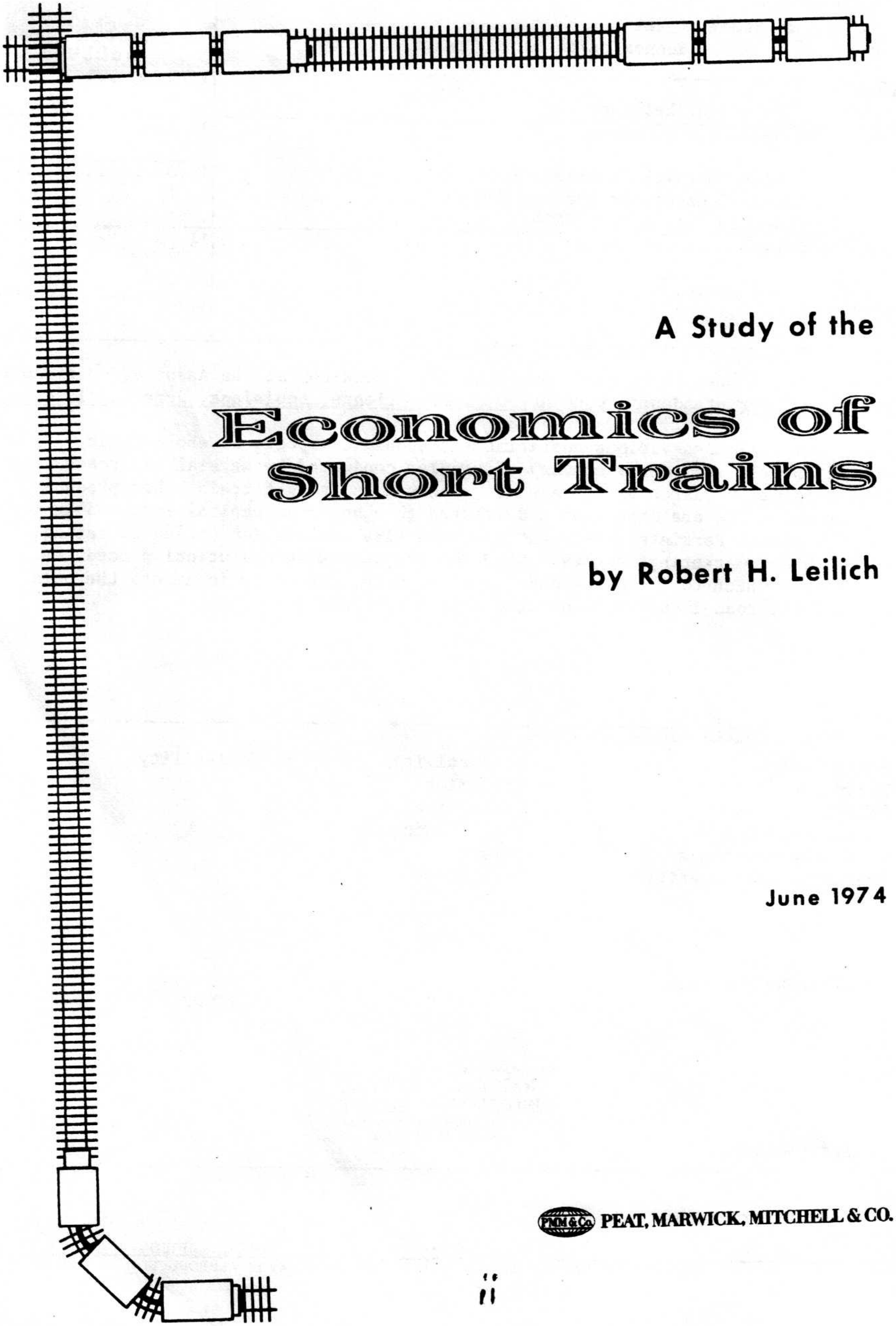

A Study of the

Economics of Short Trains

by Robert H. Leilich

June 1974

PEAT, MARWICK, MITCHELL & CO.

ACKNOWLEDGMENT

This study is an outgrowth of research undertaken for the Association of American Railroad Superintendents (AARS) Convention, New Orleans, June 1974. The author is grateful to the following AARS members who made substantial contributions to its preparation:

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I. INTRODUCTION

BACKGROUND

Evolution of Long Trains

Ever since the first steam train operated in the United States, railroad management has looked to longer trains as a means of reducing and controlling operating costs. This trend, given impetus by the development of larger and more powerful steam locomotives, was furthered by the invention of the Janney coupler and the building of still bigger locomotives. Westinghouse's invention of the air brake made undreamed of train lengths possible. Then came the development of solid steel underframes, successful operation of compound (or even triple) expansion steam locomotives, and invention of the A-B brake valve. By 1945, trains of 120 to 130 cars were not uncommon.

The diesel put almost unlimited drawbar pull under one engineman's hand and made it possible to start heavy trains without bunching slack. Roller bearings, further air brake system improvements, long cars, and composite brake shoes gave rise to trains nearly 1-1/2 miles long--lengths limited only by the shear and tensile strength of steel couplings between cars. Now, with mid-train radio-controlled slave power and flat-maintaining air brakes, the length of trains is theoretically unlimited. Trains with 500 cars that stretch over 4-1/2 miles have been tested. Coupling slack alone, at 6 inches per car, amounts to 250 feet, which means that the head end of a train can move about five car lengths before the rear end starts moving.

Why has the industry placed such emphasis on long trains? Is it all attributable to efforts to reduce operating costs?

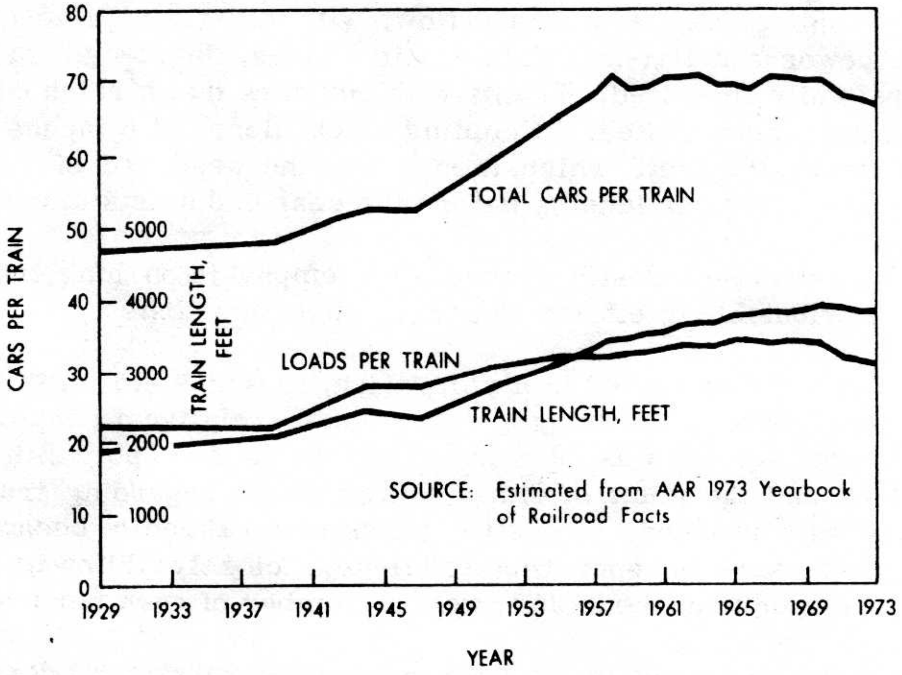
The trend is rooted in history: longer trains did initially reduce operating costs. Years ago, labor costs, relative to capital costs, were high, service was less important in the monopoly situation that existed, and the point of diminishing returns regarding train length had not been reached. Gross ton miles per train-mile became a near sacred measure of operating efficiency, closely followed by gross ton miles per train-hour and average number of cars per train.

On the other side of the coin, over-the-road delays, derailments, difficulties in arranging meets due to short sidings, yard tie-ups caused by doubling long trains, congestion, and so forth, were sobering statistics that suggested things may have gone too far. Such information, however, rarely reached the presidential suite in a manner convincing enough to warrant a review of main line operating practices.

Many carriers today do not operate symbol trains below specified minimum tonnages, and extras are operated only when sufficient tonnage is available. Although the principle may be reasonable, the economics of it are not necessarily sound, particularly if such practices seriously affect service and discourage use over the long run.

Growth and Productivity

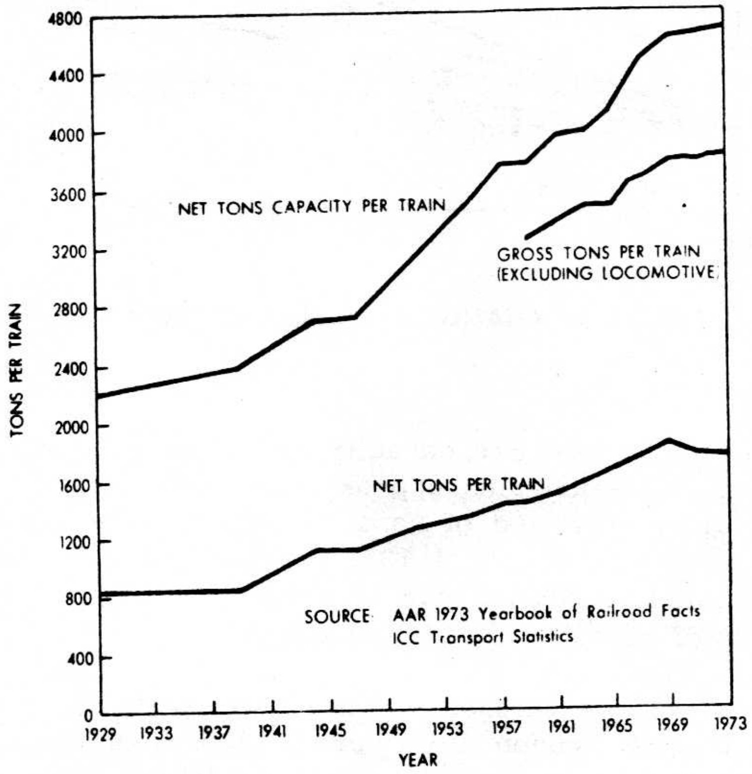
As shown in Figure 1, the number of cars per train increased from an average of 47.6 in 1929 to a peak of 70.5 in 1962 and 1967, an increase of 48 percent. Since 1967, the average dropped slowly to the 1973 level of 67 cars per train. Meanwhile, the length of the average car also increased (from 38 to 55 feet) so that the length of the average train increased by an additional 110 percent (from 1,802 to 3,808 feet) between 1929 and 1970. Revenue loads as a percentage of total cars in the average train has remained virtually unchanged at just under 50 percent.



SOURCE: Estimated from AAR 1973 Yearbook of Railroad Facts

FIGURE 1: HISTORICAL CHANGES IN TRAIN SIZE

As shown in Figure 2, net tons per train, which is perhaps a better indicator of productivity, increased by 126 percent from 1929 to 1970. Train capacity increased by 112 percent over the same period. In 1929, 36 percent of a train's available tonnage was utilized, compared with 38 percent in 1973, a statistic that should concern management. In 1929, the average train had 1,400 tons of unused tonnage capacity at a capital investment averaging $33 per ton (although cube utilization may have reduced the space actually available). In 1973, the average train had over 2,900 tons of unused capacity at an average capital investment of $130 per ton. In 1974, new cars average about $190 per net ton of capacity.



SOURCE: AAR 1973 Yearbook of Railroad Facts
ICC Transport Statistics

FIGURE 2: FREIGHT TRAIN TONNAGE UTILIZATION

Figure 3 shows the changes that have occurred in several important indices between 1929 and 1972. Although total freight train and engine labor costs per freight train-mile have increased nearly five-fold since 1929, improvements in freight train productivity (longer trains and more cars) have reduced the increase to a factor of three when measured on a car-mile basis. When measured in terms of revenue ton-miles, train and engine labor costs have only doubled. This last relationship, probably the most appropriate measure of the productivity of freight train labor, is significantly lower than the 4.3 multiple increase of equipment capital costs during the same period.

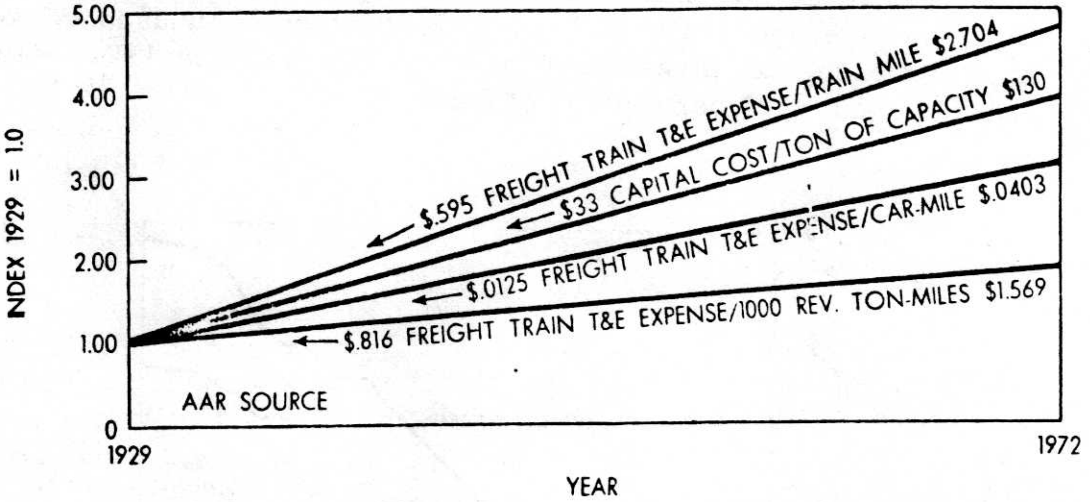


FIGURE 3: CHANGE IN TRAIN CAPITAL AND LABOR INDICES

One ton of freight car capacity costs the railroad about $25 per year ($12 depreciation plus approximately 10 percent in opportunity costs, or $13). One ton of capacity generates about 7,780 revenue ton-miles per year.[1] With 1974 freight train and engine (T&E) expense estimated at $1.569 per 1000 revenue ton-miles, annual T&E cost per ton of capacity is only about $12.

These statistics emphasize that labor costs alone are not necessarily the biggest economic concern in line-haul train operation. It is true that, taken as a whole, railroad labor costs are 51 percent of the revenue dollar, but in some areas, specifically line-haul train operations, capital costs for equipment alone are more significant than labor costs. And they can be controlled, at least as readily as labor costs. The only "contracts" or "work rules" governing use of equipment (capital) costs are shipper/user privileges and car service rules set up by the industry on its own volition.

1/ $\frac{\text{1,481 revenue ton-miles per car day in 1972} \times \text{365 days per year}}{\text{69.5 tons capacity per car}}$

THE PROBLEM

The dilemma of railroad main line operating practices centers on resolving conflicts between service and cost--between the tangible and intangible. Basing train size only on tangible, or visible, operating cost factors is likely to result in suboptimum operating policies and strategies. Optimization of main line operating practices requires consideration of service factors--intangible costs that most roads do not attempt to measure or quantify in any meaningful way. Consideration of service factors is equivalent to recognizing the well-established discount store philosophy that greatest profitability is not achieved by maximizing the margin between price and cost but by maximizing the product of margin times volume. Thus, for a given price (rate), higher quality (service) and higher cost may be more than offset by increased sales (traffic)--up to a certain, optimum, point.

The present unknown in mainline operating strategies is the cost elasticity of incremental levels of service. The question then is, will improved service (at a higher cost) increase car utilization, traffic, and revenues enough to improve total profits? Or, can profits be increased by improving capital utilization at the expense of labor productivity? Can the short train justify higher rates?

The industry must be selective in answering these questions. Short coal trains do not make economic sense. Neither do 150-car trains of auto parts, forwarder traffic, white goods, or other high revenue traffic. But where is the line drawn for other commodities? What effect does the addition of service factors have on train length and profits? How can we develop and implement a policy that produces the greatest profit?

For unregulated industry, profitability is the measure of success in melding economic and marketing relationships. The same is true for regulated industry, except when regulations prevent industry from implementing desirable economic and marketing relationships and from terminating undesirable ones.

STUDY OBJECTIVES

The object of studying short train operating economics was to:

- identify key parameters relevant to analyzing short train economics;

- summarize economic and operational studies made by selected carriers and evaluate their actual operating experiences; and
- discuss marketing implications of the short train and its relation to economics.

The study shows clearly that economic justification can be made for operating trains with as few as 50 cars or as many as 150. Given the present analytical methodology within the industry, however, optimum train size cannot be determined--even for specific point-to-point operating situations--since wide-ranging assumptions, policies, costing approaches, etc., bear so heavily on the outcome. This study, then, is confined to contributing to the state-of-the-art in analyzing various aspects of short train operation. If it serves to spark an industry desire to better identify economic parameters and to develop an analytical methodology, then it will have served its purpose.

DEFINITION

Opinion varies on the question of what constitutes a "short" train. The only agreement is that a short train is one with less tonnage than would normally be operated for a particular road or territory. For roads accustomed to operating 5,000- to 6,000-ton trains, a 4,000-ton train is a short train. For other roads, where 3,500 to 4,500-ton trains are the rule, a short train would be one of 3,000 tons or less.

For purposes of this study, a short train is one with 40 to 75 cars, ranging from 2,500 to 3,500 gross trailing tonnage.

II. TRAIN LENGTH AND OPERATING CHARACTERISTICS

The findings of two previous studies--a published report by the Massachusetts Institute of Technology[1] and an unpublished report by an eastern railroad--are summarized here as they relate to the question of train length and operating performance.

M.I.T. STUDY

The results of the M.I.T. study on train delays suggest that, for a given territory, trailing tonnage and track profiles do not correlate well with train delays, but that train length does. Longer trains appear to incur not only more frequent delays, but longer delays as well. Further, road delays contribute to additional delays in terminals, both to the original train and to other arriving and departing traffic. In other words, delays cause delays, creating a chain reaction of missed connections.

Causes of Delay

Burst Air Hoses

Burst air hoses occurred three times more frequently on trains with 75 or more cars (one failure for each 8,500 train miles) than on trains with fewer than 75 cars (one failure for each 28,000 train miles).

Sticking Brakes

The frequency of sticking brakes for trains with 75 or more cars (one failure for each 3,300 train miles) was a striking 8.5 times greater than that for trains of less than 75 cars (one failure for each 28,000 train miles).

1/A. Lang and R. Reid, Railroad Car Movement Reliability: A Preliminary Study of Line Haul Operations, (Cambridge: Massachusetts Institute of Technology, 1970).

Coupler Failure

For trains with less than 75 cars, the incidence of coupler failures was low (one failure for each 14,000 train miles). For trains with 75 or more cars, however, the frequency of coupler failures rose by a factor of 7.4 (to one failure for each 1,900 train miles).

Duration of Delay

The study found that trains of less than 75 cars averaged delays of 51 minutes per failure, while trains with 75 cars or more experienced average delays of 88 minutes per failure. Thus, delays encountered by the longer trains lasted 1-1/2 times longer than those of the shorter trains. The table below expresses this problem in a different way:

Train Length	% of Individual Delays Exceeding Two Hours	% of Individual Delays Exceeding Three Hours	% of Individual Delays Exceeding Five Hours
Less than 75 Cars	9	3	0
75 Cars and Over	21	12	4

Figure 4 summarizes the M.I.T. study findings for train delays over a 170-mile haul and a 500-mile haul (the study is cautious concerning data reliability). The effects of both distance and train length are noted, but train length has a much greater impact on total delays than does distance.

EASTERN RAILROAD STUDY

Many of the M.I.T. findings are reinforced by a study conducted by an eastern railroad.

Non-Track Caused Derailments

Derailment Probability As Function of Length

Figure 5 shows the historical probability or frequency of derailment per trip for various train lengths. Longer trains have a

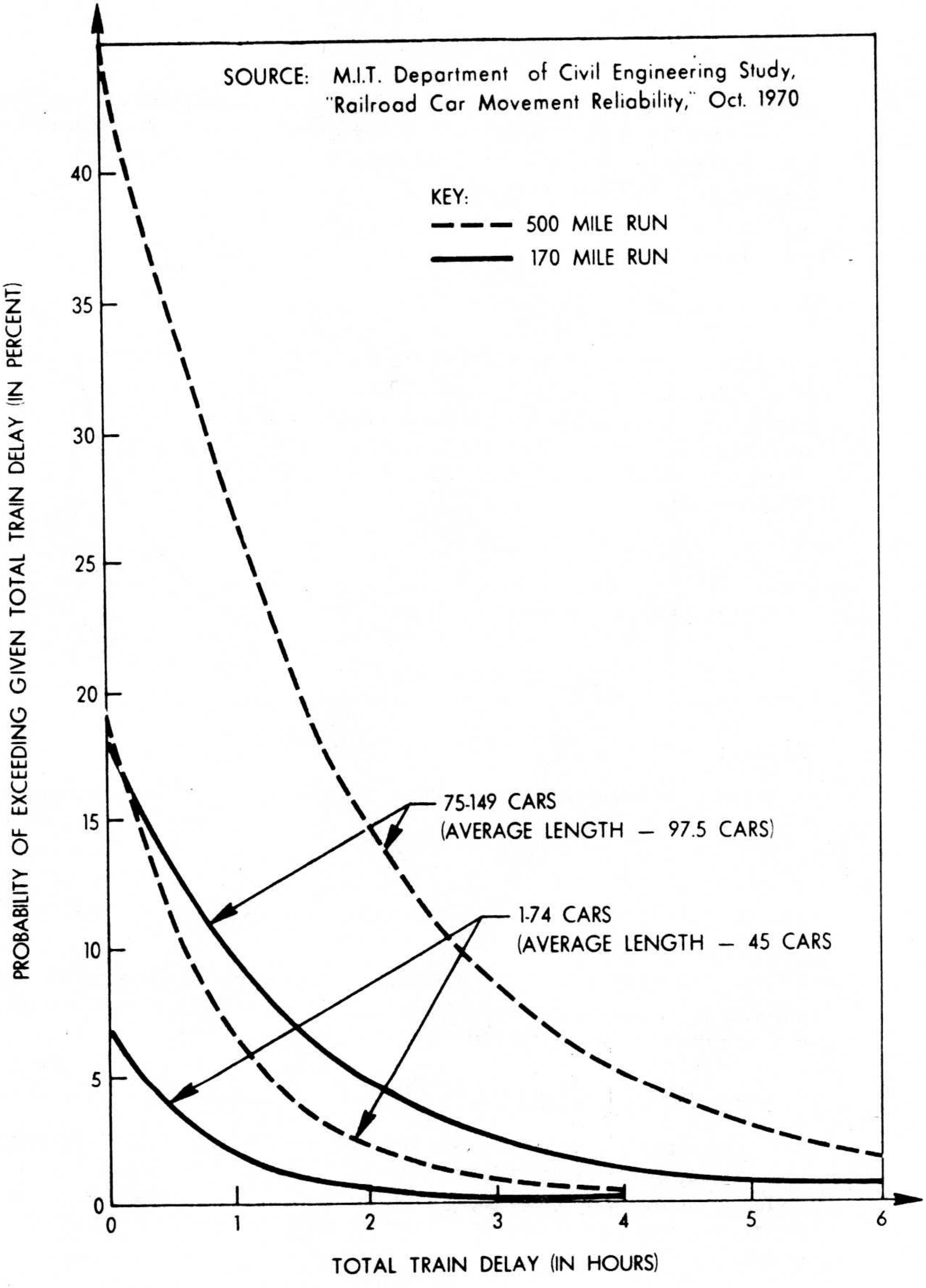


FIGURE 4: TRAIN DELAY DISTRIBUTION: 170 MILE RUN 500 MILE RUN

greater probability of derailment. Beyond 150 cars, derailment probability increases at an accelerated rate. Doubling the size of a 125-car train increases the probability of derailment nearly 16 times, so that one train out of 50 is likely to derail.

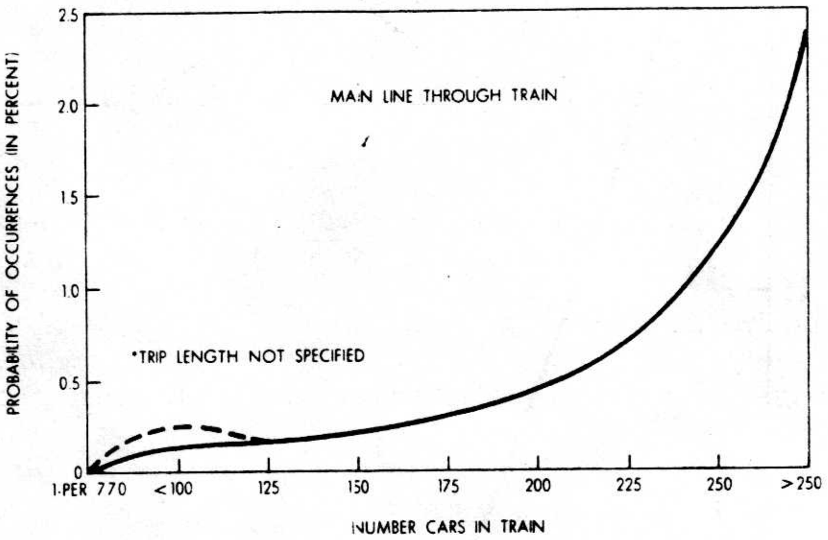


FIGURE 5: DERAILMENT PROBABILITY PER TRIP AS FUNCTION OF TRAIN LENGTH (NON-TRACK CAUSES)

The dashed line at the low end of the curve represents the influence of short, heavy trains (primarily coal), illustrating that weight, too, increases the probability of derailment.

Derailment Probability As Function of Weight

Although the weight of a train is often a function of its length, the eastern railroad study carefully selected a broad sample of weights within a narrow range of lengths. The result of correlating train weight with non-track causes of derailments is shown in Figure 6.

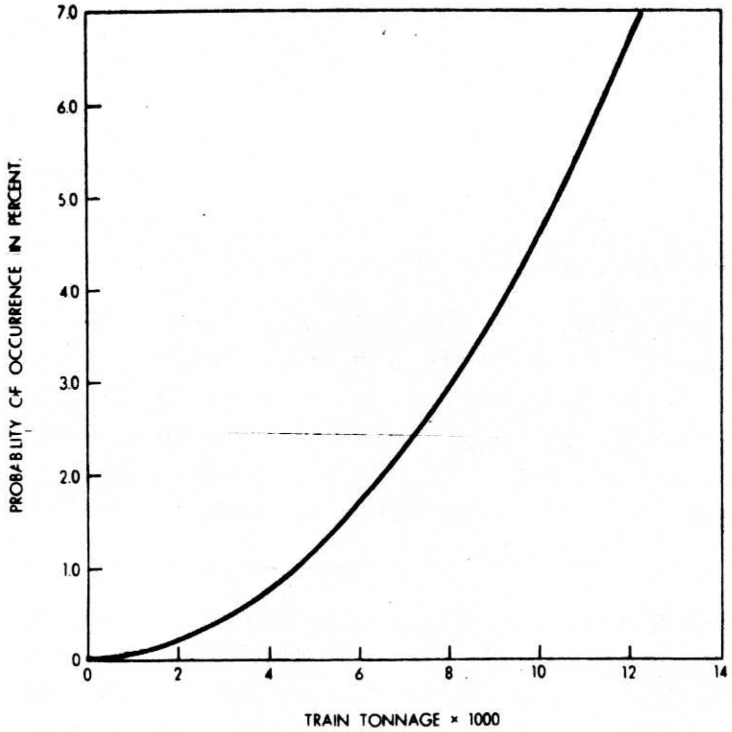


FIGURE 6: DERAILMENT PROBABILITY AS FUNCTION OF WEIGHT(TRAINS <100 CARS)

Again, the curve is exponential, with the rate of change increasing sharply beyond 3,000 tons. Note the high rate of occurrence in the range of very heavy tonnage. At 12,000 tons, the probability of derailment is more than twice that of trains 250 cars in length (although train length undoubtedly contributes to derailments in heavy trains, and weight contributes to derailments in long trains).

Derailment Severity As Function of Length

Figure 7 shows that the severity of derailments increases with train size. In the eastern railroad study, trains with more than 250 cars average 7.1 cars per derailment, as opposed to 4.6 cars for trains with 100 cars or less. Although derailment severity should theoretically also be a function of the square of velocity, significant correlation could not be established for non-track causes.

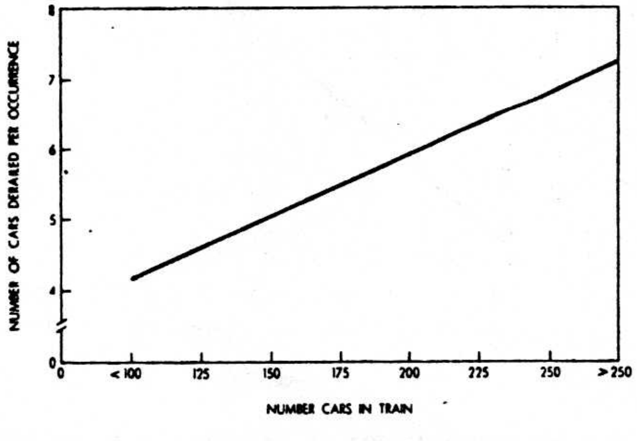


FIGURE 7: DERAILMENT SEVERITY AS FUNCTION OF TRAIN LENGTH(NON-TRACK CAUSES)

Track-Caused Derailments

No significant relationship was found between the probability of track-caused derailments and train length. The severity of track-caused accidents, however, is related to length because mass and kinetic energy ($MV^2/2g$) usually increase with train length, assuming speed as a constant. Thus, with more mass, longer trains tend to have more severe derailments because more kinetic energy must be dissipated in stopping.

The relationship between the severity of track-caused derailments and train length is shown in Figure 8. Consistent with the physics formula, the relationship tends to be linear. As train length increases, the number of cars derailed increases proportionately. Given the same train length and speed, derailments caused by track failure are much more severe than those attributed to other causes. For trains with 100 cars or less, the average derailment will involve 4.6 cars when caused by other than track conditions compared with 10 cars for trains of the same length (and speed) involved in derailments caused by track failures. Furthermore, the severity of track-caused derailments (compared to non-track caused derailments) increases at a faster rate (slope of line) as train size increases.

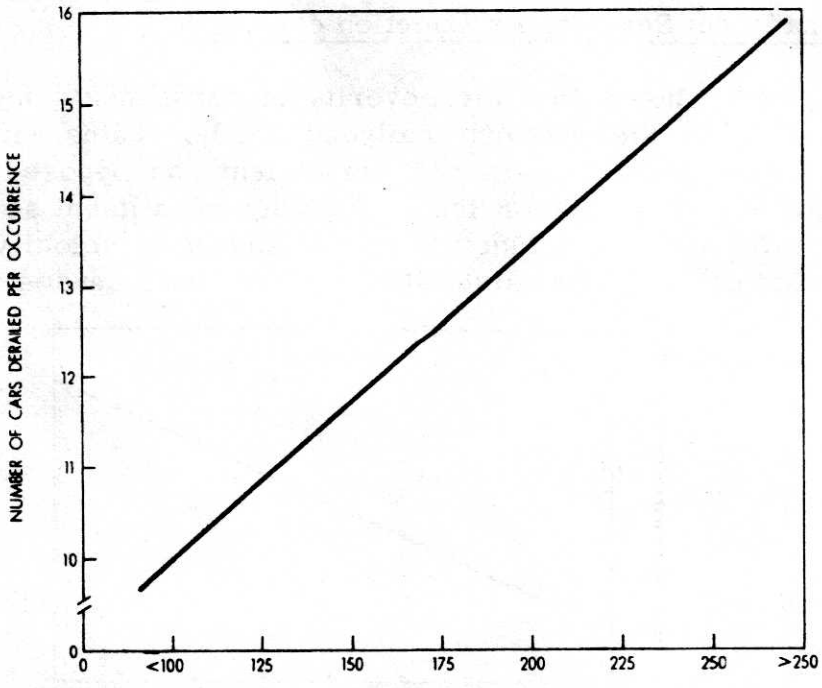


FIGURE 8: DERAILMENT SEVERITY AS FUNCTION OF TRAIN LENGTH (TRACK CAUSES)

Train Separations

Broken Knuckles and Drawbars

The rate or probability of broken knuckles and drawbars increases exponentially as train length increases. As illustrated in Figure 9, the curve increases most sharply over 200 cars.

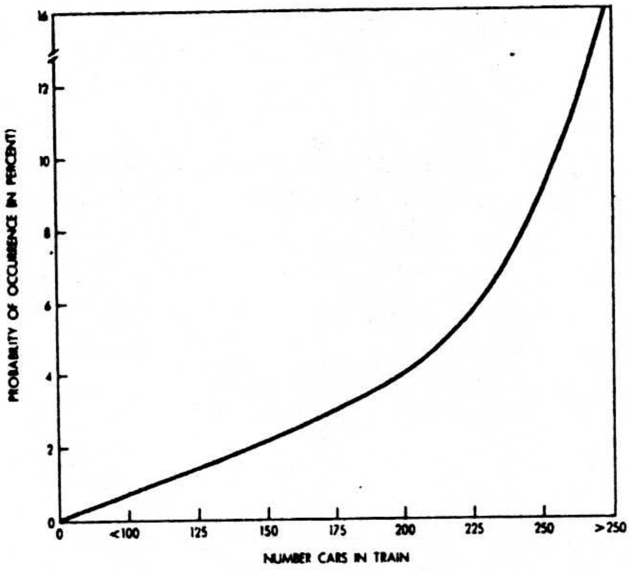


FIGURE 9: TRAIN SEPARATIONS PROBABILITY-KNUCKLES AND DRAWHEADS

Chances of breaking a knuckle or drawbar in a trip with a train of more than 250 cars is 23 times as great as for a train with 100 cars or less. For the very large trains, a separation once in six trains can be expected compared with one in 136 for the short trains.

Analysis of the delays caused by broken knuckles and drawbars reveals that delay increases linearly as train length increases. This relationship is shown in Figure 10.

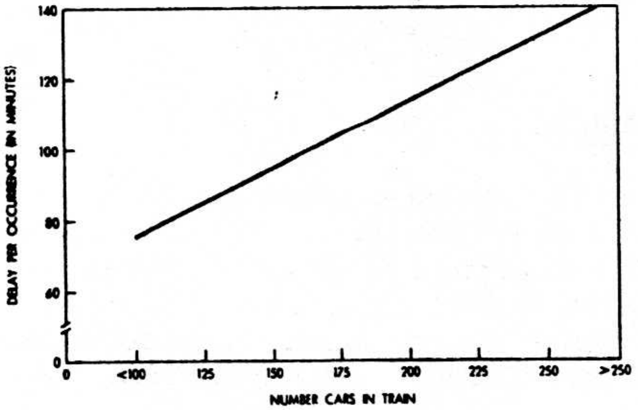


FIGURE 10: TRAIN SEPARATIONS - DELAYS, KNUCKLES, AND DRAWHEADS

Uncoupling

Figure 11 shows that the probability of uncoupling increases exponentially as trains become longer. The probability of a 250-car train uncoupling is one in 33 trains, compared with one in 500 for a train with 100 cars, which is 15 times as great.

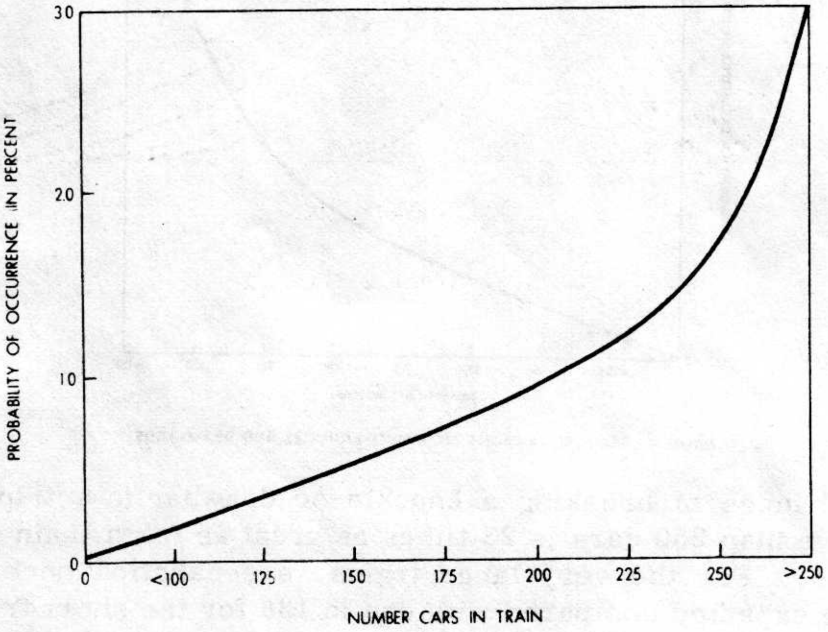


FIGURE 11: TRAIN SEPARATIONS PROBABILITY-UNCOUPLINGS

Schedule Reliability

Figure 12 relates schedule performance of an eastern railroad's trains to the size of the trains. Trains under 100 cars generally make schedule (at 90 percent of schedule elapsed running time) with a relatively small deviation from standard performance. Lengthy trains consistently require longer running times (even for the same horsepower per gross ton) and deviate much more from standard.

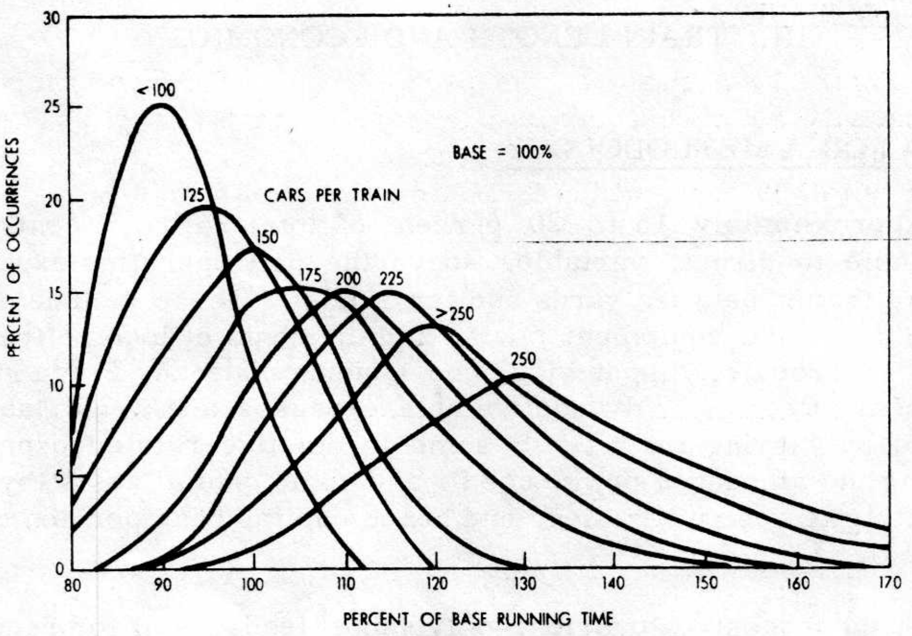


FIGURE 12: SCHEDULE RELIABILITY

III. TRAIN LENGTH AND ECONOMICS

NEED FOR A METHODOLOGY

Approximately 15 to 20 percent of total railroad costs are attributable to direct, variable, above-the-rail operating expenses for moving trains between yards and terminals. These include only train labor, fuel, and equipment costs, and the costs of locomotive maintenance and repair, dispatching, and superintendence. For a given volume of traffic, the only controllable expenses are train labor (controlled by varying train size), some locomotive-related expenses (by varying the amount of power used), and some capital costs (by altering transit time, car utilization, and hence capital cost per ton of freight carried).

Of these cost categories, only labor lends itself to precise measurement. Because labor is so highly visible, there is a tendency to minimize it by operating longer trains, since the costs incurred by longer trains are not easily identified. But to examine the economics of short train operation, cost increases must be weighed against cost decreases, and operating economics must be related to marketing economics.

Although many railroads have studied the advantages and disadvantages of short trains, review of work in this area leads to one major conclusion: There is a vital and demonstrated need for the development of a thorough, flexible, and universal methodology for evaluating economics of shorter and longer trains. Such an understanding is vital to the establishment of the best profit-oriented marketing and operating strategies.

The development of this methodology can go a long way toward resolving differences between traffic and operating departments and clear the way for a marketing program that will capitalize on the inherent economics of a given operating and marketing environment. Specifically, a methodology should develop economic, variable-cost relationships (however intangible) for the following factors:

- Train Operating Costs. This includes train labor, other crew-related expenses, fuel, equipment capital (utilization or turnaround), maintenance and repairs, dispatching, etc.

- Yard Operating Costs. Train size impacts yard costs, including expenses for switching, equipment capital, yard capacity requirements, overtime, congestion, interchange services, etc.

- Maintenance of Way. Shorter trains may be operated at slower speeds to maintain a given schedule because fewer (and shorter) delays are encountered per train. Reduced speeds may lower maintenance standards or reduce costs for a set standard. On the other hand, shorter trains mean more trains, which may reduce on-track time for maintenance-of-way gangs and increase maintenance costs.

- Derailment, Loss, Damage, and Accident Costs. These expenses, although a relatively minor portion of total operating expenses, are vital to the extent their relationship to train operations can greatly affect optimum strategies.

- Revenue. Shorter trains improve service, speed, and reliability. This will attract additional traffic and possibly permit premium pricing of certain traffic, all with favorable economic connotations. A methodology should include the economic impact that would be achieved from predicted changes in service, speed, and, most importantly, reliability. In economic terms, it is an elastic three dimensional relationship between demand, price, and service.

The methodology must be sensitive to peculiar commodity and traffic requirements of a railroad; establishing one level of service for all situations is not a solution. The optimum strategy is to provide varying levels of service, defined by the economic relationships inherent in each service as well as its relationship with other services. For example, running short, fast trains for a certain class of traffic may adversely affect stone traffic because fewer trains will be available to handle this traffic, which often moves on a space-available basis.

RELEVANT STUDIES

Although this research does not necessarily support all the findings of studies conducted by carriers, several of these studies are abstracted here because of their relevance and contribution to the central issues.

Southeastern Railroad

The following annual economics (1974 cost level) and statistics are estimated for operating 100-car trains versus 150-car trains over a defined section of railroad.

TABLE 1

ECONOMIC SUMMARY OF 100-CAR VS 150-CAR TRAIN
(1974 DOLLARS)

	Incremental Cost Per Train (100-Car - 150-Car)	Total Incremental Difference
Number of Trains		+ 19,274
Cost Increases, Short Train		
Crew Costs	$290.00	$5,589,460
Fuel	143.31	2,762,100
Crossing Accidents	3.96	76,402
Total	$437.27	$8,427,962
Cost Decreases, Short Train		
Car Hire	315.16	6,074,340
Radio Train Equipment	22.16	427,134
Derailments-Non-Track	105.59	2,035,121
Derailments-Track	5.44	104,838
Train Separation	7.61	146,740
Uncouplings	.83	16,037
Terminal Delay	6.50	125,209
Deadheading	4.13	79,650
Yard-Car Handling	24.57	473,486
Total	$491.99	$9,482,555
Net Annual Savings Before Taxes	$ 54.72	$1,054,595

It is interesting to note that the original study, conducted seven years ago, produced estimated savings of $3.1 million, suggesting that the economy of shorter trains has decreased during the period. Also noteworthy is the trade-off between car-hire (essentially a capital-related expense) and labor expense.

Unfortunately, this study did not examine the economies of other train lengths to determine what the optimum length might be. But it did suggest that trains with less than 100 cars would produce further economies.

Major Midwestern Railroad

A study conducted by a major midwestern railroad included the following observations.

The goal of railroad operating departments is to minimize total costs (that is, the sum of labor, material, and capital costs). Labor cost varies with the train mile or yard engine hour; capital costs vary with time. Therefore, the operating problem is to determine the point at which the sum of labor and capital cost is minimized. The longer the cars accumulated, the longer the train, and the lower the labor cost per unit; conversely, the higher the capital cost per unit.

The present high labor cost per train-mile relative to low per diem rates makes it generally economic to delay cars to run long trains. It should be noted that the present low profit margins per unit tend to minimize service considerations in the capital/labor trade-off.

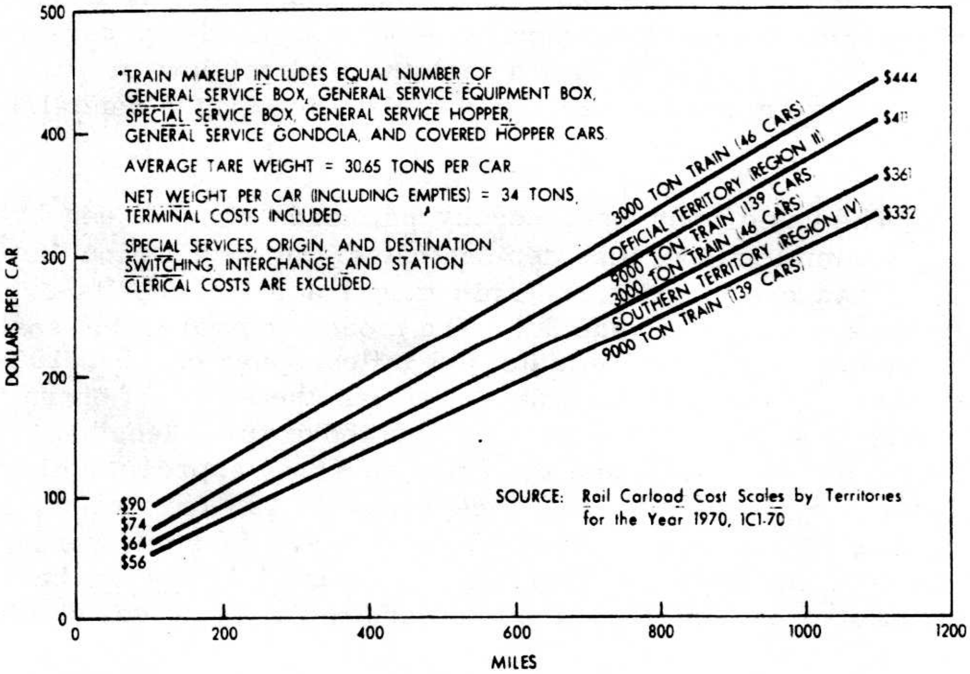
The basic problem faced by railroads can be seen by constructing a simple model that demonstrates the interaction between crew costs and capital costs. (This model and the results are presented in Appendixes 1, 2, and 3.) The model compares the cost of moving a car between two terminals 300 miles apart on 50-, 100-, 150-car trains. The model also demonstrates the effect of operating various levels of service frequency for the above train lengths. The results show, for example, that the railroad saves approximately $7 per car handled by moving blocks once a day in 150-car trains, rather than moving 50-car trains three times a day. In other words, the added car cost incurred by delaying trains until 150 cars have been accumulated is far less than the additional crew costs that would be incurred by running three 50-car trains. (Thus, from the previous study, one might conclude that the economic train from an operating viewpoint is somewhere between 50 and 100 cars.)

The $7 per car figure is a significant amount because of the narrow profit margins in the railroad business. In 1970, the average pre-federal income tax net railway operating income per carload was less than $20 for the subject railroad.

The present economies involved in the capital/labor trade-offs do not favor rapid movement of cars. If there is to be any significant improvement in car supply and service, the cost of a train mile must be reduced so that it will be economical to run shorter and more frequent trains.

RAIL FORM A ECONOMICS

Figure 13 shows an adjusted Rail Form A cost comparison for a 3,000-ton (46-car) train and a 9,000-ton (139-car) train for various distances in Southern (low cost) and Official (high cost) Territories. Non line-haul related costs are excluded.



*TRAIN MAKEUP INCLUDES EQUAL NUMBER OF GENERAL SERVICE BOX, GENERAL SERVICE EQUIPMENT BOX, SPECIAL SERVICE BOX, GENERAL SERVICE HOPPER, GENERAL SERVICE GONDOLA, AND COVERED HOPPER CARS

AVERAGE TARE WEIGHT = 30.65 TONS PER CAR

NET WEIGHT PER CAR (INCLUDING EMPTIES) = 34 TONS, TERMINAL COSTS INCLUDED

SPECIAL SERVICES, ORIGIN, AND DESTINATION SWITCHING, INTERCHANGE AND STATION CLERICAL COSTS ARE EXCLUDED

SOURCE: Rail Carload Cost Scales by Territories for the Year 1970, ICI-70

FIGURE 13: RAIL FORM A ESTIMATED 1974 VARIABLE LINE HAUL COSTS FOR VARIOUS SIZE TRAINS* (INCLUDING ALLOWANCE FOR EMPTY RETURN)

Cost differences are summarized in Table 2.

TABLE 2

PER-CAR LINE-HAUL COST DIFFERENCES BETWEEN 3,000- AND 9,000-TON TRAIN

	3,000-ton Train - 9,000-ton Train			
	Southern Territory		Official Territory	
Expense Per Car	100-Mile Trip	1,100-Mile Trip	100-Mile Trip	1,100-Mile Trip
Freight Train Operating	$+15	$+61	$+26	$+89
Intermediate Switching	0	-25*	0	-46*
Origin/Destination Freight Train Car Cost	- 7	- 7	-10	-10
Net Increase	$+ 8	$+29	$+16	$+33
Total 9,000-Ton Train	55	332	74	411
Total 3,000-Ton Train	64	361	90	444
Percentage Increase	14%	9%	22%	8%

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*Assumes only one intermediate classification for 3,000-ton train versus per car-mile regional average allowance for 9,000-ton train.

Although Form A may be appropriately used to develop these cost differences, it fails to provide the accuracy of an industrial engineering analysis of available costs. Nevertheless, several interesting observations can be made:

- Short trains operated over short distances incur the smallest cost penalty over larger trains in terms of dollars, but the largest penalty in terms of percentage increase.
- Conversely, short trains operated over long distances incur the largest cost penalty over large trains in terms of dollars, but the smallest penalty in terms of percentage increase.

- Intermediate switching savings are negligible or nonexistent for short hauls, but significant for long hauls.
- Origin/destination car costs (capital or per diem) are not related to distance and diminish in relative importance for long haul traffic.

It must not be concluded that because operating costs are higher for short trains, short trains are uneconomic. The converse may be true. Where marginal increases in short train operating costs are less than marginal increases in the market value (earnings) generated by improved service, short trains are preferable to long trains.

When data and resources are limited, the economics of short trains must be developed for each situation. Once a methodology and data base are developed to take into account both marketing and operating economic relationships, specific, measurable, and known operating conditions and marketing parameters can more readily be related to optimum train length (where train length is a function of service).

Where new, fast trains are to be operated for new traffic, implementation should be based on maximizing profits (not necessarily gross revenue) and should reflect tested relationships, including marketing (pricing) demand elasticity, competitive transportation alternatives (demand), service (cost) levels, and alternative investment opportunities. Profitability should usually be calculated on the basis of fully allocated costs because incremental margin-based profit opportunities almost always belong at the bottom of the list of investment alternatives available to railroads.

For existing secure traffic, the short train operation is purely a question of total economics and of maintaining at least the minimum service expected by the traffic.

EXAMPLES OF SHORT TRAIN ECONOMICS

Western Railroad "A"

In late 1973, the historical scheduling between two major areas, nearly 1,800 miles apart, called for train departures approximately every eight hours. Frequently more than one section was operated. Under a trial operating concept, train departures were scheduled every four hours. The results have been remarkable: To date, indications are that freight car turnaround time between these areas has improved by an average of better than two days per car.

For TOFC traffic, it has greatly improved flat-car availability. Within 30 days after trial start-up, TOFC flat-car shortages disappeared, even though business increased. Eliminating the flat-car shortage reduced trailer congestion in major TOFC yards and helped to eliminate seven hostling positions and overtime at one terminal alone.

While the figures with respect to perishable freight claims take several months to catch up, studies have indicated that this major perishable hauling line has substantially increased its capability to meet advertised perishable schedules. Another significant benefit of improved, more frequent service has been the reduction in delays for power and cabooses and reduced intermediate yard congestion.

In hard dollars, studies indicate that the 48-hour improvement in equipment turnaround time on the main line will result in gross savings of $17.5 million annually, whereas annual operating crew costs will increase only by $4.27 million, producing net before-tax savings of about $13 million.

Until the recent energy crisis developed, almost every operating manager on the railroad was convinced that the short train with high frequency scheduling is the way to go. Observations over the past two years conclusively indicate that a train of 3,000 tons or under can beat schedule. The heavier train, in spite of additional power, often performs oppositely.

Other significant observations from the trial include:

- 3,000- to 3,500-ton trains operating at speeds of up to 70 MPH use 15 percent more fuel than 5,000-ton trains operating at 50 MPH.

- Track and bridge maintenance suffer from high frequency of train operation.

- The short, fast train markets itself: Fast trains become a link in shippers' assembly lines; short or light fast trains become a dependable, fast link in the shippers' assembly line.

- Speed and schedule reliability are greatly improved.

Western Railroad "B"

For some time this road has operated a number of trains that fall in the short, fast category. These trains, run primarily for mail and merchandise, eliminate the service irregularities that shippers find in conventional freight trains. These trains are limited to modern equipment with roller bearings, operate at speeds above those of conventional trains, and carry 110 pounds of train-line pressure to give effective braking power. As a result, these trains are quite free of equipment failures, can be operated on consistent schedules, do not disrupt intermediate terminals, and provide the dependability of service that shippers of merchandise traffic demand. They have been well received, and the railroad is able to hold traffic once it is placed consistently on this type of train. These trains require no switching at intermediate points and carry traffic for one limited geographical area. They run up to 2,000 miles or more without the need for reclassification that is usually found necessary in conventional trains.

Studies suggest that widespread operation of this type of train could reduce the need for large classification yards that cost about $20 to $40 million each. It is difficult to run large trains for more than about 500 miles without the need to reclassify the train, or at least to take off and add blocks of traffic. This is especially true on lines with relatively light traffic density and those that have several diverging and converging routes where cars must be left or taken.

Midwestern Road

In 1972, this midwestern railroad proposed changes to test the profitability of operating short, fast trains over an entire section of railroad. The central concept of the study was that frequent train service with small crews can generate much new revenue, improve equipment utilization, and make the section of railroad much more profitable.

A vital conclusion of the study was that short, frequent trains will not succeed unless the railroad can operate with small crews. To test this basic concept, costs were recalculated to reflect application of manning agreements in effect at the end of 1971, when all existing runs will have two brakemen and all new runs will have firemen. Also, all so-called "must" jobs for firemen will be filled, and the proportion of conductor and helper yard jobs will remain unchanged. Projected 12-month results suggest a reduction in profit margin to about current levels.

In terms of improved earning, a breakeven operation is highly undesirable from the company's standpoint because of the risks of experimentation. The nature of the experiment guarantees that the railroad will incur many categories of expense, but attainment of revenue goals is necessarily much less definite. It is, therefore, apparent that the railroad cannot justifiably operate an experiment under a conventional manning agreement. Since the United Transportation Union and the railroad could not agree on work rule terms, the experiment has not yet been conducted.

Other Railroads

The number of short trains operated by railroads in special situations is increasing. Some prime examples are the "Super C" run by the Santa Fe; "Commoditrains" operated by the Chicago and North Western; a rock train operated by the Rock Island; a "Fresh from the West" perishable train operated by the SP, UP, and PC; and TOFC "hot shots" on many roads. All are tied to new business or to reducing costs of handling existing business by conventional means; only few are run from operating necessity or simply to preserve existing traffic.

Each railroad believes these trains are successful in meeting profit objectives. It is a strong indication that even on heavily traveled main lines, short trains have their place and make economic sense.

IV. SUMMARY

The purpose of this study is not to dwell on current short train operations, which represent only a fraction of present revenues, but to focus efforts on much larger opportunities. Although this report studies the economics of short trains in some length, it leaves unanswered the basic question relating to the desirability of operating short trains either for specified traffic or as a matter of policy. The most significant conclusion reached in this study is the need for a more sophisticated methodology to evaluate the economics of train size. This methodology should incorporate economic parameters relating to operations, capital, market demand, traffic pricing, shipper service requirements, and other factors found relevant.

Because railroads exchange a great deal of traffic with each other, the development of a methodology should have universal application to promote coordinated efforts by carriers. For joint interline traffic, the go-it-alone approach by an individual railroad could cancel the efforts of another to improve service to interline traffic.

If this study does not provide answers to the basic question of short train economics, it does point up several facts relevant to the operation of freight trains:

1. The annual capital cost of providing freight train equipment has increased at twice the rate of freight train labor expenses, as measured in terms of revenue per ton-mile.

2. The average ton of freight car capacity costs about $25 per year in capital and opportunity costs plus about $12 in train and engine labor expenses.

3. Main line operating practices should focus on maximizing profit opportunities--not on minimizing either line haul cost or maximizing revenue. It is a classical economic problem for which no methodology or answer now exists and for which relationships are relatively unknown or difficult to measure. Yet a methodology can be developed and answers can be found to resolve the conflict between operating and traffic department with a very positive and substantial financial impact on the railroad industry.

4. Because of wide-ranging assumptions, policies, costing approaches, etc., it is difficult to make a conclusive case for short or long trains for a given situation.

5. Train length by itself appears to be a material contributor to poor freight train schedule performance. In general, this relationship increases geometrically with arithmatic increases in train length.

6. The probability and severity of train accidents or derailments also increases geometrically with arithmatic increases in train length. Although the severity of train derailments correlates more closely with train weight (for a given speed), train weight is generally a function of length, except for such specialized operations as coal unit trains.

7. Whereas the per-car cost of operating short trains increases rapidly as train size decreases, there are several costs decreases that are wholly or partially offsetting: intermediate switching, origin/destination costs, freight train car costs, loss and damage claims, accident costs. Further, new traffic may contribute to a higher level of profit in spite of lower margins.

8. The economy of short trains is not necessarily restricted to short hauls. While short trains operated short distances incur the smallest cost penalty per car, the penalty is largest in terms of percent increase in costs. The reverse is true for short trains operated long distances.

9. Equipment capital car costs at origin/destination are independent of length of haul and diminish in overall importance as the length of haul increases. Thus, for short hauls, the economics of short trains are more greatly influenced by the ability to reduce origin/destination freight train car costs. For longer hauls the ability to reduce intermediate switching is a more important factor.

10. Prima facie evidence of higher operating costs for short train operations does not mean that short trains are uneconomic. The reverse may be true if it can be demonstrated that short trains bring in more revenue.

11. Some carrier studies suggest that unless railroads can substantially reduce the cost of T&E labor per train mile, it is unlikely that broad application of a short-train strategy would decisively improve the railroads' financial position. The very difficulty of determining whether short trains are justified strongly suggests that the real trade-offs for a broad range of traffic are probably very nearly balanced. Thus, unless railroad labor contracts change significantly, it is likely that motor carriers will retain the vast majority of high-value traffic, even in today's era of high fuel costs.

12. Several railroads have experimented with short train operations; some as a general operating policy and others for specific applications. Many of these trains have proven to function well and to make good economic sense. In some cases, they have provided additional profits from existing businesses. In others, they have been the principal tool with which to solicit and develop selected new business, often from motor carrier competition.

13. In view of the existing energy crisis, the short train has a distinctive place in spite of its greater fuel requirement for a given volume of traffic. The advantage comes with the recognition that only the short train can provide competitive service. Compared to the motor carriers' thirst for fuel, fuel requirements for short train operations are still greatly lower per net ton of freight handled. The energy crisis is a good reason why the railroad industry should capitalize on the opportunity to run short trains for the deliberate purpose of soliciting and winning high revenue traffic away from the motor carriers.

APPENDIX 1

ECONOMIC RELATIONSHIPS

To quantify the effect of train length and schedule frequency on capital costs (i.e., car costs) it is necessary to identify the primary relationships that involve train length, frequency, and car costs. Appendix 2 summarizes these relationships algebraically; Appendix 3 utilizes sample data to calculate the effect of varying train lengths and frequency of movement on costs.

I. Train size effects

  A. Car and locomotive ownership costs

    1. Car queuing time in the departure yard - time consumed while building a train - collecting blocks and pumping air

    2. Car queuing time in the arrival yard - time consumed while processing train to class yard (bleeding, shoving high, etc.)

    3. Car and locomotive costs in line haul service as a result of set outs and pick ups enroute

    4. Car and locomotive costs in line haul service (as a result of variations in running time)

    5. Locomotive costs in terminals - waiting for a return schedule

  B. Labor Costs (crew costs per unit handled)

II. Block size effects

  A. Car costs

    1. Car inventory time in the class yard

    2. Cost per block for set outs and pick ups

  B. Labor Costs

    1. Switching costs per block

    2. Transferring block from class yard to departure yard

APPENDIX 2

COST FORMULA

A. Car cost in class yard:

$$\left(\frac{12}{N_{TB}}\right) \cdot \left(PD_C\right) = \text{Cost per car handled}$$

where:

N_{TB} = Number of trains handling Block B per day

PD_C = Average hourly per diem value per car

Assumptions:

1. Cars arrived in class yard randomly.
2. Departures of trains are evenly spaced throughout day.
3. At least one train is processed per day.

B. Locomotive cost in yard (per car cost):

$$\frac{(12) \cdot (N_L)}{(N_T)(\text{Vol})_{B1,\,2\ldots N}} \cdot (PD_L) = \text{Cost per car}$$

where:

N_L = Average units per train

N_T = Number of trains

PD_L = Average hourly ownership cost per unit

$(\text{Vol})B1,\,2\ldots N$ = Number of cars per day

C. Block switching costs:

$$\frac{(N_{BT})\ (\$40)\ (Ts)}{Vol_{B1,\,2\ldots N} \big/ N_T} = \text{Cost per car}$$

where:

$40 = Out of pocket cost per switch engine hour

Ts = Standard time in hours for switch engine round trip departure yard to class yard

N_{BT} = Number of blocks per train

$Vol_{B1,\,2\ldots N}$ = Total volume cars

D. Car cost consumed in train make up:

$$\frac{(N_{BT})\ .\ (Ts)\ .\ (PD_C)}{2} = \text{Cost per car}$$

E. Set out and pick up car and locomotive costs per set out or pick up:

$$.75 \left(PD_C + \frac{(N_L)\ .\ (PD_L)\ .\ (N_T)}{Vol_{B1,\,2\ldots N}} \right) = \text{Cost per car}$$

<u>Assumption:</u>

Average pick up or set out takes 45 minutes = (.75 hours)

F. Crew Cost

$$\frac{K_{B1, 2... N} \times N_T}{Vol_{B1, 2... N}} = \text{Cost per car}$$

where:

$K_{B1, 2... N}$ = Crew cost of trains handling blocks 12...N

G. Car cost consumed queuing at destination yard:

$$\frac{Vol_{B1, 2... N}}{N_T} (T_{Bld}) \ (PD_C) = \text{Cost per car}$$

where:

T_{Bld} = Standard time to bleed a car

Hours = .017

APPENDIX 3

VARIATIONS IN COSTS PER CAR BECAUSE OF CHANGES IN TRAIN LENGTH AND SERVICE FREQUENCY

(1972 Dollars)

SAMPLE DATA

<u>Operating System</u>: 300 miles long; 60 blocks; total volume 3, 000 cars

<u>Values for Variables</u>

Train Size:	No. of Trains:	No. of Locomotives:	Frequency of Movement of Block:		
			1/day	2/day	3/day
50 car	$N_T=60$	$N_L=1$	$N_{BT}=1$	$N_{BT}=2$	$N_{BT}=3$
100 car	$N_T=30$	$N_L=2$	$N_{BT}=2$	$N_{BT}=4$	$N_{BT}=6$
150 car	$N_T=20$	$N_L=3$	$N_{BT}=3$	$N_{BT}=6$	$N_{BT}=9$

<u>Values for Constants</u>

PD_C = 4/. 24 = \$. 17 (\$4 per diem rate)

PD_1 = 100/24 = \$4. 17 (\$100 per diem rate)

$Vol_{B1,2...N}$ = 3, 000 cars

T_s = . 50 hours (Assumes 1/2 hour round trip, class yard to departure yard)

$K_{B1,2...N}$ = (3) (\$200) = \$600 (Assumes train labor cost per 100 miles is \$200)

T_{Bld} = . 006 hours (= 22 seconds) (Assumes a train can be bled at a rate of one car per 22 seconds)

RESULTING VARIATIONS

		50-Car Train	100-Car Train	150-Car Train
Once-a-Day Frequency - per Block				
A.	Car Cost in Class Yard	$ 2.00	$ 2.00	$ 2.00
B.	Locomotive Costs in Yard	.02	.03	.05
C.	Block Switching Costs	.20	.20	.20
D.	Car Cost Consumed in Train Make Up	.02	.04	.06
E.	Set out and Pick up Cost	--	.20	.40
F.	Crew Cost	12.00	6.00	4.00
G.	Car Cost Destination	.14	.28	.42
	Total Cost Per Car	$14.38	$ 8.75	$ 7.13
Twice-a-Day Frequency - per Block				
A.	Car Cost Class Yard	1.00	1.00	1.00
B.	Locomotive Cost in Yard	.02	.03	.05
C.	Block Switching Cost	.40	.40	.40
D.	Car Cost Consumed in Train Make Up	.04	.08	.12
E.	Set out and Pick up Cost	.20	.40	.80
F.	Crew Cost	12.00	6.00	4.00
G.	Car Cost Destination	.14	.28	.42
	Total Cost per Car	$13.80	$ 8.19	$ 6.79
Three-Times-a-Day Frequency - per Block				
A.	Car Cost Class Yard	.67	.67	.67
B.	Locomotive Cost in Yard	.02	.03	.05
C.	Block Switching Cost	.60	.60	.60
D.	Car Cost Consumed in Train Make Up	.06	.12	.18
E.	Set Out and Pick Up Cost	.40	.60	1.20
F.	Crew Cost	12.00	6.00	4.00
G.	Car Cost Destination	.14	.28	.42
	Total Cost Per Car	$13.89	$ 8.30	$ 7.12