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Transportation Costs and Their Implications: An Empirical Study of Railway Costs in Canada

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In transportation economics, the efficient allocation of resources and the method of allocation whether by the market or by regulation require detailed knowledge of market, market structure, and costs. All too often the policy deliberations of economists are hampered by inadequate empirical study. This paper describes a study which resulted in producing costing systems currently used by the Canadian National Railways and the Canadian Pacific Railway Company. The purpose of the paper is to shed light on an important area of transportation economics—railway costs.

Brief History of Railway Costing

In the late 1890's, a number of engineers, notably Lorenz, attempted to approximate railway cost behavior through engineering formulas. The work of J. M. Clark[1] is, however, the starting point of modern cost analysis in railway transportation. Clark's procedure was to develop a cross-section statistical relationship based on a number of U.S. railroads to demonstrate that significant overhead or constant costs existed in railway transportation. Ford K. Edwards, a student of Clark's, applied his techniques, first, with the California Public Utility Commission and, second, with the Interstate Commerce Commission.

[1] J. M. Clark, *Economics of Overhead Cost.*

From this emerged cost-finding procedures still in use in railway pricing and regulation in the United States.

The ICC costing procedures have had a significant effect on the economics of railway transportation through extensive railway regulation, and the intermingling of regulation and management. Essentially, the ICC procedures are a compromise between the need of the accountant to record all the costs in a specific set of accounts, often on a somewhat arbitrary basis, and the desire of the economist to trace expenses to the output that occasions them, in order to determine the costs associated with specific changes in service or output.

Currently, all railway expenses are grouped on the basis of an accounting classification prescribed some eighty years ago by the Interstate Commerce Commission and still used with little modification in both the United States and Canada. The classification is designed to achieve a uniform reporting of railway expenses, but it does not facilitate cost analysis.

The first step in the ICC costing procedure is to distribute expenses in each account into five service areas: line-haul, switching, station and platform services, special or ancillary services, and overhead. Accounting methods are used in some phases of the allocation. For example, an analysis of the time spent in a sample of stations is used to distribute station labor expenses among the various services performed at stations. While the study itself may be arithmetically accurate, little can be inferred from it about the behavior of total station expenses as a result of changes in the volume of output or in its mix.

A method of analysis that would reflect the fact that not all railway expenses vary with traffic volume was needed. A simple, linear, cross-section regression analysis, based on total operating expenses, rents, and taxes, of a number of United States rail systems, as well as arithmetic comparisons of time variability of expenses with time variability of traffic volume, were developed and used by regulatory agencies. The dependent variable in the cross-section analysis was operating expenses per mile of road, and the independent variable, gross ton-miles per mile of road, or density. The procedure, in effect, was a simple regression on ratios. The value at the intercept on the dependent expense axis was then subtracted from the average value of expense among U.S. railways. The residual, expressed as a percentage of the average value of the dependent variable, was used to measure the per cent of variability among all railway operating expenses. A similar procedure was used to assess variability of road and equipment capital investment, to which was then applied a cost-of-money factor.

Certain basic steps in this procedure are unacceptable in any analysis designed to measure a marginal or variable cost function. The allocation of expenses among different service categories, not on the basis of behavior of the expense, but rather on the basis of arbitrary factors such as time allocation of employees, will not produce an estimate of the extent to which total expenses will change as a result of change in traffic volume, or in its mix. In addition, the procedure for development and application of an average per cent variable leads to serious distortions in the estimates of variable cost. The distortions arise for two reasons: linear regression, based on ratios, can lead to serious distortions if the error terms of both the numerator and denominator if the ratios do not follow a homogeneous distribution; and a constant per cent variable, regardless of length of haul, volume, density of traffic, or commodity carried, is inherently fallacious, even if the regression model used did accurately portray the cost relationship. The type of expense incurred can differ substantially for different types of commodities and different lengths of hauls. For example, yard expenses form a much greater proportion of the cost of commodities moving a short distance. Since yard expenses are almost entirely variable with traffic volume, application of an average per cent variability will underestimate variable costs of traffic volume having less than an average length of haul, and overestimate costs of traffic moving over much longer than average distances.

Another deficiency of the average per cent variable method is that it associates variation in all operating expenses with variation in one measure of output—gross ton-miles—and ignores the many different types of railway output produced, which have substantially different influences on cost. Size of plant, a factor known to influence railway expenses, is either ignored or improperly handled as the denominator of ratios.

For the reasons set forth above, a simple transplantation of ICC cost-finding procedures to the Canadian transportation scene was not desirable.

Railway Costing in Canada

Since 1959, the Canadian railways have carried out extensive research programs on costing methods in order to determine which will best produce accurate costs of railway operations. The detailed presentations by the two major Canadian railways to the recent Royal Commission on Transportation on the cost of moving grain and grain products at statutory rates were subjected to rigorous scrutiny by transportation experts and economists engaged by all interested parties, as well as those of the Royal Commission.[2] The weaknesses and strengths of the railways' methods were tested by that forum of expert witnesses and also in private meetings, sponsored by the Commission, of transportation, economic, and statistical experts from both Canada and the United States. The methods used by the railways were accepted with modification by the Royal Commission which also suggested fields for further study. Since then, the two railways have devoted much attention to refining and bringing up to date the costing methods presented to the Royal Commission. The research on costing methods and their application embraces the broad spectrum of applied transportation economics.

Costing methods must enable a railway to determine expenses variable with traffic volume, that is, those traceable to the traffic under study, given a period sufficient to allow management to make all necessary changes in operations and plant. The railways have not been concerned with a short-run cost function. Moreover, every effort has been made to avoid confusion between the short- and long-run cost functions. Basic sources are quantitative data on operations and expenses actually incurred as recorded in the accounts prescribed by the Board of Transport Commissioners, to which were added the results of special studies and operating, engineering, and technical knowledge.

MEASUREMENT OF PHYSICAL WORK, VARIABLE WITH TRAFFIC VOLUME

Essentially, there are two steps in developing the variable cost of moving a category of traffic. First, physical work requirements for movement of a particular category of traffic must be developed. Second, variable unit costs must be developed and attached to the traffic under study. The first step involves tracing individual movements in order to determine the associated car-days, car-miles, gross ton-miles, train-miles, and yard switching minutes used by the traffic under study.

To develop work requirements for moving the traffic, the first step is to establish, through a sample or by other means, the origin and destination points, as well as the route followed. This permits development of route-miles which, when combined with the loaded weight of the traffic and the tare weight of the equipment used, permits calculation of gross ton-miles, revenue ton-miles, car-miles, and car-days loaded.

[2] Report of Royal Commission on Transportation, Ottawa, 1962.

One of the most difficult aspects of developing basic output units is to determine the movement of empty cars traceable to the traffic under study. In theory, the empty movement traceable to a category of traffic is the difference between total empty movement with and without handling of the traffic. Such a calculation is impossible, however, with analytic procedures available at present. In addition, it has little meaning in the case of small categories of traffic where traffic patterns are subject to considerable variation. As a consequence, somewhat arbitrary methods are frequently used, including application of a general empty return ratio, or a more specific ratio, arrived at on a sample basis, through tracing the cars used in moving the traffic. Tests made indicate that such methods result in an accurate measure of avoidable car supply or empty movement, provided that unusual peaking characteristics are not present, and that the traffic under study is similar in its direction and distribution to that of freight traffic as a whole.

A good example of the complexity inherent in the determination of these measures is that of estimating the yard switching minutes required in handling a particular category of traffic. When the route and the trains used by a particular car have been determined, the yards through which the car moves are also known. Then it is necessary to determine the movement pattern of the car through those yards and to estimate the yard switching time required to perform that movement. Unfortunately for the cost analyst, each and every yard has a different physical layout as well as other varying operating characteristics. As a result, the amount of time required to perform similar switching moves may vary from yard to yard and, additionally, to put a car through a yard might well entail a different mix of moves.

To provide adequate data, it was necessary to conduct a study at all major yards as well as a good sample of the smaller yards. Each railway required a team of from eight to ten men with yard experience working for a six-month period to analyze only the yards in Western Canada. The men spent several days in each of the yards collecting detailed information on switching movements. An interesting aspect of applied economics in this case was the need for achieving cooperation of yard forces in assessing the productive time spent in various assignments and the total nonproductive time. When the minutes for each element of switching at each yard are known, it is possible to determine the total number of switching minutes assignable to a car for each yard through which the car passes.

Other principal measures of output to be made are: the gross ton-miles, that is, the total weight of shipment and car times the distance travelled; train-miles, usually calculated on the basis of actual train weight by train run; diesel unit miles, which reflect the number of diesel units used on a train for each train run; and car-days and car-miles.

VARIABLE COSTS INCURRED FOR EACH UNIT OF WORK PERFORMED

The second major step is to estimate the expenses incurred for each one of the units such as car-days and car-miles, which are variable with a particular movement, and the expenses associated with possible changes in size of fixed plant. The operating expense accounts generally divide into three groups: those which vary directly with volume (about 37 per cent of the total operating expenses); those partially variable with volume (about 58 per cent of the total operating expenses); and those entirely unrelated to volume changes (about 5 per cent of the total operating expenses).

The unit costs for expense accounts entirely variable with volume can be calculated quite simply when the variability has been determined. The yard-crew wages and train-crew wages were tested by regression analysis to assess variability and were found over a long-term period to be completely variable with traffic volume. The same conclusion was reached with respect to the fuel expense for road and yard diesel locomotives.

As an additional test, the functional relationship between output and expense can be established through engineering analysis or an examination of operating procedures. Thus, in assessing variability of train costs with traffic volume, primary consideration was given to the dispatching decision rules, which determine how frequently trains are dispatched. For the lowest priority traffic, trains are dispatched when a sufficient volume of traffic has been accumulated to utilize the power available. However, schedules of other trains dispatched to provide service are fixed on a short-term basis but are adjusted extensively over a longer period, depending on the volume of traffic available. Local trains, operated primarily on branch lines, are adjusted to the volume of traffic available through changes in the frequency of train service.

In the case of yard expenses, once again, the rules for operating-yard engine shifts are based on traffic volume and subject to adjustment with relatively small variation. There are substantial differences between types of yards but, within each yard, statistical procedures were used to identify the variability between yard operations and traffic volume handled.

Car repair expense, by type of car, is available from accounting records. Engineering analysis made possible a division of car maintenance and capital costs between the portion variable with the passage of time, measured by car-days, and the portion variable with work performed by the car, measured by car-miles.

Train fuel expense is computed individually for each train run and is based, in part, on the grades over which the train travels, its speed, and its weight. Fuel consumption estimated on this basis has proved to be extremely accurate when matched against actual consumption on a train-run basis.

The group of accounts which are only partially variable with volume pose a more serious problem. For them, it is necessary to rely upon engineering knowledge, operating experience, and historical data pertaining to actual operations. These data reflect the cost variations associated with differing volumes of traffic, differing physical plant, and geographical influences. Engineering knowledge and operating experience suggest, in a general way, how these costs, traffic volumes, and other items are related, but do not provide detailed estimates.

Fortunately, regression analysis could be used to measure relationships between changes in volume of traffic and the changes in a particular category of expense. Both railways have historical data for their operating divisions, which numbered over thirty on each railway. The data showed the costs, by operating division, most measures of the volume of operations, by division, as well as measures of the physical plant, such as miles of track and number of bridges. Having the statistics recorded in this fashion made possible use of cross-sectional regression analysis. With the aid of electronic computers, it was possible to estimate the costs variable with a particular measure of traffic volume. In addition, the costs of performing special services were, in many cases, available in the accounts and could be directly traced to the services provided.

The accounts not entirely variable with volume were checked to find the relationship of volume and plant size to the various expenses. This involved estimating many hundreds of regression models and selecting those which best fitted the many tests made of them. The cost curve must, in each case, be tested to determine whether it is linear or curvelinear. The models were tested by arraying the data representing costs, size of plant, and output for all the operating divisions. The residuals from each regression model were plotted against the various measures of traffic volume to observe whether there was any indicated nonrandom pattern in these residuals. Such tests indicated that curvelinearity was not present in railway costs within the range of observations.

The problem of collinearity was, of course, the chief reason so many models were tested. The main test for collinearity was to determine the R^2 or coefficient of determination between the various pairs of independent variables. The coefficient of determination used to test the applicability of the model as a whole was in all cases statistically significant and—more than that—was such as to allow use of the model without misgivings. A "t" test was used to ensure the significance of the individual parameters in the model.

Aside from purely statistical tests, it was necessary to apply two others. One was the test of the models against the experience of a particular year's expenses, division by division, to find whether the models selected would have estimated the actual expenditures fairly accurately, given only the volume of traffic and the size of the division. The second nonstatistical test was the so-called common sense test. Did the models used make sense to the engineer and to the practical railroader? The models passed both tests.

In the third set of operating expense accounts, those not variable with volume of traffic, some accounts—notably maintenance of fences, snow sheds and signs, and snow, sand, and ice removal—were tested by regression analysis and found not to be variable with traffic volume.

The roadway property investment accounts present significant difficulties in railway cost analysis. As a result of regulatory requirements, property investment is accounted for on a subdivision and division basis, with full accounting breakdown, depending upon the type of property involved. Since there are not significant differences between divisions in the age of property invested in, it was possible to analyze variability of railway road property investment through multiple regression analysis. The cost of the capital must be applied to the variable railway property investment traceable to the particular segment of operations being costed. The cost of money was calculated as the amount which, after payment of corporate income taxes, was sufficient to make investors indifferent about the choice between retention of their investment in railway operations or placing it in other pursuits with similar risk and opportunity for gain.

There were left some expenses which could not be analyzed through direct and regression procedures. Such accounts were allocated to the traffic under study following survey or other procedures designed to assess general variability relationships.

Table 1 shows the methods used in analyzing the various accounts and groups of accounts by the Canadian Pacific Railway, the

TABLE 1

GROUPING OF EXPENSE ACCOUNTS IN THE COST STUDY AND METHODS USED TO DETERMINE COST, CANADIAN PACIFIC RAILWAY

Account Number	Group of Accounts	Method
Road maintenance		
201,274,276,277	Road maintenance, superintendence and overhead	Regression analysis
202,208,212,214,216, 218,229,266 (Track) 269,271,273,281	Track maintenance and depreciation	Regression analysis
221-266	Fences, snowsheds, and signs, maintenance and depreciation	Regression analysis
227-266	Station and office buildings, maintenance and depreciation	Regression analysis
231-266	Water and fuel stations, maintenance and depreciation	Regression analysis and direct
235-266	Shops and enginehouses, maintenance and depreciation	Regression analysis
237-266	Grain elevators	Not applicable
241-266	Wharves	Not applicable
247	Rail communication systems	Allocated
249-266	Signals, maintenance and depreciation	Regression analysis
253-266	Power plant maintenance and depreciation	Regression analysis
265-266	Other structures	Not variable
270	Dismantling retired road property	Not variable
272	Removing snow, ice, and sand	Not variable
275,278-279	Insurance and joint facilities	Allocated
Equipment maintenance		
301,302,305,306,329, 332,333,334,335,336, 337	Equipment maintenance, superintendence and overhead	Regression analysis
308-311-331	Road locomotive repairs and depreciation	Direct
308-311-331	Yard locomotive repairs depreciation	Direct
314-331	Freight train car repairs and depreciation	Direct and allocated
317-331	Passenger train car repairs and depreciation	Not applicable
323-331	Vessels, repairs and depreciation	Not applicable

(continued)

TABLE 1 (continued)

Account Number	Group of Accounts	Method
Equipment maintenance (cont.)		
328-331	Other equipment, repairs and depreciation	Not applicable
Traffic		
351,352,353,354,356, 357,358,359	Agencies, advertising, associations, industrial and immigration bureaus, insurance, stationery, and other expenses, superintendence	Allocated and not applicable
Transportation		
371,374,410,411,415, 416,420	Transportation, superintendence and overhead	Regression analysis
372,373,376	Dispatching and station employees and expenses	Regression analysis
375	Coal and ore wharves	Not applicable
377	Yardmasters and clerks	Regression analysis
378,379,380,382,385, 389	Yard expenses	Regression analysis
386,388	Yard, other expenses	Regression analysis
390-391,412-413,414	Joint facilities and insurance	Allocated
392,394,401	Trains, enginemen, locomotives, fuel and power, trainmen	Direct
397	Train locomotive water	Direct
398,400	Trains, enginehouse expenses, and locomotives, other supplies	Regression analysis
402	Trains, other expenses	Direct and allocated
403	Operating, sleeping and parlor cars	Not applicable
404	Signals, operation	Regression analysis
405	Crossing protection	Not variable
406	Drawbridge operation	Not variable
407	Rail communications system, operation	Allocated
408	Operating vessels	Not applicable

(continued)

TABLE 1 (concluded)

Account Number	Group of Accounts	Method
Transportation (cont.)		
418	Loss and damage, freight	Direct
419	Loss and damage, baggage	Not applicable
Miscellaneous operations		
441	Dining and buffet service	Not applicable
442	News service and restaurants	Not applicable
443	Grain elevators	Not applicable
446	Other operations	Not applicable
447-448	Miscellaneous joint facilities	Not applicable
General		
451,452,453,454,455 457,458,460,461-462	General officers, clerks and attendants, office expenses, legal expenses, insurance, pensions, stationery, other expenses and joint facilities	Allocated
Equipment rents		
463-464	Equipment rents	Direct and allocated
Joint facility rents		
465-466	Joint facility rents	Allocated
Railway tax accruals		
468	Other railway taxes	Allocated
Investment		
	Road property	Regression analysis
	Locomotive, steam and diesel	Direct
	Freight train cars	Direct
	Passenger train cars	Not applicable
	Vessels	Not applicable
	Work equipment	Allocated
	Other equipment	Not applicable

TABLE 2

VARIABLE PORTION OF ROAD MAINTENANCE EXPENSES APPLICABLE TO THE TRAFFIC UNDER STUDY, CANADIAN PACIFIC RAILWAY

Account Groups and Account Numbers	Independent Variable	Unadjusted Coefficient or Unit Cost (Canadian dollars as of Dec. 31, 1958)
Road maintenance: superintendence and overhead (201, 274, 276, 277)	Road maintenance expenses, excluding superintendence	0.03586
Track maintenance and depreciation (202, 208, 212, 214, 216, 218, 229, 266, 269, 271, 273, 281)	Freight gross ton-miles (000's)	0.16441
	Yard- and train-switching miles	0.41394
Station and office buildings: maintenance and depreciation (227, 266)	Carloads	1.33237
Water and fuel stations: maintenance and depreciation (231, 266)	Yard-locomotive miles	0.00626[a]
	Train miles	0.01677[a]
	Train-switching miles	0.02864[a]
Shops and enginehouses: maintenance and depreciation (235, 266)	Direct equipment maintenance ($)	0.03124
Signals: maintenance and depreciation (249, 266)	Train miles	0.04772
Power plants: maintenance and depreciation (253, 266)	Station employees ($)	0.01546
Insurance and joint facilities (275, 278, 279)	Road maintenance ($)	0.01060
Equipment maintenance: superintendence and overhead (301, 302, 305, 306, 329,332-337)	Direct equipment maintenance, excluding depreciation ($)	0.04990
Road locomotive: repairs (308-311)	Road-locomotive miles	0.38790
Road locomotive: depreciation (331)	Road-locomotive miles	0.17301
Yard locomotive: repairs (308-311)	Yard-locomotive miles	0.20848
Yard locomotive: depreciation (331)	Yard-locomotive miles	0.13106
Freight-train car: repairs (314)	Car miles	0.01529
	Car-days active	0.57354
Freight-train car: depreciation (331)	Car miles	0.00408
	Car-days active	0.47814
Work equipment: repairs (326)	Road maintenance ($)	0.01314
Work equipment: depreciation (331)	Road maintenance ($)	0.00498
Transportation: superintendence and overhead (371, 374, 410, 411, 415, 416, 420)	Transportation expens ($)	0.02442
Dispatching and station: employees and expenses (372, 373, 376)	Carload	5.61490

(continued)

TABLE 2 (concluded)

ccount Groups and Account Numbers	Independent Variable	Unadjusted Coefficient or Unit Cost (Canadian dollars as of Dec. 31, 1958)
ardmasters and clerks (377)	Yard-switching mile	0.46992
ard expenses (378-380, 382, 385, 89)	Yard-switching mile	2.37435
ther yard expenses (386, 388)	Yard-switching mile	0.14389
rain enginemen, train locomotive uel and power, trainmen, train witching (392, 394, 401)	Direct	
rain enginehouse expenses and ther train locomotive supplies 398, 400)	Locomotive miles	0.13997[b]
rain locomotive water (397)	Direct per locomotive mile	0.01298
ther train expenses (402)	Direct per car mile	0.00250
	Grain doors (direct), train miles	0.10819
ignals operation (404	Train miles	0.01146
oint facilities and insurance 390, 391, 412-414)	Transportation ($)	0.01206
reight loss and damage (418)	Direct	

procedures being explained in Appendix A. The unit variable cost coefficients which required adjustment for various overhead and other factors are set forth for the Canadian Pacific Railway in Tables 2 and 3. Data for the Canadian National Railways is not shown since it is very similar with a few differences in the models used and, of course, differences in the unit variable costs reflecting differences in the operations and management of the two railways.

COST VARIABLE WITH TRAFFIC VOLUME

Estimates of the cost variable with any particular point-to-point movement can be made by multiplication of the relevant variable traffic units by the appropriate variable costs. The procedure may be time consuming because it involves a large number of additions and multiplications which have to be carried out in a particular order, involving some hundreds of different factors. For this reason it was found advantageous to combine the various items into "unit" costs of the form, cents per 1,000 gross ton-miles, and cents per train-mile. Combining the various factors and formalizing the subsequent steps

TABLE 3

COST OF MONEY FOR INVESTMENT IN ROAD PROPERTY AND EQUIPMENT APPLICABLE TO TRAFFIC UNDER STUDY, CANADIAN PACIFIC RAILWAY

Investment Category	Independent Variable or Output Unit	Unit Variable Cost (dollars)
Road property	Gross ton-miles	0.28926
	Yard- and train-switching miles	0.84033
Diesel yard locomotives	Yard-engine miles	0.25778
Diesel road locomotives	Train miles	0.30748
	Train-switching miles	0.23700
Steam locomotives	Train miles	0.04291
	Yard-switching miles	0.06055
	Train-switching miles	0.18979
Freight-train cars	Car miles	0.02470
Work equipment	Gross ton-miles	0.00786
Shop and power plant machinery	Train miles	0.02974

has made costing a readily available tool for management and regulatory purposes in Canada.

RESULTS OF COST ANALYSIS

When the cost method described here was presented to the Royal Commission, it heard, as well, submissions about costing by opposing parties and by employed staff analysts. While changes were made in certain of the treatments, and in others further analysis was recommended, the Commission accepted much of the analysis put forward by the railways, including the use of linear multiple regression analysis and many of the other procedures described. It used the amended costs as a basis for recommendations to the government for payment of a shortfall between revenues and variable cost, as well as a contribution to cover constant costs to the railways for movement of the traffic under study.

The cost procedures described here have been adopted by both railways in pricing and in many of the other management operations described. Since the studies were completed, the Canadian railways have continued their research into cost finding, and while some changes have been made in some areas, the basic methodological framework remains pretty well as described. We believe it has resulted in improved resource allocation in transportation in Canada.

Appendix A: Empirical Results

ROAD MAINTENANCE, SUPERINTENDENCE, AND OVERHEAD

Among models used in analyzing the expenses, a relationship with direct roadway expense provided the most satisfactory explanation of the expense. Divisions that had greater amounts of direct road maintenance expense had higher levels of supervision. Furthermore, on the Canadian Pacific, road maintenance superintendence was found to vary not only with direct road maintenance expense, but also with size of plant; that is, a division with extensive branch-line mileage requires more supervision than one with only main-line trackage, even though the maintenance expenses are the same. As might be expected, there is a high proportion of expense not variable with traffic volume in this category of costs.

TRACK MAINTENANCE AND DEPRECIATION

After testing with approximately three hundred models in each company, a model relating track maintenance costs to size of plant and freight, passenger, and yard output produced the best explanation of variation in this category of cost. Canadian National found also that the variable miles of tunneled track was related as a geographical variable to this category of cost. While recognizing that such influences were present, Canadian Pacific found that the influence of terrain was absorbed by the constant term in the regression analysis, and that introduction of a variable would not significantly affect the output coefficients used in estimating variable cost.

Road maintenance expenses are a good example of the blending of engineering and statistical analyses. The regression equation for the Canadian Pacific indicated a constant track maintenance cost of some $1,136 per mile of track. The estimate was confirmed through an examination of track maintenance expenses on many extremely light-density branch lines throughout the Canadian Pacific system. Similarly, because of collinearity between freight and passenger output measures, it was impossible to obtain separate statistically reliable coefficients for each of them. An engineering analysis, based on influence of speed and weight on track maintenance, was performed and used to obtain a weighting factor between freight and passenger traffic.

OTHER ROADWAY MAINTENANCE ACCOUNTS

As might be expected, maintenance of fences, snow sheds, and signals was found to be closely related to miles of roadway fences and not variable with traffic volume. Maintenance of station and office building expenses were found to be related to the number of less-than-carload cars originated, and to passenger car miles on the various divisions. This relationship indicates the primary use made of stations, and also reflects the fact that no strong relationship could be found with operations independent of the measures of output described. Water and fuel station maintenance and depreciation expenses were related to fuel and water expenses, which indicates that where there is a large charge-out of fuel and water for train service, there is a significant maintenance expense involved. Similarly, maintenance of shops and engine houses was found to be closely related to direct equipment expenses; signal maintenance and depreciation, to train miles; and power and protection, to station labor expenses. The last arises because power plants are used primarily to generate power for heating stations.

EQUIPMENT MAINTENANCE, SUPERINTENDENCE, AND OVERHEAD

These three accounts included all elements of supervisory expense involved in equipment maintenance and injuries, as well as shop machinery. The regression analysis indicated a relationship with direct cost of maintenance expense with a large constant term.

ROAD AND YARD LOCOMOTIVE REPAIRS AND DEPRECIATION

Regression analysis was not attempted on these accounts, since locomotives maintained on one part of a railway system usually run out their mileage over the system as a whole and, as a result, output on a division level may bear no relation to division expenses. A major portion of locomotive repair expenses on both Canadian railways is occasioned by inspection and preventive maintenance. Certain work is carried out on a diesel locomotive when it has completed a specified mileage, and such work, which may be approximated by an engineering function, accounted for a large portion of the expense. For major overhauls, analysis was made of the records which showed run-out mileage, locomotive number, and expense. It was possible to analyze the major overhaul work done in relation to mileage of the locomotive. As might be expected from the preventive maintenance policies, locomotive maintenance expenses were closely related to locomotive miles.

FREIGHT-TRAIN CAR REPAIRS AND DEPRECIATION

A special study was performed to segregate light and heavy repair expenses, as well as inspection, for various classes of freight cars. Following this, an ICC engineering study, which showed the relative effect of time and use as they influence freight-car expense, was brought up to date in the light of railway operating practices by mechanical officers. That study was used to divide freight-car repair expenses between those associated with the passage of time and those associated with mileage.

WORK-EQUIPMENT REPAIRS AND DEPRECIATION

Work equipment is used for road maintenance; hence a time-series analysis was used to relate work equipment repairs and depreciation to road maintenance expenses.

TRANSPORTATION SUPERINTENDENCE AND OVERHEAD ACCOUNTS

On the Canadian Pacific, these accounts were found to be closely related to dollars of direct transportation expenses on each division. On the Canadian National this expense was related directly to train miles and yard switching miles.

DISPATCHING AND STATION EMPLOYEE EXPENSES

These expenses were difficult to analyze on both railways. Somewhat different solutions were obtained for each railway, reflecting the different operating and station-organization patterns of the two. For Canadian Pacific, after a substantial amount of statistical analysis, the most satisfactory explanation was afforded by the number of cars of freight originated, less-than-carload cars originated, and passenger-car miles.

For Canadian National, the solution was somewhat different. After considerable investigation, two separate models were developed. The first covered a group of expenses called train control expenses, including the expense of maintaining and operating signal systems, as well as dispatching expense. The model expressed these expenses as a function of train miles and car loads originated. The second model embraced station employees' expenses and other station expenses. It expressed them as a function of car-load traffic originated and less-than-carload cars originated.

YARD EXPENSES

Yard expenses were found to be closely related to yard-switching miles—not surprising, since a majority of yard expenses vary with yard work performed. Little or no constant expense was found in this category of cost. Observation of the residuals against volume and size of yard indicated that there were no measurable economies in large yard operations.

TRAIN EXPENSES

Direct treatment of train expenses was possible because of special records kept on both Canadian railways. On Canadian Pacific, the records show labor and fuel expenses by direction, on each subdivision, divided between through and local trains, as well as the volume of traffic handled and the volume of train miles produced. On Canadian National, fuel required was computed for each individual move by use of an engineering formula which takes into account grade resistance, axle resistance, weight, speed, and wind resistance. Crew wages were also computed by train run, using current wage rates. The number of trains imputed to a particular traffic in the study was determined separately for each train run on the basis of gross tons per car plus axle resistance, as compared with actual average train handling achieved on each train run.

ROAD-PROPERTY INVESTMENT ACCOUNT

Reference was made earlier to the accounts which made possible estimates of the variability of road-property investment. These accounts were on a division basis, and regression analysis proved appropriate. The analysis showed, as one might expect, that investment was most closely related to size of plant, as measured by miles of track operated, and to gross ton-miles, as well as by yard and train switching miles.

EQUIPMENT INVESTMENT

Investment in the majority of the diesel locomotives was found to be completely variable with change in traffic volume. A few special-purpose diesel locomotives, used primarily in servicing branch lines, did not show that relationship.

Variability of freight-car investment with traffic volume proved to be an important area of analysis, and various methods were used to show the relation. A time-series analysis on the two Canadian railways proved difficult as a result of technological changes, both in size of equipment and speed of movement. Reliance, therefore, was placed upon internal management of the two railways in Canada both of which provide that freight-car inventory is adjusted to changes in traffic volume through car retirement and replacement policy. This is one more example of how an economist may, on occasion, have to rely on judgment rather than analysis.