Excerpts from Study of Cost Structures and Cost Finding Procedures in the Regulated Transportation Industries

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Study of Cost Structures and Cost Finding Procedures

Preface

The following excerpts relating to cost concepts in transportation, and certain relationships between them, are taken from a special study prepared for the United States Department of Commerce in November, 1959, by R. L. Banks & Associates of Washington, D.C. Since the study is, as yet, not generally available to the public, we sought permission to publish relevant portions which were particularly useful to an understanding of many of the cost concepts related to our conclusions.

Omissions from the original in this portion of the study have to do mainly with specific United States experience and examples. The omissions do not, in our opinion, alter the purpose or change the concepts found in the original document. However, for any inadvertent misconceptions caused by the abridgement, we take responsibility.

We acknowledge with gratitude the authors' permission to reproduce these portions of a study which sets out the bases of a subject so often confused by definitional ambiguity.

Part One—The Place of Costs in Transport Policy

Section 1

Some Basic Concepts

By the term "cost" is meant the total expense, both cash and non-cash, incurred to sustain the operation of a transportation enterprise. This includes both replenishment of operating expenditure and return upon capital in amounts sufficient to attract investment as the need arises.

A knowledge of costs and their relationship to traffic and rates is basic to effective public policy and intelligent business behavior. But the cost knowledge essential to carrier management relates primarily to expenditures of the transportation firm itself, whereas the proper concern of regulatory bodies comprehends cost incurred both within and outside the individual firm.

For meaningful administration of their public duties, regulatory bodies must concern themselves not merely with carrier cost, but also with intercarrier and intermodal cost comparisons. Likewise they are required to weigh the cost elements of time, risk and obsolescence embodied in consumer evaluation of service. Finally, they need to consider these transportation costs not charged directly through carrier books of account, but assumed instead by government.

The differences between carrier and regulatory concern with costs serve to emphasize a point essential to fuller understanding: costs are highly complicated phenomena which vary widely under differing circumstances, and are frequently difficult if not impossible to measure with precision. Accordingly, the cost which is significant varies from one situation to another. Therefore, meaningful cost analysis always starts with the question: What purpose are these costs to serve?

The point is perhaps best illustrated by a brief examination of the differences between corporate and public cost usage. Corporate cost knowledge is required by the profit incentive which underlies the existence of the firm. In this framework cost analysis is essential, since it provides the only effective means for control of expense, and for its measurement against revenue in profit determination. . . .

Regulatory bodies, by contrast, use cost knowledge to fulfill their obligation to ensure that the public is provided with safe, adequate, economical and non-discriminatory service. Since competition is, in theory, the device employed to attain these objectives, and since costs and rates would be equal under conditions of perfect competition, cost analysis provides regulatory agencies with a means to assess the competitive imperfections indicated by undue margins between costs and rates . . . .

Despite the implications of cost for both corporate and public policy in transportation, an awareness of its central significance has been a relatively recent development. This has been a result of displacement of the railroads from their former predominance of inland transportation. Prior to the development of motor carriers, pipelines, and airlines, the railroads had only water competition, and that embraced but a minor fraction of their operations. As a practical matter rail transportation operated under conditions of monopolistic competition (i.e., few sellers and many buyers) at many traffic points. . . .

Section 2. (Deleted. *See* Preface)

Section 3

Cost Limitations

The meaningful application of specific costs to particular situations in transport regulation has lagged substantially behind the growing awareness of the implications of "cost" for rate levels, traffic volumes, and service standards. There are four basic reasons for this.

Absolute Precision Unattainable. First, many transportation costs, even those which have already been incurred, cannot be measured with complete precision and related to components of traffic. The classic example of this is maintenance expense attaching to intercity traffic ways, which for railroads, highways and waterways is a function of both the passage of time and traffic volume. The physical plant of these traffic channels is exposed to action of the elements and to the passage of traffic. Drainage systems become clogged, embankments erode, the impact of rain, snow and frost necessitates offsetting expenditure to keep channels open, highways smooth and tracks aligned in a manner suitable for passage of traffic. But passage of traffic itself contributes to erosion, through impact on road surfaces, wear on rails and wash against channel embankments. A continuing and largely unresolved issue has centered about attempts to define the proportion of way maintenance cost properly chargeable to traffic and time, respectively, and once the latter is isolated, its appropriate attachment to traffic components.

By contrast, other transportation costs can be traced directly to their source. Most costs of vehicular movement, such as fuel and wages of operating personnel, can be determined with adequate accuracy and related to the traffic to which they pertain.

Thus some transportation costs can be assigned directly to traffic and others cannot, although they are apportioned or distributed amongst traffic or user groups by more or less arbitrary methods, which attempt compromise between theory and experience, between mathematics and empirical observation. The objective of cost analysis is to isolate cause and effect relationships; that is, to find out what costs are incurred by doing a specific thing. Some costs are simply *not* caused by doing a specific thing, but are caused by doing many things. The question of how these latter "must" be apportioned or distributed amongst traffic or user groups is not a question of *cost* analysis, but rather a policy question of how much overhead can or should be collected from particular users. This is pricing, not costing. Where costs of both types, assigned and apportioned, are inseparably mixed, and together relate to the production of multiple services, as in railroad transportation, for example, meaningful cost derivation becomes somewhat obscured in a mass of involved computations and complex numbers which lend a not altogether justified air of precision to the computed results.

Difficulty in Relating Past to Future. Second, meaningful cost development has also been hindered by the difficulties inherent in relating past cost experience to future operating results. Excepting only past period subsidy ascertainment in air transport, the appropriate costs for consideration in either rate or service (i.e., public convenience and necessity) cases, are *future* costs. In either situation the relevant question *always* is: "What will be the change in future total profit (future total revenue minus future total cost) as a result of the proposed change in price or service?" Very obviously, the starting point for determining future costs is past cost. These past costs must be adjusted for known or anticipated changes in price-levels, operating conditions, technology, and the general economic situation. It is often stated that these adjustments are just guesses, and so they are. It is well to remember, however, that the simple extrapolation of past data, despite all of the seeming arithmetic precision which surrounds it—may be of limited pertinence to the future.

Past data, then, are only the starting point in estimating future costs. In order for these to be a useful starting place, it must be decided whether the most recent period of time or a longer period will provide the most useful basis for projections. In any cost estimate this will clearly depend on the relevant length of the projection. This is, to project one month ahead, data for the most recent month will most likely be more relevant than those relating to any other previous month (except, perhaps, in cases of pronounced seasonality). By the same token, data for the most recent month will hardly be relevant to a projection into the indefinite future.

It seems apparent that most regulatory proceedings, whether they concern price changes or service adjustments, relate to an indefinitely long future. An abandonment is clearly a rather permanent and long-run act, as is the institution of service to a previously unserved route or point. A price change is not permanent, but a new freight rate is usually expected to govern for a fairly long period. The future costs and revenues relevant to a regulatory appraisal of these decisions must be long-run, and consequently, the past costs used as a basis for these predictions should be long-run. To the extent that the past is relevant to the future, it is clearly the *typical* past that is relevant for whatever period of time is involved. For a long-run future, the past month or six months or year is unlikely to be *typical.*

Thus meaningful cost development for most regulatory purposes relates to the future primarily. Where inadequate selection of the typical past is compounded by inadequate adjustment to reflect future operating conditions, and to this is added the ingredient of insufficient market information, computed results must necessarily diverge from actual cost.

Absence of Defined Cost Standards. Third, ignoring for the moment the technical difficulties described above, it can be observed that the development of meaningful cost data has been hindered in perhaps a more significant sense by conceptual uncertainties regarding not merely the costs themselves, but also the situations in which they may be appropriately applied. An illustrative example is the variety of bases relied upon in ICC rate proceedings to measure "out-of-pocket" (variable) railroad costs. The range of permitted and presumably relevant data relied upon to establish this single significant cost level has included, among others:

(1) Directly assignable cost only.

(2) Directly assignable cost plus apportionments of indirect railway operating expenses.

(3) Directly assignable cost plus apportionments of indirect railway operating expenses, rents and taxes.

(4) Directly assignable cost, plus apportionments of (*a*) indirect railway operating expenses, rents and taxes, and (*b*) return on equipment.

(5) Directly assignable cost, plus apportionments of (*a*) indirect railway operating expenses, rents and taxes and (*b*) return on road *and* equipment.

The proportion of out-of-pocket to total cost has of course varied with the method employed, with corresponding confusion in establishment of their pertinence to the situation assessed.

No single cost standard is suitable for the variety of rate cases which the Commission must adjudicate, but the absence of a policy pronouncement clearly definitive of those costs construed as relevant to various kinds of cases has very likely hindered meaningful cost ascertainment in this area.

In evaluating service adjustments, a similar obscurity has perplexed the participants. Various concepts such as "above the rail," "direct," "avoidable" and "fully apportioned" costs have been introduced and relied upon in rail service reduction or abandonment proceedings, and a like uncertainty as to costs properly attaching to the inauguration of new, or the suspension of existing service, beclouds the decisions of the Civil Aeronautics Board.

Value-of-Service. Fourth, in the quasi-judicial regulatory environment, cost becomes the one element of "fact" which can be challenged, analyzed and argued over. Cost calculations, because they involve mathematical processes, unfortunately create an illusion of precision, and the assumption is frequently made that costs can be measured with the same precision that one can measure a person's height and weight. "Either it takes 50 gallons of fuel to move a rig from here to there or it doesn't." Such treatment ignores the fact that on a large carrier there may, at any one point in time, be literally thousands of different things being done, and to sort out precisely the ultimate effect upon cost of any one of these things is virtually impossible. Such treatment, also indicates an ignorance of the fact that the measuring tools of the accountant, statistician and economist are far removed from the precise measuring tools of the physicist or engineer.

The price-maker knows that precise measurement is illusory, especially in terms of final future financial impact. The regulator may know this too, but because he is cast in the role of impartial finder and arbiter of facts, he must discharge his responsibility to judge the "facts" of record. Therefore, a primary objective of future price regulation should be to attain a perspective on the place of costs in price-making and consequently in rate hearings.

Casting aside the imperfections in current cost ascertainment and presentations, the fact remains that were it possible in rate-making to ascertain with complete precision either the out-of-pocket (marginal) cost or the full (average total) cost of the service to be measured, neither would fully serve the regulatory purpose. As will later be shown, reliance solely upon average total cost pricing would hinder optimum utilization of the transport plant, whereas complete resort to marginal rates would produce revenues insufficient to cover total costs of the transport service. Another element therefore also enters into the development and execution of a socially desirable policy, namely, demand. As a reflection of market conditions and user judgments, demand factors, embodied in the so-called value of service concepts, must continue to supplement cost ascertainment for regulatory purposes. At the present time, however, there cannot be very much argument over price/volume estimates, because it soon becomes apparent that with the current state of knowledge about transport market forecasts, such argument centers more directly on guesswork. This points up the absence of adequate data for demand measurement; without it many cost computations must necessarily be of limited value to the regulatory agencies. In short, more balance is needed between cost and demand data development. . . .

Part Two—Transportation Cost Characteristics

Section 4

Cost Classification

Costs can be classified in several different ways. To assess their relationship to both economic objectives and to profit contribution, costs can usefully be compared in three different frameworks:

(*a*) Fixed costs versus variable costs. Fixed costs remain constant at virtually any traffic volume and over relatively long periods of time. Variable costs (all other costs) usually vary more or less in proportion to the volume of traffic.

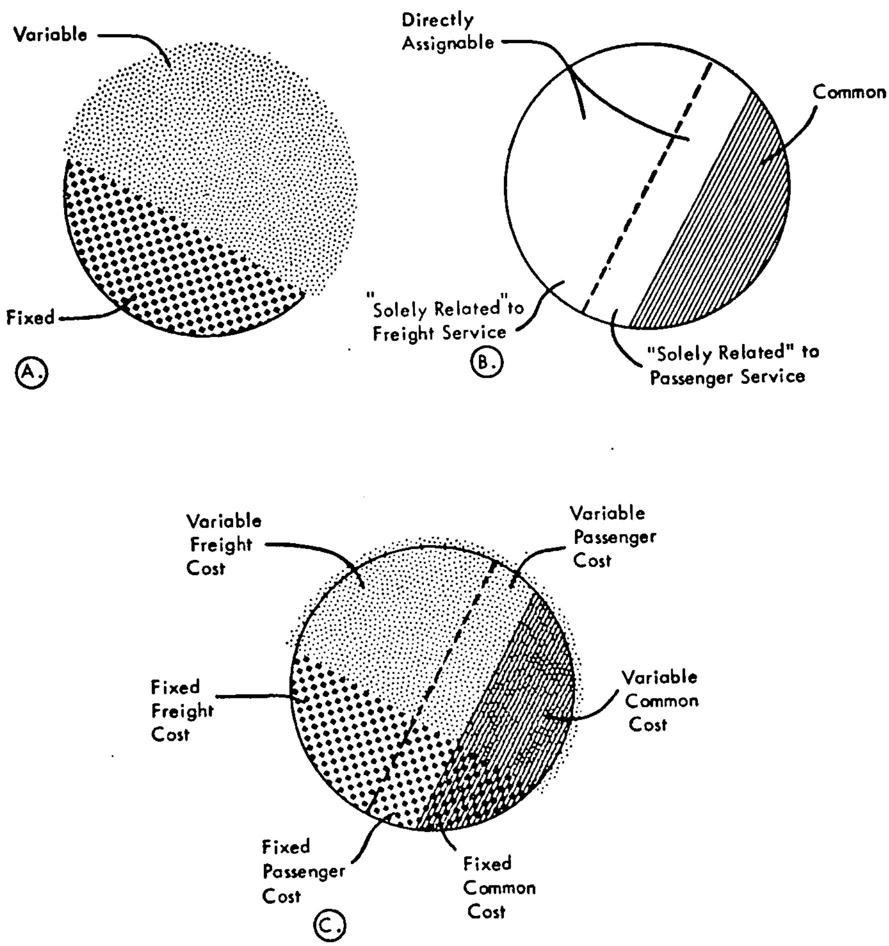
(*b*) Common costs versus directly assignable. Common costs are incurred in the production of more than one type of service, thus can not be allocated* to any particular service. Directly assignable costs on the other hand are incurred in the production of only one type of service.

* directly

(*c*) Total costs versus costs per unit. Total costs are all the costs incurred by the firm, and may be segregated in the manner of (*a*) or (*b*) above. Cost per unit represents the association of specific costs with specific quantities of output (traffic).

It is important to remember that considerations (*a*) and (*b*) above involve no more than a different segregation of the same total cost. It is analogous to cutting the same pie in two different ways, as Figure 1 shows. Using railroad costs for illustration, total cost "A" is divided into its fixed and variable components. By contrast, "B" shows total cost divided between

Figure 1
TOTAL COST COMPONENTS



directly assignable costs and those incurred in common by more than one type of service. Directly assignable cost in "B" is further fragmented into components associated with freight and passenger service: these are designated as "solely related" costs. The two distinct separations of total cost shown in "A" and "B" are not mutually exclusive, and do not lose their particular characteristics when superimposed, as in "C".

In its exploration of cost characteristics and ascertainment, this report devotes relatively more attention to railroads than to other types of transportation. This emphasis is unrelated to the predominant historical position of the rail carriers, it originates rather in the basic and only useful purpose of transport cost analysis: to determine, in terms of cost, what occurs when a carrier handles, or ceases to handle, specific traffic. It happens that fulfilment of this basic purpose is more difficult for rail than other carriers due to (*a*) the large proportion of fixed and common costs inherent in the physical characteristics of the railroad plant, and (*b*) the resultant higher degree of complexity in associating rail costs with rail traffic.

To a markedly lesser extent fixed costs are also present in the air and water carrier industries. These likewise have a substantial element of common costs, but much of this is related to the government-built facilities which they use. Furthermore, the common costs of these carriers reflected in their current operating expense are predominantly associated with one major category of service or product, and not, as with the railroads, fragmented more equally between them.

With absence of ownership in their roadbed, and relatively small equipment units and capital requirements, motor carrier costing presents fewer technical handicaps to adequate cost-finding. The adjustment of capacity through addition or elimination of vehicle units facilitates identification of expenses with traffic, and limits the potential long-run economies of scale. Common costs are present, but occupy a much less prominent role.

These intermodal differences are fairly obvious, and have often been considered. By contrast, similarities which may be of equal or greater importance in their public policy consequences have received relatively less attention. These involve, first, potential discrepancies between user costs and user taxes relating to government provided facilities. This is an area much discussed about which relatively little is known, despite some strenuous but spotty efforts at measurement. Second, they include distribution costs which are a function of transportation use: inventory, packaging, warehousing, purchasing, risk, interest, obsolescence, and so forth. Here too, relatively little is known, but there have been incipient attempts at measurement which indicate the costing problem is not insuperable. Third, a consideration also of consequence is the impact of transportation upon land use, land values, urban congestion and the alternative uses of scarce human and material resources. Practically nothing has been done to measure costs attaching to these interactions. The combined weight of these factors indicates that there is a substantial gap between the corporate and total economic cost of all types of transportation.

In a very real sense, therefore, the conventional scope of transportation costing deals with dimensions somewhat less than the all-inclusive economic cost of transportation. By the same token, therefore, intermodal cost comparisons based on available data are, and will continue to be, imprecise, pending the development of more sophisticated techniques for assessing costs not reflected on carrier books. However, since corporate costs provide the only readily available data, and probably constitute the largest fraction of total transportation costs, comparisons must necessarily be principally on this basis, despite the possible consequence that the results may be somewhat misleading. . . .

Section 5

Fixed and Variable Costs

One of the most elusive problems in transportation cost-finding is the separation of fixed from variable costs. As to both business in general and transportation in particular, the quantitative segregation into these two categories is of controlling significance in cost appraisal.

The General Case

Any business commits itself, *for a period of time,* to establishment. The costs of having this establishment (physical plant, *ad valorem* taxes, property protection, minimum supervisory staff, etc.) will be incurred during the lifetime of the establishment more or less independently of the extent of the activities which it carries on. This group of costs is called *fixed costs.*

During the life of the establishment, the business will engage in producing and selling its products or services. It will earn revenue from its sales and it will incur costs for producing and selling, which are *in addition to* the basic costs of the establishment. These costs are designated as *variable costs.*

If a company sells its products or services at a price which is greater than the variable costs incurred in producing and selling, it will have dollars left over to meet the costs of its establishment, i.e., fixed costs. If the process of production and sale with dollars left over is repeated sufficient times, the company will have enough dollars to meet the fixed costs, and dollars received in excess of both variable and fixed costs are profit.

Whether or not each turn of the production and sale cycle yields the same amount or proportion of dollars is irrelevant. Profitable operation depends on receiving more than enough of these marginal dollars, from whatever source, to meet the fixed establishment costs. It makes no difference that one particular product or service brings in half the marginal dollars required and the other half comes in varying amounts from a large number of products or services. Indeed, an attempt to collect a stated proportion of the fixed costs, i.e. to "fully distribute" costs may inadvertently lead to smaller profits. "Distribution" of a portion of fixed cost to variable product costs has nothing to do with the process of judging whether a price is compensatory; it is in itself a process of *price-making.*

The only test of compensativeness (looking not at the business as a whole, but rather at each specific kind of output or traffic) is to compare revenues (price times volume) with *variable* cost. To be sure, a company will lose money in the long run if it fails to cover its fixed costs out of the difference between revenue and variable cost. It avoids this, however, not by "distributing" these fixed costs but by maximizing the spread between the revenue from selling the service and the variable cost of producing the service.

"Distribution" of fixed cost to individual services is a method of price-fixing, and does not result in a relevant measure of cost. The only sound point of departure for the pricing process is a measure of variable cost.

The Transportation Case

The significance of fixed and variable costs and of their relationship to each other can best be stated in terms of a cost function. This describes, graphically or by formula, the relationship between cost expressed in dollars, and various levels of traffic expressed in physical output units (such as available ton-miles or gross ton-miles). Figure 2 illustrates such a cost function.

For a carrier of any given size, total cost (C_1 or C_2) is comprised of both fixed and variable elements, as can be seen by examining the costs at both T_1 and T_2 volumes of business. The "True Cost Function" shown in Figure 2 is a graphic statement of the total costs of the firm at various levels of business. At the present level of traffic (T_1) total costs are C_1; if the proposed traffic (T_2) were acquired, total cost would become C_2.

Fixed costs are so designated because they do not fluctuate in relation to the level of business. Whether at volume T_1 or T_2 or any other, fixed costs hold constant. Consider the significance of this characteristic as business increases from T_1 to T_2: fixed costs at T_2 are no larger than at T_1, but there are more units of output (or traffic) over which to spread them. The average fixed cost per unit has gone *down* at T_2.

Total variable cost, on the other hand, increases directly with increases in volume. For example, if the variable (or product) cost is $200 to carry 100 passengers, then it will cost $400 to carry 200 passengers. The variable cost here is $2.00 per passenger; the *total* variable cost is $2.00 times the number of passengers carried. Since variable costs vary directly* with volume (as we have assumed in our elementary model) the cost per unit remains constant, as illustrated by our $2.00 product cost per passenger. The rate of change ($2 per unit) is customarily called marginal cost.

These distinctions are of lesser consequence where technology permits the facile adaptation of cost to traffic, as with corporate expense incurred by air, motor and water carriers. They are of importance however, where inherent physical characteristics preclude short term adjustment of many cost components to traffic fluctuations, as in the rail and pipeline industries. Even with these however, there are indications that the plant size of a going concern can in the very long run, be adjusted to traffic volume.

What is the significance of fixed and variable costs? A separation into the two elements is essential for the determination of the True Cost Function, hence for the determination of the cost of additional or subtracted business. The significance of sizeable fixed costs is that after the variable costs have been met, there is a large residual which must also be covered if the firm is to have any net income. This residual can be covered in any way possible; no mathematical formula can determine how. In fact, the application of mathematical formulas to this particular problem can be a detriment to increasing net income.

The transport industries differ from each other in the composition of their fixed and variable costs, as Figure 3 illustrates. Industry A is typified by very low fixed costs at the typical volume of operation, whereas Industry B has high fixed costs. For Industry A the average cost function (total volume divided by total cost) is a fairly close approximation of the true cost function. But in Industry B the average cost function is a poor measure of true costs: for levels of business *below* the typical level it drastically understates costs, for additional business it drastically *overstates* the increased costs.

In the transportation industries the corporate cost behavior of airlines, most inland water carriers, and motor truckers resembles Industry A. This is so because their operations are conducted in small units, (trucks, vessels, planes), which are cost entities in themselves. As business increases, these firms purchase additional equipment. Most of the fixed costs in these technologies exist *outside* the firm; "conventional accounting" provides a satisfactory measure of their costs, since most costs can be meaningfully associated with a single production unit.

On the other hand, railroads and pipelines resemble Industry B. Large fixed costs are a prerequisite to operations: land for right-of-way, tracks, yards, pipelines, pumping stations, signal systems. Heavy volume is

* and more or less proportionately

the only way to lessen the impact of these fixed costs. As a consequence of these characteristics, railroads pose by far the most complex cost analysis problem; until now pipelines have carried a limited number of commodities in which their cost advantage has been so markedly superior that little or no cost precision has seemed necessary.

Figure 2

SIMPLE COST FUNCTION

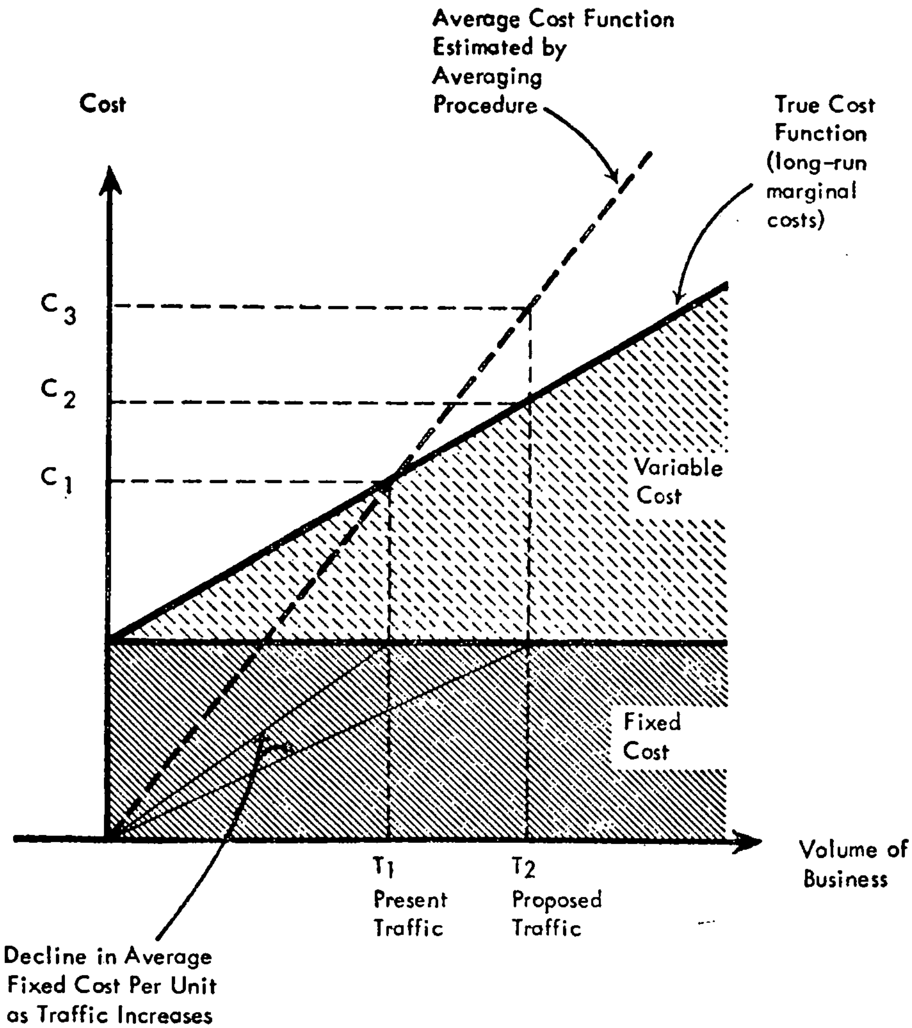
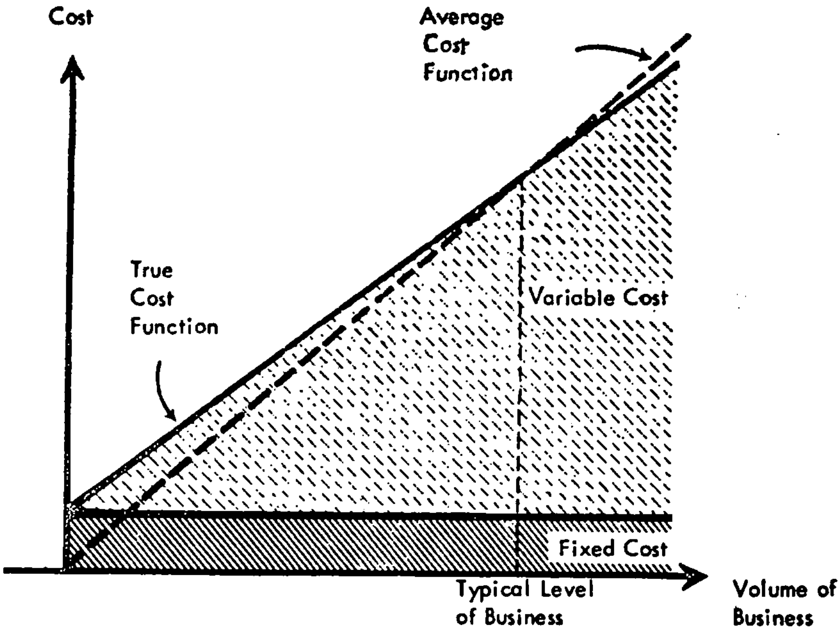
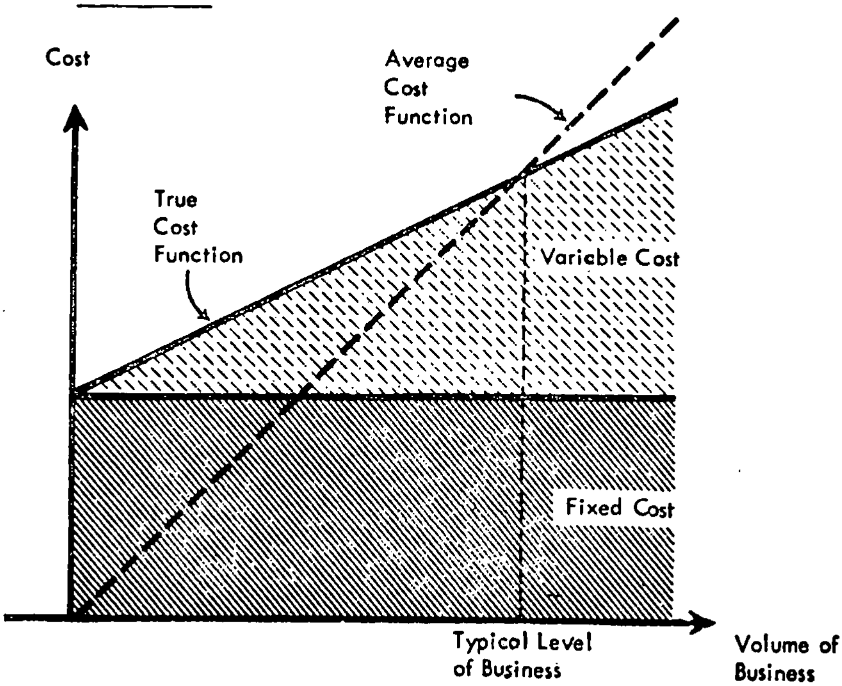


Figure 3

VARYING INDUSTRY COST STRUCTURES



INDUSTRY A



INDUSTRY B

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Fixed Costs

Railroads have large fixed costs for a considerable period of years. Roadbeds, rights-of-way, bridges last for half a century or more. In recent years technological developments have hastened the economic obsolescence of line-haul equipment and terminal facilities. Thus, the modernization drive manifested by dieselization, centralized traffic control, and electronically controlled yards has resulted in the write-off of old and the introduction of new fixed costs; new depreciation bases and new fixed charges on indebtedness. Indeed, there is some evidence, treated later in this report, that technological progress may be in the process of altering conventional concepts of rail cost "fixity," and in its place substituting a type of inverse variability, inasmuch as by contrast with pre-World War II days the rail carriers today handle more traffic with a smaller fixed physical plant.

Investment affords a reasonable measure of the significance of fixed costs, especially in the railroad industry where two-thirds of investment is in road and structures, which are rather permanent, and only one-third in equipment.

For railroads fixed costs loom large because the investment is large relative to output. This relationship is measured by the annual capital turnover; the ratio of gross revenues to capital investment. For railroads the usual ratio has been 1 to 3; that is, there have typically been 3 dollars of invested capital for every dollar of annual receipts. In other words, the average capital turnover required a three year period. In the war years, the ratio was higher than 1 to 3, and in a prior year like 1932, it was as low as 1 to 6. By way of contrast, the steel industry has a capital turnover of once a year or better, while department stores average 3 or 4 times annually. . . .

In brief, it would appear that railroads have the smallest capital turnover in the transportation industry, with airlines enjoying a considerably larger turnover and motor trucks and buses the largest. It follows that such fixed costs as property taxes, fixed rents and interest would loom larger in the railroad cost picture and play a more prominent role in their rate making processes, than would be the case with other agencies of transportation.

Pipeline companies, like the railroads, have large fixed plants, and since their capacity is not fully utilized, a substantial proportion of their expenses are constant in the short run, more so than in any other mode of transportation. Pipeline operating ratios have usually been lower than 50, as compared with the motor carriers, whose operating ratios exceed 90.

Variable Costs

Variable costs may be calculated by comparing total carrier costs incurred when a described service is performed with those incurred in its absence. Examples of such costs are the wages of flight crews, drivers and trainmen, and fuel. Other costs, such as depreciation of equipment partially accrue with traffic (wear and tear) and partially with other factors (obsolescence, weather). One authority believes that the variable costs of railroads are probably "less than 50 per cent of total costs for the short run."[8] Such is not the case in the trucking industry, where the additional traffic will most likely involve adding an entire transportation unit (tractor, trailer and drivers). Thus the out-of-pocket cost incurred by the addition of another unit is only slightly lower than average cost prior to handling the additional traffic, and is almost equal to average cost after the addition of such traffic. It is commonly agreed that at least 90 per cent of all operating expenses, rents, and taxes of motor freight carriers are variable. The great bulk of all costs are direct, since the narrow gap between revenues and expenses motivates variation in fleet size in response to current levels of capacity and profits. Additional traffic handled therefore raises total cost more or less in proportion to the increase in traffic, and thus the out-of-pocket cost of additional traffic is not substantially less than the full or average cost of handling all traffic.

Air carrier cost characteristics are basically similar to those of motor carriers, although the short run proportion of fixed to total costs is growing as equipment becomes larger. A dozen years ago the standard flight unit was a DC-3 costing $100,000 and costs were fixed for only relatively small increments of passengers. As jet aircraft costing $5,000,000 are introduced, depreciation expenses and ancillary equipment with less variable characteristics loom larger in the total framework of air transport cost. In effect variability is present as before, but only in response to larger increments of traffic. Inland water carrier cost characteristics are substantially similar to those of highway transport. The principal capital outlays by the carriers themselves pertain to barges and towboats, the government providing their navigational channel, and shippers in many instances providing a large part of terminal facilities. . . .

Fixed and Variable Costs in the Railroad Industry

Because of its rate-making implications, assessment of fixed and variable costs is unavoidable in the railroad industry. Attempts at solution have been both complicated and controversial. They involve problems of definition, of concept and of measurement.

Definition

Basic to variability determination is a definition of the time dimension involved.

The distinction between fixed and variable cost cannot be examined therefore without the specification of the time period in which the adjustment

[8] Dudley F. Pegrum, *Public Regulation of Business*, Homewood, Ill., 1959, p. 522.

to changes in the volume of traffic can be made. Consider, for example, the elimination of rail passenger service from a branch line. The initial effect is merely the reduction in train service and station costs, and only these might be considered as variable. Over a longer period, however, the level of accounts for maintenance of way and structure and maintenance of equipment may be reduced so that part of these costs become variable with changes in the volume of traffic. Over some longer period even general administrative expenses might be reduced as less administrative effort is required for the numerous problems of passenger traffic management.[21]

Consequently, it would appear that an appropriate time-period for measurement of variability would be one in which management has had ample time to adjust cost to typical traffic volume.

Since variable costs in transportation are equivalent to the economic concept of marginal cost, the phrase "long-term marginal cost" is useful in describing cost behavior which comprehends elimination of the inevitable lag between traffic variation and responsive adjustment in operating expense. It follows that any prospective traffic which is offered at rates above the level of long-run marginal cost will reduce the burden of fixed cost on existing traffic.

But how long a time-period is "long-run"? One leading cost analyst, for example, does "not agree that out-of-pocket costs should include 100 per cent of a stated percentage return on investment in equipment and 50 per cent of a stated return on investment in road property. Because of the significant effects of imbalance and seasonality of traffic, he is of the opinion that the railroads have, *during the greater portion of any given year,* considerable excess capacity in equipment and motive power." (Emphasis supplied) Such an analysis is indicative of the absence of agreed definitions. Greater clarity may accrue if out-of-pocket or variable cost was fragmented into the three separate concepts to which it has been applied. These differ from each other primarily in terms of the time dimension that each comprehends, and in the common usage the distinction between them is often overlooked and definitions become hazy. These concepts are (*a*) very short-term cost, which takes into consideration only those expenses directly traceable to the traffic in question, such as added fuel cost; (*b*) short-term marginal cost, which includes both traceable and some other expenses, but allows insufficient time to permit plant to adjust to the changed level of activity, and hence does not reflect the altered operating costs of the changed plant; and (*c*) long-run marginal cost, which not only reflects the traffic impact on *all* categories of cost but also permits reasonable time for plant adjustment. The concept to which reference is made above appears most closely to approach short-term marginal cost. For this reason we believe it to be in-

[21] John R. Meyer, Merton J. Peck, John Stenason and Charles Zwick, *The Economics of Competition in the Transportation Industries,* Cambridge, Mass., 1959, pp. 18-19.

appropriate, since equating out-of-pocket with variable cost has no economic significance unless such out-of-pocket cost contains a fairly conclusive measure of variability. This seems impossible to secure in a relatively short time period. Hence the long-run yardstick, which involves a period long enough to shake out laggard but nonetheless truly variable cost function, is preferable. . . .

Some of the literature treating of marginal cost also contributes to the conceptual difficulties, no doubt due to inadequate definition of terms. For example, in a recent discussion of the subject, it is stated that "In recent years the 'gospel of marginalism' has captured the fancy of many transportation economists. These economists believe railroad rates should be based, largely if not wholly, on the 'marginal' (or additional) cost incurred in moving an added unit of traffic (whether this unit be expressed in hundredweight, tons or carloads)." After thus correctly defining marginal cost, the discussion continues, ". . . any rate equal to marginal cost will contribute nothing to 'the burden' (i.e., fixed costs and those not readily allocated). The 'burden' includes great bundles of *variable* costs which cannot be assigned to specific pieces of traffic."[26]

Everyone may of course define his own terms but "burden" as commonly understood and used is the difference between variable cost and total cost (i.e., between out-of-pocket costs and the total revenue required to meet operating expenses, rents, taxes, and return, as well as deficits from unprofitable services). The difference between these two dimensions is usually regarded as substantially equivalent to fixed or constant cost. Thus in effect, the above text contradicts itself by assuming that fixed cost includes variable cost. Perhaps the apparent supposition that burden includes non-traceable cost explains this paradox, but if so, it begs the question, since the economic objective is to separate long-run variable costs from fixed or non-variable costs.

Figure 4, may assist to clarify this conceptual difficulty. As before, present volume of traffic is represented by T_1. Obviously no one would suggest reducing all rates up to this volume to the variable cost level, since nothing would be left to cover fixed costs, and a *fortiori* net income would long since have disappeared. Additional business (T_1 to T_2) is contemplated. What is the "cost" of the added business? The "average cost" function, which is nothing more or less than an extrapolation of past experience, would yield the result C_3. The true cost function would yield the result C_2. By definition this includes *all* costs, not just those costs which are easily assignable. In the above quotation the "marginal" cost referred to seems to be a function like Figure 4's "Partial-Cost Function," which does *not* include *all* added costs. It would represent easily traceable costs or costs which are affected in the

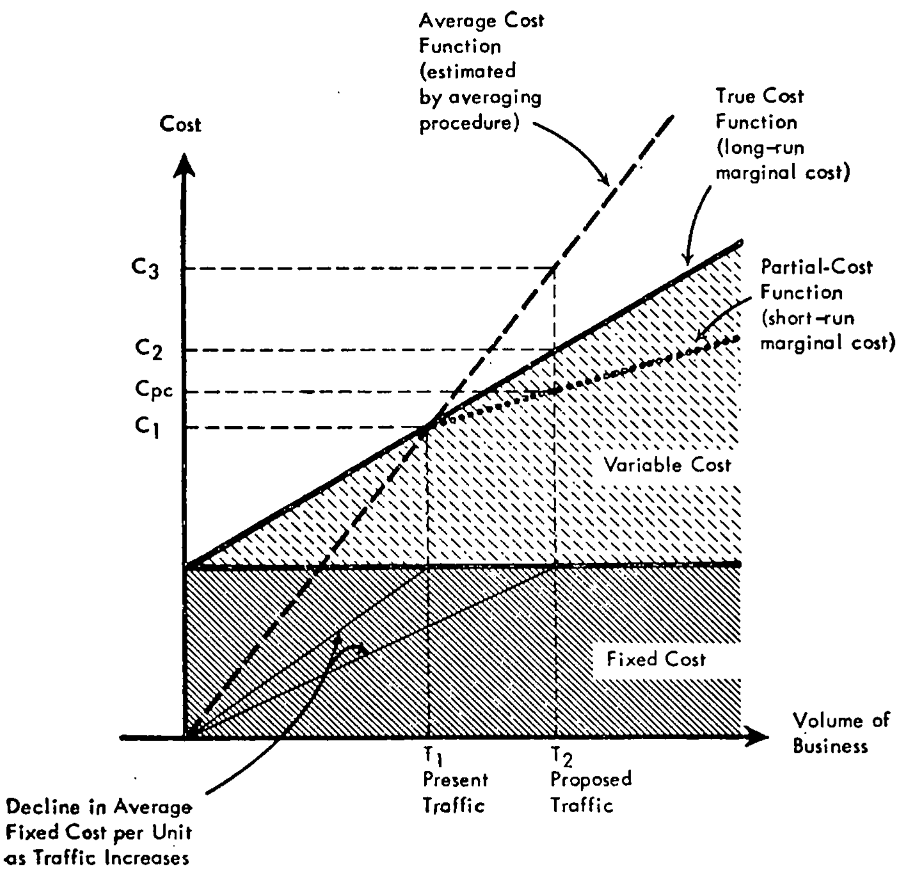
[26] George W. Wilson, "Base Rates on Cost or 'Demand'?", *Railway Age,* September 7, 1959, p. 24.

short-run, i.e. short-term marginal cost, C_{pc}. If the "gospel of marginalism" is to be deplored, a clear distinction must be drawn between the Partial-Cost Function and the True Cost Function. In drawing such a distinction, it must not be overlooked that at volume T_2 (assuming reasonable stability in demand) all traffic carried at volume T_1 remains with the carrier, and presumably continues to pay the same rates as it did before, thus contributing revenues sufficient to cover fixed costs.

Assuming no carrier disposition to grant rate reductions to purely marginal levels for existing traffic sources (and no persuasive reasons have been advanced to indicate that this would be a practical consequence of a marginal pricing policy), all the cost that has to be covered is the *added* cost of volume (T_1 to T_2), which is represented by (C_1 to C_2). This is the true

Figure 4

TRUE AND PARTIAL-COST FUNCTIONS

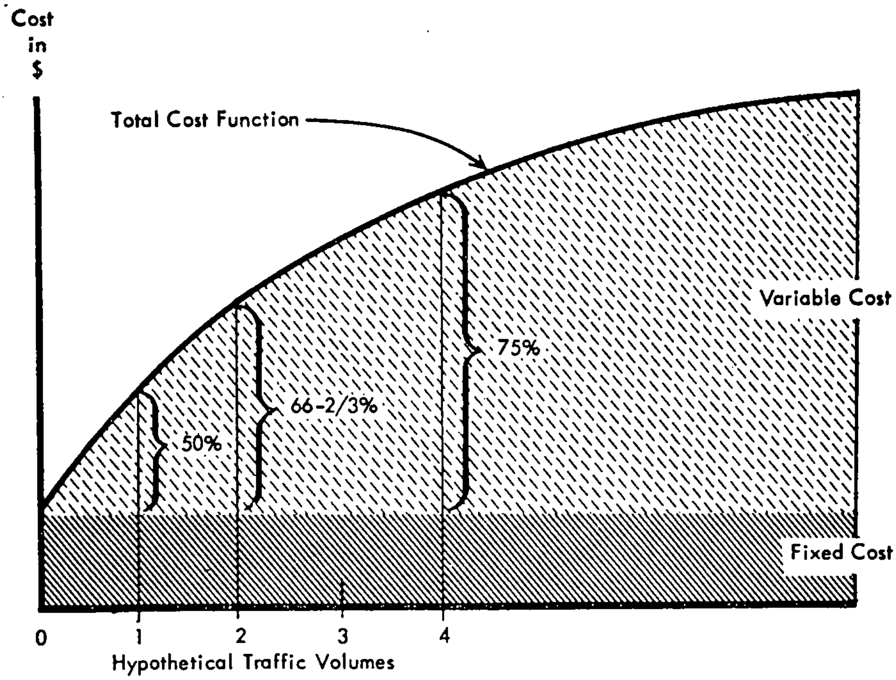


variable cost, i.e., long-term marginal cost. Any rate *above* this cost adds to net income, even though that rate may not approach C_3.

In Figure 4, "fully distributed cost" at present traffic levels is fixed cost plus variable cost; "out-of-pocket cost" is simply variable cost. Hence a change in traffic volume from one level to another does not involve fixed costs, since these will not in any way be altered. The significant point for regulatory agencies and for carriers in considering prospective additional traffic, is that all added costs are represented by the variable or out-of-pocket costs; any rate above this level adds revenue in excess of increased expense. Thus the concept of fully distributed cost has no relevance to pricing added traffic.

Figure 6

VARIABLE COST PORTIONS DIFFER WITH TRAFFIC VOLUME



Section 6

Directly Assignable and Common Costs

Another major problem in transport cost finding relates to the substantial fraction of total cost, which under most conditions cannot be directly assigned to particular types of traffic. This stems from the fact that transportation is essentially a multi-product industry, with several services typically using the same facilities, and with huge expenditures made on behalf of all of them.

Directly Assignable Costs

Directly assignable costs are those which are immediately traceable to particular items of output; in transportation they are said to be costs which can be allocated to particular traffic. They are largely composed of the actual expense involved in moving equipment from point to point, and costs incurred on behalf of specific traffic or traffics. These costs are similar to what the ICC labels "solely related costs" in passenger or freight service, and in connection with rail branch lines whose existence is "solely related" to one particular freight commodity. In truck transportation fuel and driver wages are directly assignable costs: here their identity with variable costs is at once manifest. Similarly, in air and rail transport, plane and engine fuel and crew wages comprise the largest proportion of so-called directly assignable cost. The concept of "above the rail" costs frequently employed in rail passenger curtailment cases, is substantially equivalent to directly assignable cost, and as such falls short of measuring all costs properly associated with the service being analyzed.

Common Costs

Common costs are those incurred by several types of traffic, e.g., in rail by freight and passengers, (or LTL and truckload, in the case of motor freight carriers. Since such costs cannot be allocated, they must be apportioned. For example, if a particular flight carries all types of traffic, or a train carries mail and express as well as passengers, the wage and fuel costs of the flight or of the train movement are largely (but sometimes not exclusively) common to all the types of traffic. These costs may be compared with the cost of a stewardess or food on the plane which would be cost traceable to passengers only, a single traffic component. In other words, costs are common when incurred on behalf of more than one service. . . .

Common costs, while not precisely separable with respect to a product service, may nonetheless be variable with output. Thus, all flying operations and maintenance expenses of a plane carrying mail, express, freight and passengers represent common costs incurred directly on behalf of all four traffic categories. The same is true of a rail car carrying express and mail.

The significant difference between the common cost situation of railroading and those of the other regulated carriers lies in their location. The common costs of railroads are experienced largely within the industry itself. Where more than one carrier is involved, joint facility arrangements apply. By contrast, the common costs typical of other modes occur substantially outside the transport firm (which is to say, they are borne in the first instance by the government). This should not be allowed to obscure the fact that the measurement of common costs is a significant, and largely unresolved issue for these modes also.

The predominant common cost situation in motor transportation for example, centers about joint use of the highways by both private autos and trucks. Thus highway transportation officials are faced with apportioning not only pavement costs, but also such expense as:

Right of Way Requisition	Snow Removal
Fences	Drawbridge operation
Markers and Signs	Earthwork
Traffic Lights	Guide Line Painting
Dust Palliatives	Sidewalks
Traffic Counts	Soiling, Seeding, Sodding

among the various categories of vehicular traffic.

Enormous efforts and expense have gone into attempts to resolve the common cost question in motor transportation. These involve both empirical engineering tests and abstract mathematical analyses. The more sophisticated of such studies have used the "incremental" method, which involves isolation of highway costs incurred for common use and their separation from costs incurred especially for particular groups of highway users, among which the vehicles commonly used by regulated motor carriers loom large. The practical questions are, by analogy, much the same as in the railroad industry. However, the promise of solution in the incremental method is more potential than actual; before precision can be obtained, large gaps in current knowledge remain to be filled. . . .

Difficulties attaching to measurement of such costs have not of course, precluded attempts at cost recovery through user charges for highway and airport facilities in which governmental entities have substantial investments. A multiplicity of fees and taxes now imposed for this purpose on motor and air carriers are reflected in their operating expenses. However, these fees and taxes are quite inadequate measure of such costs. This is not to say that the user charges now imposed are, in the aggregate or in any specific case, too high or too low. The point of significance here is simply that no one really knows. The great disparity in such fees and taxes among the jurisdictions which levy them would tend to indicate that relatively little progress has been made in relating them with precision to the costs they are ostensibly designed to cover. . . .

It is thus apparent that common costs pose difficult administrative and technical problems in cost ascertainment. At this writing much remains to be done with this particular matter; it cannot be allowed to remain in limbo if public policy requires an increased measure of precision in transport costing.

Joint Costs

Common costs not traceable to individual products are, in the economic sense, further classifiable into joint and alternative product costs. True jointness exists only when the production of one commodity (e.g. butter) necessarily results in the production of another (e.g. buttermilk). Therefore, an increase in the production of one commodity necessarily increases the output of the other. If, however, the output of butter resulted in a decrease in the output of buttermilk, then the products would be alternative. An example of the latter in transportation would result from relocating an aircraft bulkhead to enlarge cargo capacity, thereby decreasing the passenger cabin. An increase in time of railroad top management devoted to freight service rather than passengers is likewise a case of alternative product cost.

Illustrative of joint costs in transportation is the return movement of line-haul equipment, for supply of return capacity is totally dependent upon outward supply. An increased demand for service between points X and Y (unaccompanied by service demands between Y and X) will have to be met by a rate covering all costs encountered in the backhaul or empty return. Return traffic may be encouraged at rates approaching out-of-pocket cost for the backhaul, and revenues received from such traffic apply against entire round-trip cost. However, if low rates on the backhaul stimulate sufficient traffic to warrant increased capacity or an increase in service from Y to X then the rates are uneconomic for the added capacity. The return capacity that was a "by-product" now becomes a "primary product" and the outward mileage is the "by-product". Thus the established rates are inadequate since total revenues are now insufficient to cover out-of-pocket round trip costs.

Larger carriers attempt to minimize their joint costs through operation of "cornered trade," in other words, equipment moving from A to B need not necessarily return empty directly from B to A, but instead may go under load from B to C to D to A, thus reducing the joint cost impact.

Differences between Constant and Joint Costs

The characteristic shared by both constant and joint cost is that neither is assignable to individual units of traffic. On the other hand unit joint costs are unaffected by the extent of plant utilization, whereas constant costs are minimized as a carrier reaches the volume of output (transportation service) at which maximum utilization is obtained. At such a traffic level, the law of decreasing costs no longer applies and all costs become variable with output. By contrast, the return movement of transportation equipment is as much a joint cost when a carrier is operating at capacity as it was at a lesser traffic volume.

A Note on Multiple Regression Analysis and A Note on Tests of Significance

by

Wm. C. Hood

TORONTO 1961

A Note on Multiple Regression Analysis

In this note, the main principles of multiple regression analysis are explained simply. We start first with simple regression analysis, move on to multiple analysis, then offer an interpretation of results and compare regression methods of distributing costs with methods.

Simple Regression Methods

Regression analysis is concerned with measuring the degree of relationship between or among variables. It derives its name from an early application to the study of the relation between heights of sons and heights of fathers to determine whether heights of sons "regress" to heights of fathers. The name "regression" has continued to be used to describe the method whatever the application.

Let us suppose that because of our general knowledge of railroad operations, we believe (or are willing to propose as an hypothesis to be tested) that a particular category of railway expenses (E) is related

(a) principally to traffic (T)

and also to (b) unspecified variables (U)

which collectively may be important at times though not on the average, but which individually are presumed to have no significant effect, ever.

Let us suppose further that we have measurements on this expense item and on traffic for each division of the railroad and that we plot the pairs of observations pertaining to each division as points on a diagram such as Diagram I.

If the scatter of points gives an impression of a straight-line relationship between E and T and if this accords with our preconceived ideas we will postulate that the relation between E and T is a straight line and our problem will then be to find the line which in some sense best fits the divisional observations. Clearly we do not expect the line of relationship to pass through every point, for that would imply that the unspecified variables U have no effect ever, and not merely no effect on the average.

We think of the line as being described by the equation

$$E = a + bT$$

where, as in Diagram II, a is the amount of expense incurred irrespective of the amount of traffic and b is the slope of the line, that is the increase in expense per unit increase in traffic. It might be thought desirable to choose a and b so as to minimize the average values (over all divisions or observations) of the deviations of the points from the line. As a matter of fact we do rather better than that; we choose a method that makes this average value zero and which minimizes the average of the squared values of the deviations. (Squaring the deviations gives special emphasis to the large deviations and avoids the nuisance that some deviations are positive and others negative.)

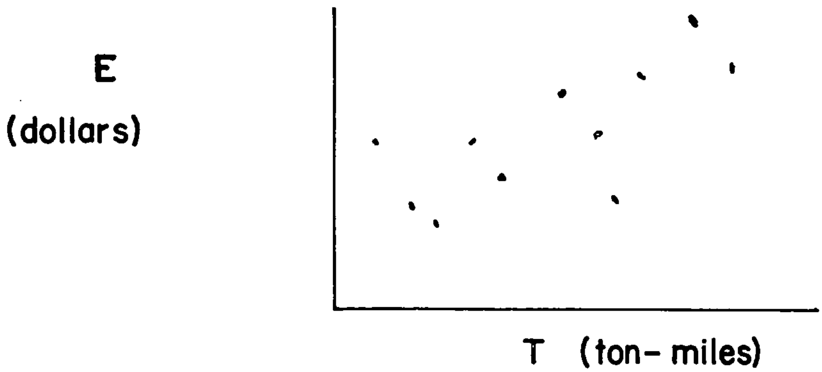


DIAGRAM I

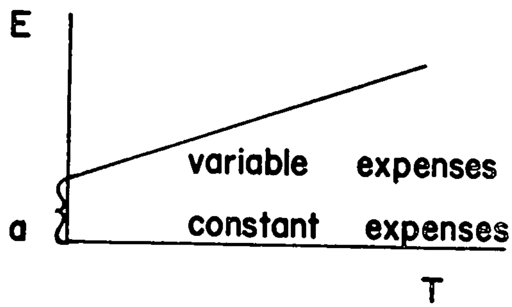


DIAGRAM II

Simple regression analysis, using straight lines, then involves choosing the constants a and b of the line of relationship so that the average of the squared values of the vertical deviations of the observations from the line is a minimum, *i.e.,* so that

$$\frac{\underset{\text{all d}}{\text{Sum over}} \left\{E_d - (a + bT_d)\right\}^2}{\text{Number of divisions}}$$

is a minimum.

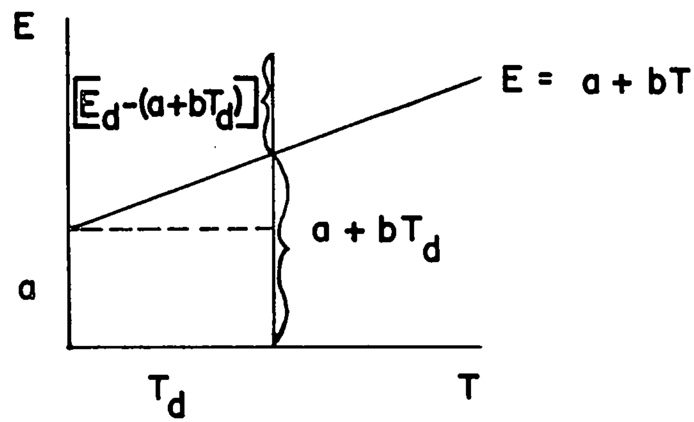


DIAGRAM III

Multiple Regression

We have considered the case in which only one specific variable was used in explaining expenses, multiple regression involves the explicit use of two or more variables to explain expenses.

Let us suppose that our general knowledge of railroad operations would lead us to believe that expenses (E) are related

(a) principally, though in different degree to passenger traffic P and freight traffic F, and

(b) to unspecified variables U.

Let us suppose further that we have measurements on this expense item and on passenger traffic and freight traffic for each division of the railroad and thus we plot the two graphs shown in Diagram IV where each point in a graph pertains to a division.

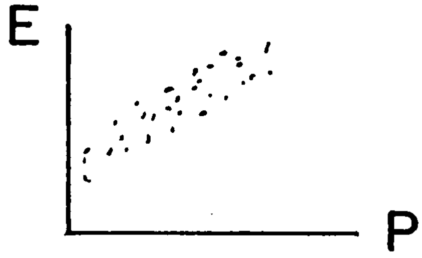


DIAGRAM IV

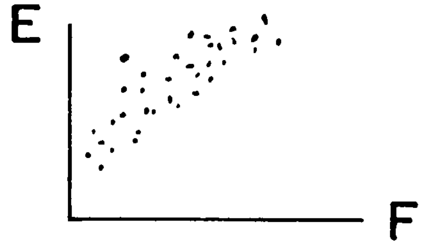


DIAGRAM IV

If these two scatters of points each give an impression of straight-line relationships between expenses and the component, passenger or freight, of traffic and if these impressions accord with our preconceived ideas we will postulate that the relation among E, P and F is a straight line of the form

$$E = a + b_P P + b_F F$$

where a, as before, is the amount of expense incurred irrespective of the amount of traffic, b_P is the increase in expense per unit increase in passenger traffic for any fixed level of freight traffic, and b_F is the increase in expense per unit increase in freight traffic for any fixed level of passenger traffic. Geometrically, the equation represents a plane, instead of a line as before, and multiple regression analysis involves the choice of a, b_P and b_F on the basis of the divisional observations in such a way as to minimize the average, over all divisions, of the squared deviations of expenses as observed from expenses as calculated from the equation, that is so as to minimize

$$\frac{\text{Sum over all d of} \left\{E_d - (a + b_P P_d + b_F F_d)\right\}^2}{\text{Number of divisions}}$$

As in the case of simple regression, the choice of constants will always be such that the average of the calculated deviations will be zero.

Interpretation

It is to be noted the method of regression analysis divides a particular category of expense into that portion which is constant and that portion which is variable and that further it allocates the variable cost among the several variables which give rise to its variation. Thus, for example, a total expense ΣE_d, considered over all divisions, which let us say number N, is broken up as follows:

Na	— constant portion
$b_P \Sigma P_d$	— variable portion attributable to passenger traffic
$b_F \Sigma F_d$	— variable portion attributable to freight traffic
ΣE_d	— total expense for all divisions

This method of allocating expense to the constant and variable categories and among factors contributing to variation may be contrasted with two alternative schemes.

1. Consider first a scheme to be called *prorating*. It may be thought that the category of expense E under consideration is wholly variable and to be attributed to passenger traffic and to freight traffic. Suppose that the data on these variables are expressed in passenger car-miles and gross ton-miles respectively. It is then necessary first to convert these measures to a common unit. If the expense item under consideration is for example, station expenses, it may be thought that station expenses depend on hours taken to process the paper (waybills, tickets, etc.) governing passenger and freight traffic and that these time factors depend on the respective volumes of traffic. It is then necessary to find the factors—here called H_P and H_F—by which to convert car-miles and ton-miles to common units. Having determined these, the proportions of hours devoted to passenger and freight traffic respectively are calculated and applied to the total of expenses in the category under consideration to determine the distribution of expenses as between passenger and freight traffic. The division may be expressed as follows, using notation already introduced:

$$\left(\frac{H_P}{H_P\Sigma P_d + H_F\Sigma F_d} E\right)\Sigma P_d \text{ — variable portion attributable to passenger traffic}$$

$$\left(\frac{H_F}{H_P\Sigma P_d + H_r\Sigma F_d} E\right)\Sigma F_d \text{ — variable portion attributable to freight traffic}$$

$$\Sigma E_d \text{ — Total expenses}$$

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Comparing the items in brackets with b_P and b_F in the regression analysis, it is readily seen that the prorating method here described is complicated in that (a) it has to adduce hypotheses not necessary in regression analysis in order to convert explaining variables to common units, and (b) there is a tying together of the two terms in brackets imposed by the common terms in each, which is not featured in the same way in regression analysis.

2. In the example just given we argued as though all expenses in the given category were thought to be variable. If they are not all thought to be variable, the constant portion must be separated and the prorating scheme applied only to the remaining variable portion. A common method for effecting this separation employed widely in ICC cost studies, for example, is to perform a simple regression of *total* operating expenses in all categories against a traffic variable covering all operations of the railroad and determine the per cent of all expenses variable (as we did in the first part of this paper) and apply this percentage to *all* categories of expense. The very high degree of approximation involved in this procedure need not be stressed.

Conclusion

It would be wrong to leave an impression that the use of multiple regression techniques reduces railway costing to an artless routine. There is a good deal of art or judgment involved in the use of these techniques. For example, the choice of which variables to settle upon finally as determinants of a particular item of expense involves art, though there are several widely accepted rules, with firm foundations in the theory of the subject, to guide one. No doubt these rules will be further developed in the years to come.

The use of multiple regression techniques represents a breakthrough in railway costing permitting some escape from the particularly restrictive assumptions involved in the variations of prorating now in such wide-spread use. The adaptation of this long established statistical procedure to problems of cost accounting may be expected to show pronounced development in the next few years.

A Note on Tests of Significance of the Coefficients of the Independent Variables in Statistical Cost Equations

It is the purpose of this memorandum to give a brief account of the statistical theory underlying tests of the significance of the coefficients of the independent variables in least squares regressions.

In particular, the railways have used, for example, equations of the form

$$E = a + b_P P + b_F F \tag{1}$$

where E is the total expense of a specified category, measured in dollars,
a is a constant measured in dollars
P and F are independent variables, measuring passenger traffic and freight traffic respectively in natural units such as ton-miles;
b_P and b_F are constant coefficients, measured in dollars per unit of passenger traffic and dollars per unit of freight traffic respectively.

So-called "t-tests" of significance of the coefficients b_P and b_F have been applied as one indication of the acceptability of a statistical cost equation. We shall explain (a) what a t-test is; (b) what is the difference between a "one-tailed" and "two-tailed" test; and (c) the reasons for the appropriateness of the "one-tailed" tests in the tests of the coefficients in the equations used by the Canadian Pacific and Canadian National Railways.

What is a "t-test"

Using the illustration given above, the theory underlying the application of least squares regression to the explanation of the generation of expense E is that in each division of the railway in the three-year period for which the observations were taken, the expense E_d is to be explained by the sum of the constant a and the linear combination of traffic variables $b_P P_d + b_F F_d$ *plus* a random factor, U_d, standing for unspecified factors which collectively may be important at times though not on the average. It is an integral part of the theory that this random factor U_d is prescribed to be characterized, in each division, by the *same* normal probability distribution, having mean equal to zero and some particular finite variance. The data for each division imply a particular value of the random variable U_d, the value that is handed to us by nature as it were, making a random selection for us from this normal

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distribution. According to this view, the amount of expense in division d may be expressed as

$$E_d = a + b_P P_d + b_F F_d + U_d \qquad (2)$$

where the subscript d refers to the particular division d.

The important point to note in the present context is that, regarding P_d and F_d as fixed (non-random) variables, E_d, the observation of the expense in division d is itself a random variable because of its dependence upon the random variable U_d. Moreover, since the estimates b'_P and b'_F of the coefficients b_P and b_F depend upon the observations of the variables E_d in all divisions, these estimates must also be regarded as random variables.

It is a comparatively simple matter for the theoretical statistician to prove that if the random variables U_d have a common normal probability distribution with mean zero and finite variance, the random variables b'_P and b'_F will be characterized by the probability distribution widely known as the "t" distribution. It is because the "t" distribution is used in testing the significance of the coefficients b_P and b_F that these tests are referred to as t-tests.

The "t-test" in relation to the coefficient b_P, for example, is an evaluation of the hypothesis that the coefficient b_P is in fact zero. In making the evaluation of this hypothesis the knowledge of the estimate b'_P and of its distribution—the t distribution—is used. Roughly put, the problem is to decide whether the observed value of b'_P can be held to be consistent with the hypothesis that $b_P = 0$ given the probability distribution of b'_P.

One-tailed and Two-tailed Tests

In constructing a test of the hypothesis that b_P is zero we have to

1. specify the alternative hypothesis or hypotheses that we are prepared to accept if we do not accept the hypothesis that $b_P = 0$;
2. divide the possible values of the estimate b'_P into two groups: the values which would warrant acceptance of the hypothesis that $b_P = 0$ and the values which would warrant the rejection of this hypothesis in favour of the alternative or alternatives.

It is not possible to do step 2. until after step 1. has been taken.

The alternative hypotheses mentioned in step 1. commonly take *one* of three forms:

A. $b_P \neq 0$

B. $b_P > 0$

C. $b_P < 0$

It will be noted that in the first set of alternative hypotheses the admissible alternatives include both values of b_P that are greater than zero and values that are less than zero. The test of the hypothesis $b_P=0$ against this set of alternatives is known as a "two-sided" or "two-tailed" test. In the sets of alternatives B. and C. the admissible alternatives are either greater than zero (case B.) or less than zero (case C.) but not both. The test of the hypothesis $b_P=0$ against alternatives B. is known as a "one-sided" or "one-tailed" test. Similarly the test of the hypothesis $b_P=0$ against alternatives C. is also known as a "one-sided" or "one-tailed" test. We shall argue below that in the railways' cost analysis alternatives B. are the relevant ones. First however let us examine the nature of hypothesis testing further.

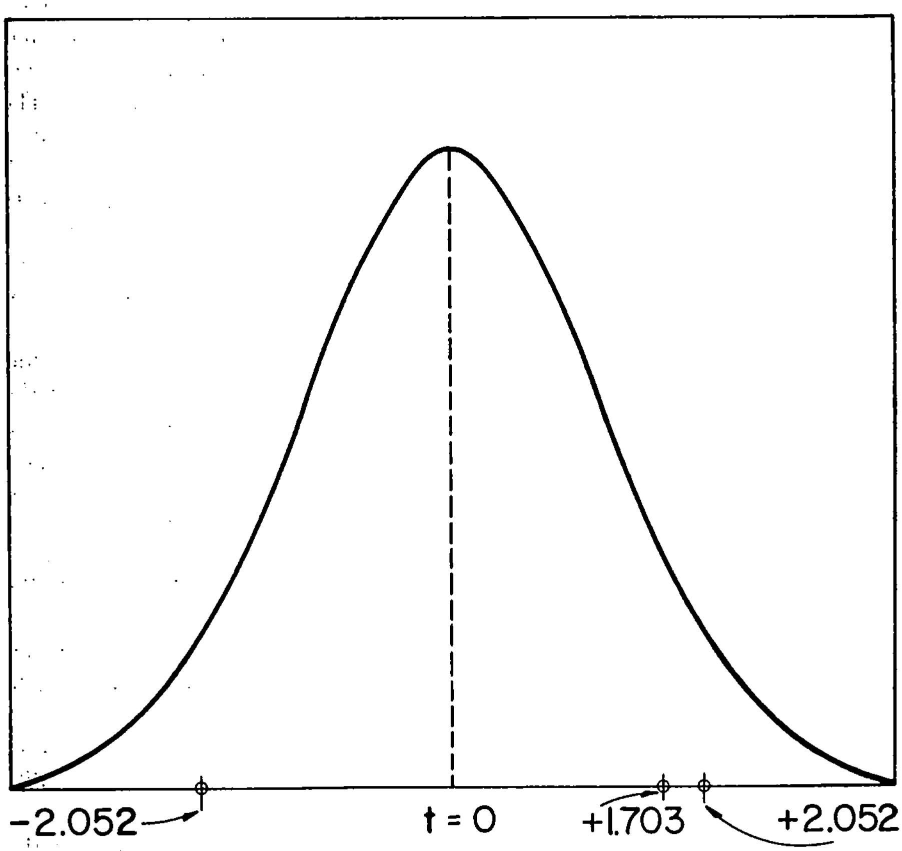
In testing the hypothesis $b_P=0$ against a specified set of alternatives, it has to be recognized that we cannot make our decision with absolute certainty. This is in the nature of the case. We must base our decision on the value of the estimate b'_P that we observe, and we have to recognize that b'_P is a random variable which can occasionally assume extreme values. In fact we must expect from time to time to make each of two kinds of error. The first type of error is that of not accepting the hypothesis $b_P=0$ when it is true. The second type of error is that of accepting the hypothesis $b_P=0$ when it is false. The commonly used strategy of hypothesis testing is to fix the probability of a Type I error at some specified level and make the probability of a Type II error as small as possible. Unfortunately we cannot arbitrarily fix the probabilities of *both* types of error; we have to trade one off against the other.

The assigned probability of a Type I error, that is of not accepting the hypothesis $b_P=0$ when it is true is known as the significance level of the test. This probability is often assigned a value of 1 per cent or 2.5 per cent or 5 per cent or sometimes higher values up to 10 per cent depending upon circumstances. The probability of a Type II error is known as the operating characteristic of the test; its complement, that is one minus the probability of a Type II error, is called the *power* of the test. It is the probability of rejecting the hypothesis $b_P=0$ when it is false. We may sum up the strategy of hypothesis testing then, by saying that after we have decided upon the set of alternative hypotheses, we fix the significance level of the test and then devise the test procedure so as to maximize the power of the test to reject the hypothesis $b_P=0$ when it is false.

To fix the significance level of the test permits the delineation of a series of ranges of values for the test statistic b'_P such that the probability that the statistic as calculated will fall within these ranges, *if* $b_P=0$, is not greater than the significance level of the test. To maximize the power of the test is to choose from the series of ranges that are consistent with the significance level of the test that one range which maximizes the probability of rejecting the hypothesis $b_P=0$ when it is false.

The power of the test can be calculated with respect to each alternative in the admissible set of alternatives. It is the probability that the test statistic, b'_P will fall within the range leading to rejection of the hypothesis $b_P=0$, calculated on the assumption that this particular alternative is true. We may denote the power of the test then with respect to each alternative hypothesis in the admissible set. It is not always possible to maximize the power of the test with respect to each alternative in the admissible set; sometimes we have to be content with achieving a maximum average power over all alternatives.

In fact, since the estimate b'_P divided by its estimated standard deviation is the standardized statistic "t", ranges of b'_P can readily be translated into ranges of "t". In the diagram we have sketched the probability distribution of t. The distribution we have drawn is based on the assumption that in fact $b_P=0$.



On this assumption it can be shown that values of t greater than 2.052 or less than —2.052 will occur with probability of 5 per cent (when the number of degrees of freedom, *i.e.,* the number of observations less than the number of constants determined by the regression equation is 27). It can further be shown that when testing against the alternatives

$$b_P \neq 0$$

this range of t values, *i.e.,* $t > 2.052$ and $t < -2.052$ gives the highest *average* power of the test, considering all alternatives in the set $b_P \neq 0$.

Still referring to the diagram, drawn upon the assumption that $b_P = 0$, it can be shown that values of t greater than 1.703 will occur with probability of 5 per cent (when the number of degrees of freedom is 27) and that when testing against the alternatives

$$b_P > 0$$

this range of t values will give the highest power of the test in respect of *each* alternative in the set $b_P > 0$.

It is very important to note in the present context, and with special reference to the problem to be taken up in the next section of this memorandum, that for any tests of specified significance level, say 5 per cent, the power of the test in respect of alternatives on one side of zero, is higher in the case of the appropriate one-sided test than in the case of the two-sided. Let us express this proposition in yet another way. Consider the hypotheses in the set $b_P > 0$. We may test the hypothesis $b_P = 0$ against these alternatives alone or, using a two-sided test, in conjunction with the alternatives $b_P < 0$. If we use the same significance level in either procedure, then if in fact $b_P > 0$, the probability of rejecting the hypothesis that $b_P = 0$ is greater when we use the one-sided test than when we use the two-sided test. We cannot prove this proposition here, but we would draw the attention of the reader to the graph of the power functions of the two-sided and one-sided t-test procedures having the same significance level that is shown on page 263 of A. M. Mood's *Introduction to the Theory of Statistics.* This graph illustrates the proposition. The adjoining discussion in the text cited, analyzes the proposition.

The Appropriateness of the One-tailed Tests of the Coefficients of the Railway Cost Regressions

When we make a two-tailed or two-sided test, if we reject the hypo thesis that $b_P = 0$, we accept the alternative that b_P is either greater than or less than zero and we make no distinction between these possibilities. If in fact we have no reason to make any distinction between these possibilities, then this is a perfectly sensible and proper procedure.

It so happens, however, that in the case of the railway cost regressions we would in no instance be prepared to countenance the view that the expense might vary *inversely* with the independent variable. In every instance we believe that the expense varies either *directly* or not at all with the independent variable. Since this is the belief and since there is no debate on this point whatever, it makes no sense, in constructing our test procedures, to allow as an admissible alternative hypothesis the possibility that expense might vary inversely with the independent variables. Since there is agreement that the relationship between expense and the independent variable is in every case either non-existent or direct it follows that we should allow as admissible alternative hypotheses only the set

$$b_P > 0,$$

to refer to our specific example for the sake of concreteness.

What are the consequences of this practice?

In the first place we make our test procedure consistent with the *a priori* information we have. In the second place, as we argued in the preceding section of this memorandum, we maximize the probability of rejecting the hypothesis of no relationship between the traffic variable (or independent variable) and expense when in fact there is a direct relationship. That is to say we maximize the power of the test in respect of the alternatives $b_P > 0$. Finally, it is to be noted that even though it is entirely possible that specific samples will yield estimates b'_P of b_P that are negative we do *not* reject the hypothesis that $b_P = 0$ when we obtain such estimates. Indeed all negative values of the test statistic (as well as positive values up to and including the value corresponding with a value of $t = 1.703$—for tests with significance level of 5 per cent and 27 degrees of freedom) lead to the acceptance of the hypothesis of zero relationship, *i.e.*, $b_P = 0$.

M. G. Kendall in volume 2 of his *The Advanced Theory of Statistics* in concluding his chapter 26 on the general theory of significance tests writes (p. 303) as follows:

> "It is difficult to reduce rather vague prior knowledge of a parameter to numerical form, and hence to extend our theory with great precision to cover these cases; but in practice it is desirable to consider, before adopting a test, whether any prior knowledge is available, or whether our interests centre on particular parts of the range. If they do, we may consider the behaviour of power functions of the possible tests at our disposal and examine which is the more powerful test *in the particular part of the range which interests us most.* The mere fact that the theory developed in this and the succeeding chapter makes no

assumptions about the prior probabilities of admissible alternatives does not mean that we should be acting sensibly in ignoring any prior information which may be at hand when applying the theory, or that we need feel compelled to apply tests with optimum properties in regions where we know the unknown parameter-values will not fall."

The Problem of Grain Costing

by

D. H. HAY

OTTAWA 1961

Table of Contents

Chapter 1

Introduction

The report contained in the following chapters attempts to meet several objectives simultaneously. In the first place, the author was directed by the Commission to examine the presentations of the various expert witnesses who appeared before the Commission to testify upon the costs of moving grain by rail from the Prairie Provinces to the export ports (the so-called Crowsnest traffic); and, following that examination, to report to the Commission his views upon the acceptability of the various conflicting views on the amount of these costs. In the second place, he was directed to pursue a course of independent study, drawing upon the resources made available by the various witnesses, to assess the art of railway costing, so far as this could be done within the limits of the information available to the Commission, and to refine the cost estimates where possible. This report embodies the results of such an examination and investigation.

While the objects of this report are, at least in concept, simple, the audiences to which it was to be aimed form a disparate group. Those members of the Commission who may not have been expert in costing techniques before their sessions began, underwent an intensive course of education during their meetings. Others who may read this report will also be experts in costing techniques. To these, some portions of this report may seem an excessively simple presentation. However, the author was instructed to prepare a document which, as far as possible, would enable members of the public, who have not been trained in costing procedures, to understand the arguments which were presented to the Commission and which may be presented in future hearings of other bodies. It is probably impossible to speak to these two groups, in one volume, to the complete satisfaction of both. It is to be hoped that the danger of satisfying neither group has been reasonably avoided.

Even those witnesses who were in partial disagreement with their conclusions paid tribute to the work which was presented by the cost analysts of the Canadian Pacific Railway and the Canadian National Railways. It was generally agreed that their extensive use of multiple correlation analysis in official proceedings was a valuable contribution to the art of railway costing.

R. L. Banks and Associates and W. B. Saunders and Associates each presented criticisms of the railway cost estimates. The value of their contributions will speedily become apparent to the reader of this report. In this connection, tribute should be paid to the officials of the two railways who freely provided material to these consultants and to the Commission staff in order that criticisms could be founded in fact.

The criticisms of the railway methods were mainly related to the presentation of the Canadian Pacific Railway. The same procedure has been followed here. For the most part, the two railways used parallel methods of estimation. To the extent that they did so, criticisms of the Canadian Pacific methods obviously apply equally to the Canadian National Railway methods. The most important differences have been noted in this report. Where it was possible to do so, preferences between alternate methods were indicated.

A cost analysis of the type discussed in these chapters deals with a great many items. It is obviously impossible to discuss each of these at great length and still preserve a volume of manageable proportions. The principle of selection has been to discuss at greatest length those parts of the cost study which have generated the most serious differences of opinion among the consultants and those parts which were of greatest importance in the final results of the cost study.

The author wishes to thank Professor F. W. Anderson, Director of Research of the Commission, Professor D. E. Armstrong of McGill University, and Professor Wm. C. Hood of the University of Toronto. Each has read this report in draft and has offered helpful suggestions. The responsibility for errors and omissions remains solely that of the author. Thanks are also due to each of the other members of the Commission staff. All have provided assistance. In particular, thanks are due to Mrs. F. Bériault who acted as secretary to the author and Miss V. Young who performed many tedious statistical calculations.

Finally, the author must thank the members of the Commission. The conclusions presented here, and many of the comments, were presented to the Commission first during some of their private meetings. The Commissioners discussed these with the author with unfailing patience and consideration. It is hoped that the contents of this report aided the Commission to reach its conclusions. It is certain that constructive criticism by the Commissioners improved the report.

Chapter 2

The Problem of Railway Costing

The total cost of operating a railway can be found without too much difficulty. One need merely keep track of the expenditures for a given period and add to these a suitable allowance for depreciation. In an era when the railways had a significant degree of monopoly on all or most of the traffic handled, they hardly needed to go beyond the measurement of total cost. If total revenues did not seem likely to carry the total cost of the railway, the entire rate level could be raised to do so. Under competitive conditions, however, it is necessary to know the cost of transporting specific commodities between specific points. If alternative means of transportation can offer a rate below the cost of that movement by rail, a railway which does not know its specific costs may attempt to compete; thereby it will, in effect, pay for the opportunity to carry the goods. The final result of such a pricing policy is, of course, bankruptcy. On the other hand, if the railway is too cautious, it may set a rate which is well above the cost but at which the traffic will move by the competitive means. In this case, the railway will be turning away a profit.

Regulatory agencies also have need of specific cost information. If it is claimed that one of a pair of rates is discriminatory, a showing of different costs may be included in the defence of the rates. Also, specific cost data is necessary if the regulatory authority is to guard against "unfair" competition. In this regard, the theory is that, since railways tend to be large organizations, they will tend to have relatively large financial resources even if they operate at a small profit (as measured against either volume of traffic or investment). If such organizations have a large number of small, but lower cost, firms arrayed against them as competitors, it is possible for them to charge rates at less than their competitors' lower costs. When this has continued for a sufficient length of time, the competitor will be driven out of business. If this happens, the railway will then be able to revert to higher, and profitable, rates on traffic which, in the absence of this tactic, it would not have had. Since the effect on the public is to substitute a carrier with higher costs for one with lower, regulatory bodies are on guard against this type of "unfair" competition. They, therefore, insist that rates lowered to meet competitive costs must cover the cost to the railway of carrying the traffic. It is worth noting that if the competitive mode is an industry which can easily be entered, as is the case with trucking, "unfair" competition is unlikely to succeed and an enlightened management would not be likely to attempt it.

Further, if the two or more carriers are of approximately equal financial strength, the competition between them may become "ruinous competition". The result may be financial failure for all and, at least for a time, there may be no carrier able to serve the public. Even if no competitor dominates the transportation field a regulatory body will wish to guard against unduly low rates of this kind.

In the following pages, some of the problems of estimating transport costs will be examined. This chapter introduces the subject by inquiring, in a general way, into the nature and behaviour of costs. Various definitions will be introduced by means of examples.

The simplest kind of business consists of a single person who buys a single product from a supplier and in turn sells it to his customers. Let us suppose that the owner of this business carries it on from his own home—to which no alterations are required because of his business activity. Further, let us suppose that he purchases his stock on consignment, paying for it only as it is sold, and that he must pay the same price whatever the quantity of the goods which he buys. Under these conditions, in any given period of time, his cash outlay will be the cost per unit which he sells multiplied by the number of units sold. Graphically, this can be illustrated as in Figure 1. Here, the vertical axis represents the total cost and the horizontal axis the quantity purchased by our businessman. As the quantity bought increases, the cost increases. In the hypothetical example pictured in Figure 1, each unit is represented as costing seventy-five cents. It has also been assumed that small fractions of a unit can be sold. This is the average cost and is constant, no matter what quantity is bought and sold by our businessman. Economists also discuss the *marginal cost*. This is the cost of

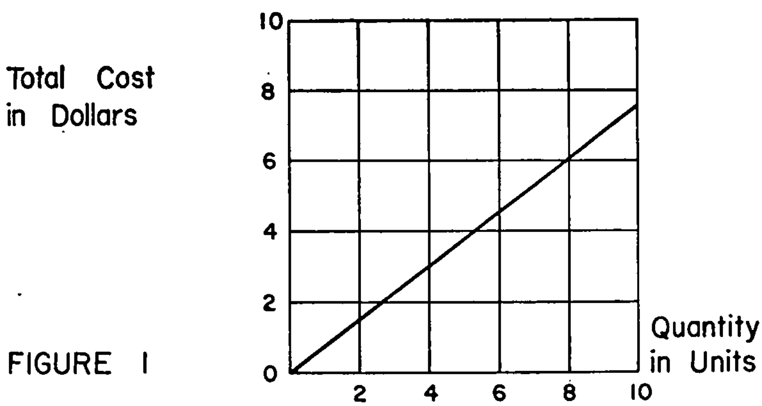


FIGURE 1

an additional unit added to any existing level of production or, in this case purchase and re-sale. In our example, the marginal cost will also be seventy-five cents. Graphically, the average and marginal costs of our hypothetical business are shown in Figures 2 and 3.

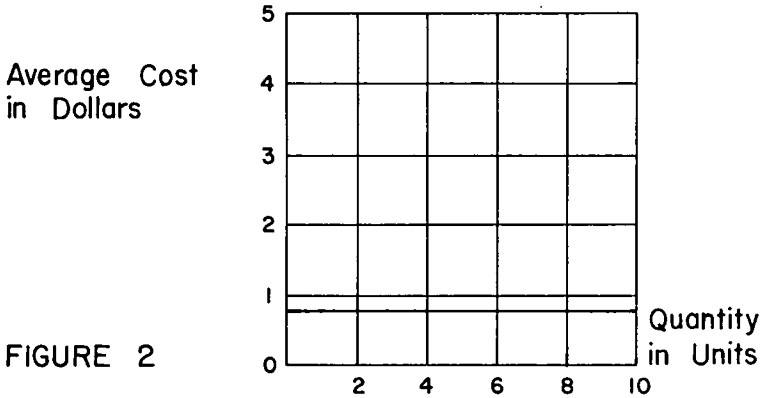


FIGURE 2

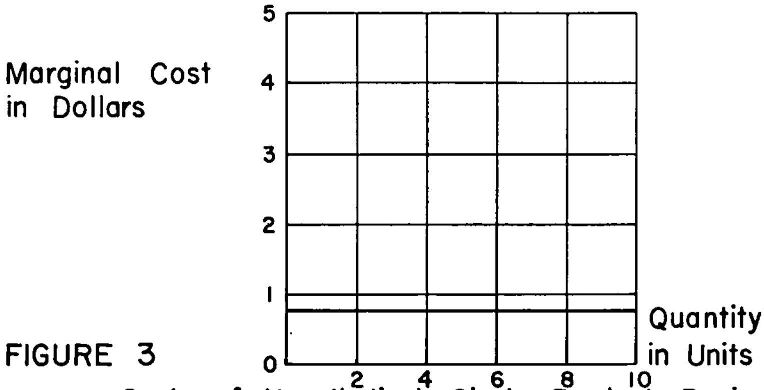


FIGURE 3

Costs of Hypothetical Single Product Business

In the example we have discussed, the cost varies with the output and disappears when there is no output. Assume, now, that the municipality in which this business is carried on passes a by-law requiring the payment of a business tax of one dollar. Then this sum of one dollar would be a cost to the business which could only be escaped by going out of business. Even if in fact nothing was sold, the business tax would have to be paid. In addition, no matter how much was sold, this part of the cost would remain fixed at one

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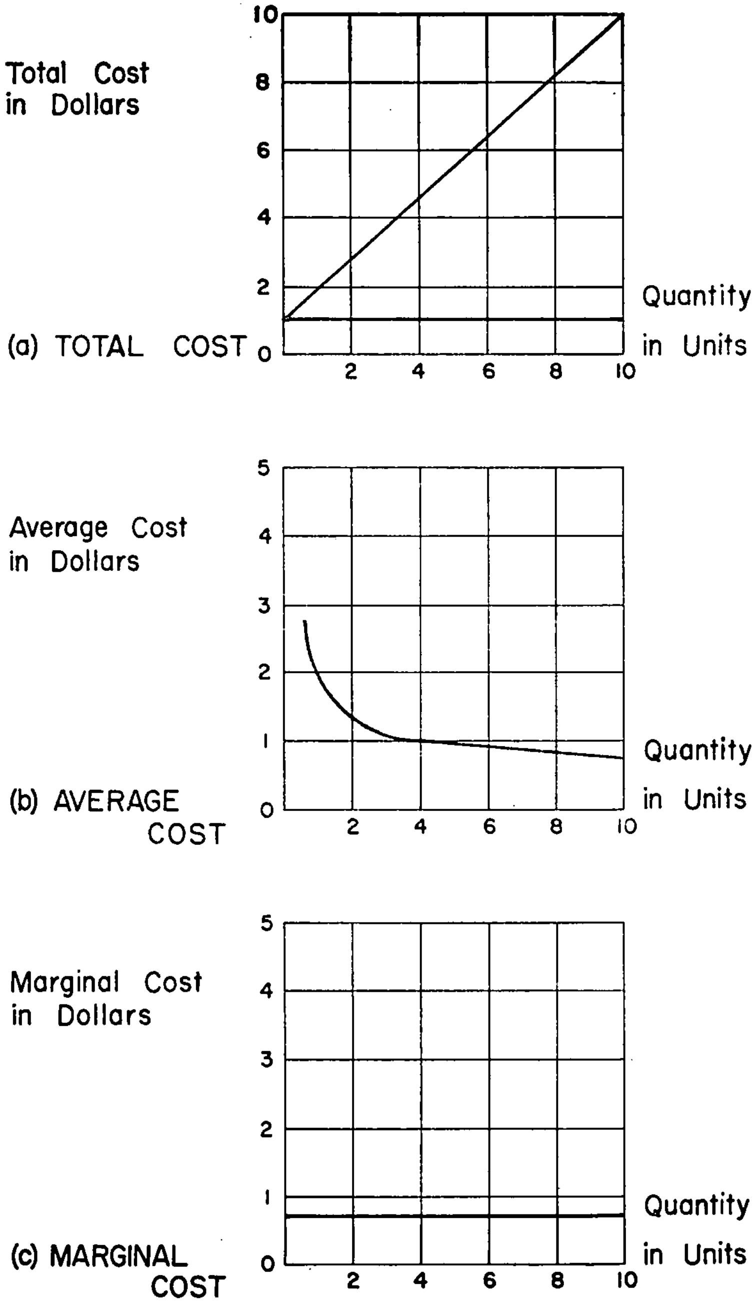

FIGURE 4: Cost Curves of Hypothetical Single Product Firm

dollar. This is an example of a fixed cost. Graphically, the total cost of our hypothetical business would now be as shown in Figure 4*a* and the average and marginal costs would be as shown in Figures 4*b* and 4*c* respectively.

The total cost shown in Figure 4*a* differs from that shown in Figure 1 only in that, at each level, the cost is one dollar higher. The average cost graph of Figure 4*b*, however, shows no resemblance to that of Figure 2. Instead of a horizontal line there is now a curve downwards to the right. At each increased number of units the average cost approaches more closely to the seventy-five cent average cost of Figure 2, for the fixed cost of one dollar is divided by the increasing number of units. The marginal cost of Figure 4*c* is identical with that of Figure 3 for the addition of the one dollar of fixed cost does not change the cost of an additional unit of output at any given level.

As yet, we have made no provision for an income for our businessman. It is to be expected that he would require an income if he intended to pursue the business—although this is not strictly necessary, there may be men of wealth who would engage in a business merely in order to remain busy. The level of income demanded will usually be set by the alternative opportunities available. If our businessman can find other work which pays more he will tend to take it. When he has evaluated the alternative opportunities and taken account of any non-monetary reasons he may have to remain in this business, he will demand a certain income from it. This amount will be a part of the fixed cost of the business.

If the supplier now changed his conditions so that our businessman had to pay for his supplies upon delivery to him rather than upon their sale, it would be necessary for the businessman to invest funds in working capital. But alternative investment possibilities will be open to him, he will therefore demand a return on this investment equal to that which he could obtain from an alternative investment of equal risk. This return is known to economists as the *normal profit*. In our example, it will be added to the variable cost since it will depend upon the quantity sold. (In order to simplify the discussion, we assume that our businessman is able to balance his purchases and sales in any given period.)

If we assume that the salary required by the businessman is one dollar per period and that the normal profit is five per cent per period, the cost graphs will have the components shown in Figure 5.

While the ideas of a minimum salary to the owner and of a normal profit are theoretically simple and theoretically easy to distinguish, in practice it may be impossible for the businessman himself to separate them, and it will almost certainly be impossible for the outsider to measure them. The income which could be earned in other employment depends upon an evaluation of skills by prospective employers or potential success in a different

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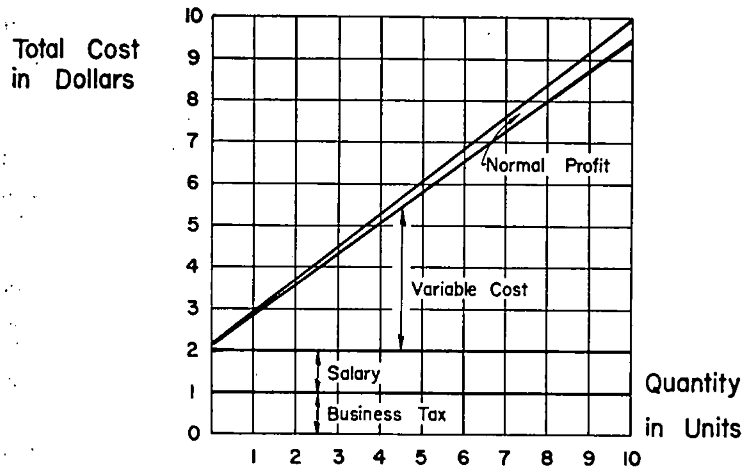

FIGURE 5: Total Cost of Hypothetical Single Product Business

kind, or different kinds, of self-employment. It may be possible to evaluate these alternatives only by applying for employment or by entering into a new business. The return which may be earned from alternative investment may be known, but the evaluation which the businessman places upon the risks involved in his own business and in others will be unknown to the outsider.

A further difficulty besets the outside analyst attempting to untangle these elements of cost. In our simple example, the analyst will be certain to see only the expenditures on supplies and business tax and a residual sum which is both the owner's salary and his return on investment. Even if a salary appears in the accounts of the business it may be a nominal figure which has no real significance. For these reasons, it is unlikely that the analyst will be able to make precise estimates of either the salary of the owner or the interest on his investment.

Let us now assume that our hypothetical businessman is so successful that he finds it necessary to move his business activities into a special building and to hire an assistant. The cost of the building will have characteristics unlike any of the costs which we have so far discussed. Like the business tax, the rent on his building, or the interest on his investment in it, is unlikely to change month by month as his business does well or poorly. Quite obviously he cannot add to or subtract from his building each month as his business volume changes. In this sense, the cost of the building represents a fixed cost to his business. But it is not as fixed nor as inescapable as the business tax, referred to earlier, which could not be escaped without going out of business altogether. If his business does very poorly, our businessman could retract to his previous position, in which he did business from his home and had no real estate chargeable to the business. Thus the cost of the building has some similarities to those costs which we have previously termed "variable costs". The cost of the building can be regarded as a fixed cost provided that the owner believes that the present amount of space will continue to be appropriate for some time to come. On the other hand, when he feels that either more space or less space will be required, he will take steps to move the business into larger or smaller quarters. Economists refer to costs such as this as costs which are fixed in the short run and variable in the long run. The economists' definition of short and long run therefore has no consistent relationship to calendar time. What is usually meant by the long run is the length of time required by the businessman to adjust the size of plant in response to a larger or smaller volume of business.

Turning now to the assistant newly hired by our hypothetical businessman it will be clear that the cost of this assistant's salary has cost characteristics similar to those of the expense of the building. This employee is unlikely to be discharged at every point where there is a minor drop in business volume. The first adjustment will likely be to the amount of stock in trade held. On the other hand, in most businesses it calls for a less drastic and less long lasting adjustment to lay off or discharge one or more employees than to sell the land and building where the business is operated. In economists' terms, the cost of the employee can be viewed as fixed in the short run when one talks of situations in which adjustments are made only in the amount of stock in trade, but variable in the short run when one speaks of situations which give rise to changes in land and building. The definitions of short and long run change from moment to moment, depending upon the degree of adjustment which is being made. They can often be qualified as very long, very short, and so forth.

In Figure 4 we noted that, as the output of our small firm increased, the total cost per unit declined. We should now note that a second effect will be noticed if the business continues to grow. At some point, the building will become crowded, it will become more difficult to work and the inefficiencies involved will lead to higher costs. Similarly, as employees are added there will be new costs of supervision. Because of these new expenses the average cost will begin to rise. Economists therefore expect the cost curves of the firm to appear as in Figure 6 with average cost first declining and then rising as output increases, either in the short run, or, often, though not necessarily always, in the long run.

The railway equivalent of our small businessman is a railway giving service only between two points and carrying a single commodity. Before going into business this railway must construct a roadbed and lay tracks. Provided that the road is built to carry a minimum amount of traffic, the

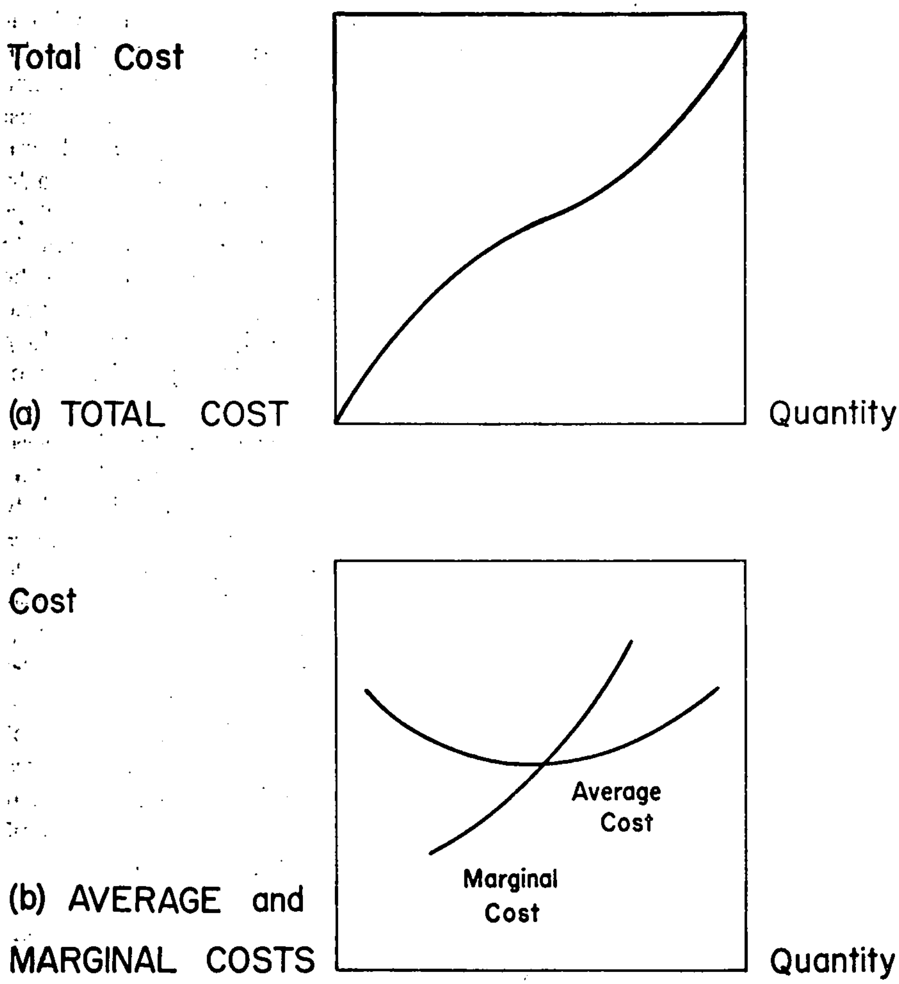

FIGURE 6: Typical Cost Curves

normal profit on this investment and the depreciation on it form fixed costs, for they can be escaped only by abandoning the business. If the traffic increases, more expensive rail will be required. Therefore, to some extent the investment will vary with traffic. In addition to the track, the railway will require cars in which to carry the traffic and motive power to move it.

The investment in these items, like the investment in heavier rail, will vary with traffic. As traffic increases, rolling stock will have to be bought. If traffic decreases, rolling stock will not be sold immediately to adjust to the new situation, but obviously investment in rolling stock can be adjusted downwards more readily than can investment in roadbed.

In addition to the investment in road and equipment, the railway must supply fuel to power the locomotives and a crew to operate the trains. In the case of the first of these, if there is greater or less traffic there will be more or less fuel required. We would expect then that the adjustment to changes in traffic volume would be almost instantaneous. That is that fuel would be a variable expense in the extremely short run. If the railway operation was sufficiently large that a great number of crews were available, crew wages could also be variable in the extremely short run, since crews could be laid off and re-hired to adjust to changed requirements without affecting the efficient operation of the railway. If on the other hand, the railway operation was small, the cost of crew wages would not be as variable in the short run as would fuel cost. At some minimum point, crews would be required to stand idle (or would at least demand the equivalent in pay) since there would not be sufficient traffic to employ them full time, yet there would be too much traffic to be moved without them. Exactly the same effect is created when overtime is worked by a smaller crew at premium rates. The cost of wages would then be variable only in a longer run than fuel costs. However, some part of fuel costs and crew wages may appear fixed since the railway may wish to preserve regular service even with a small amount of traffic offered.

The most important cost to the railway for a specific movement is the marginal cost. That is the increase in variable cost caused by increased traffic. If the rate received is less than marginal cost, the railway will be worse off the more traffic it receives. If the railway receives more than marginal cost, it will be better off carrying the traffic than not, some contribution will have been made towards paying the fixed costs. The marginal cost of the traffic is, therefore, the minimum below which the railway will not wish to have its rates fall. We will note later (Chapter 5) that in some situations the railway must receive more than marginal cost for at least some of its traffic to survive.

The discussion on the previous pages indicates one of the problems of applying marginal costs. There are a multitude of differing marginal costs. The appropriate marginal cost is determined by the degree to which it is assumed that adjustments will be made in the plant in response to a particular change in traffic. But the degree to which adjustments are made in the plant will depend upon the timing as well as the amount of traffic which it is expected will be moved. For example, suppose that the contents of a large automobile junkyard become available as scrap for a steel mill and that it is known that, once the present contents are moved, there will be no shipments in the foreseeable future. In such a case, the railway would use existing equipment at otherwise idle times. If sufficient trains were already running along the route, and if the motive power were sufficient to pull larger trains, the additional cost would be confined to the cost of fuel, crew wages and locomotive time required for switching, and the cost of the extra fuel required to haul the scrap from yard to mill. But if it were believed that the movement would be repeated from time to time, it would have to be assumed that extra rolling stock would be required since it would not always be possible to use otherwise idle cars. Similarly, it would have to be assumed that, on the average, the railway would be required to have more motive power available. Under these latter assumptions, the variable costs would rise more quickly, and the marginal cost would be higher than under the shorter run assumptions of a once-only shipment. Similarly, the marginal cost will be higher if a periodic movement occurs at times when the railway is carrying a peak load than it will if the movement occurs at off-peak periods.

The costs which are discussed in the last paragraph have also been labelled the incremental costs, that is, the additional cost which will be encountered with an increase in traffic from a given level. In their cost estimates to the Royal Commission, the Canadian Pacific and Canadian National presented decremental costs, the costs which would be escaped if traffic decreased from a given level. These are sometimes known as avoidable costs. Their estimates were estimates of the variable cost which would be avoided if they did not engage in the transport of grain to export positions. Since the railway estimates were based on linear cost relations such as those presented in Figure 5, decremental and incremental costs would be numerically equal if each were based on the same assumptions as to the extent of plant adjustment.

The railway estimates were also based on very long-run analysis. They included amounts to cover the cost of lines which were designated as "solely-related" to the export grain trade. These were lines on which the traffic is preponderantly grain but on which, except for a very few lines, other products were, in fact, carried. For this reason it was suggested that they be designated "substantially-related" lines, a term which appears more accurate. It was claimed that these lines are maintained for the export grain trade and that if this trade did not exist the lines would disappear. Therefore, the cost of maintaining these lines was included as a part of the variable cost of moving grain. In the sense that transportation between any two points can be considered a business which is separate from transportation between any other two points, the railroads, by including these maintenance costs, indicated that they would abandon a part of their business if it were not for the grain trade. In this sense, the railways cost estimates were based on a very long-run analysis in which almost all costs are variable.

If a business has only one product, or a railway carries only one commodity between only two points, all the expenses are due to the one product or to the transport of the one commodity. When more than one product, or the transport of more than one commodity is involved, a new series of problems is created. Some part of the expense will arise from the production of each product or commodity, but how much should be charged to each? It may be that some expenditures are required only for the transport of one commodity. For example, coal might be carried in hopper cars and lumber in box cars. If these cars are used only for these commodities the cost of each kind of car can be charged directly to the appropriate commodity. Suppose, however, that both commodities are transported in the same train. The cost of the locomotive, of the fuel, and of the crew will then be common to the transport of coal and lumber. These common costs cannot be charged directly to the commodities carried but must in some way be divided between them. The methods used to do this will be discussed in the following chapter.

A particularly interesting type of common costs are joint costs. These are defined as the costs of producing two products whose production cannot, for physical reasons, be separated. For example, in some gas fields, crude oil and sulphur are produced together. In railway transport a movement of equipment one way must ultimately be matched by a return movement. Passenger train service provides a clear example of a railway activity in which the movement of equipment in one direction on a route is often followed by a movement in the opposite direction on the same route. If the product which the railway is creating is viewed as the provision of capacity to transport a given number of passengers from one point to a second, it will be seen that equal capacity is provided in the opposite direction. The costs of moving the equipment away and back are therefore sometimes referred to as joint costs.

There is no way in which joint costs can be attributed specifically to one of the joint products. By definition, these must be produced in a given ratio. Therefore, an increase or decrease in the production of one product must be accompanied by an equi-proportionate increase or a decrease in the production of the other. We can estimate the cost of the package but not of the individual commodities. If the joint costs are being paid through the transport of one commodity, any payment by a second commodity, over those additional costs specifically attributable to the second commodity, will be a contribution which can be used either to increase the profitability of the railway or to lower the rates on the first commodity without impairing the railways' financial position. In the trucking industry such rates are frequently given and labelled "back-haul" rates. Unfortunately, however, the clear-cut conditions under which it can be seen that "back-haul" rates are applicable are not often present in railways of the nature of Canadian National and Canadian Pacific. (The transport of goods inbound from the Port of Churchill may be an exception.) Equipment is designed to carry many commodities, and it may carry goods over many routes before returning to the starting point. The complications of determining the extent to which the costs of these movements are jointly related are overwhelming. In practice, therefore, simplifying assumptions must be made in order to make the problem manageable. The most important of these assumptions is an assumption that all costs which can be traced to a movement of traffic can be charged or assigned to that traffic without regard to the joint nature of the costs of moving equipment. This procedure, necessitated by the complex nature of the operation of large railway systems, can handicap the railway in competitive pricing situations where "back-haul" pricing would attract business with low but still advantageous revenues. On the other hand, it cannot be claimed that this procedure is disadvantageous to the shipper since it merely forces each to pay a share, proportionate to his use, of joint facilities rather than allowing one to pass the entire cost to another on the basis that "the second will pay for it anyway if I don't".

A number of phrases which are sometimes used in discussions of costs have not been used in this report. One of these phrases is "out-of-pocket costs". As used in the railway industry the phrase appears to mean marginal cost as given above. However, many economists do not include depreciation in their out-of-pocket costs. So far as it is possible, it seems better that the phrase should be reserved for the latter use since for many problems it is desirable to have a term which considers only the flow of cash. For that reason the term out-of-pocket costs will not be used. In some analyses, costs are divided into two groups called "prime cost" or "direct cost" on the one hand, and "over-head cost" or "burden", on the other. This classification seems to be made in one of two ways. The first method is to draw a distinction between those costs which can be traced directly to the productive process itself and those which are traced to functions ancillary to production. In these analyses, costs such as those for supervision, sales and insurance are lumped as overhead while labour and materials used directly in production are called direct. The second method of classification distinguishes those costs which can be related specifically to a productive process (direct) and those costs which are common to one or more processes or which relate to other than production functions (overhead). Using this method, some part of the costs of supervision would be included as direct costs. The railways avoided this terminological difficulty by the use of the terms "variable" and "fixed" costs. The variable costs of the railway analysis include costs which, under either of the last two definitions, would be called overhead.

Chapter 3

Methods of Estimation

The accounts of the Canadian National and Canadian Pacific Railways are maintained in accordance with the "Uniform Classification of Accounts" prescribed by the Board of Transport Commisisoners. The Uniform Classification divides revenues and expenditures according to the service performed in the case of revenue, and according to the function performed in the case of expenditures.

Expenditures are classified under approximately 140 titles. These are grouped into twelve general classes:

1. Road Maintenance
2. Equipment Maintenance
3. Traffic
4. Transportation—Railway Line
5. Miscellaneous Railway Operations
6. General
7. Equipment Rents
8. Joint Facility Rents
9. Railway Tax Accruals
10. Express Operations
11. Commercial Communications Operations
12. Highway Transport (Rail) Operations

The railways keep accounts of most of their expenditures by divisions. Certain expenditures, however, are recorded only for the system as a whole.

While the classified accounts inform us of the amount of money spent on various activities, they do not aid us in determining the relationship between the work performed by the railway and the expenditures on the various tasks outlined in the accounts. The basic problem of cost estimation is that of explaining the expenditures shown in the accounts in terms similar to those of Chapter 2.

The first step in this analysis is to determine the kinds of work which are performed by the railway. Basically this work is the transport of a certain tonnage of goods over distance. This is simply expressed as *ton-miles,* the product of the number of tons carried by the distance they are carried. Work is also expended upon hauling the vehicle in which the goods are carried. It is, therefore, convenient to measure *gross ton-miles.* In practice, trains carry loads of different commodities which must not only be carried between centres of population but also must be gathered from different locations, distributed between trains, and delivered to different locations within the same centre of population. The work performed in these switching movements can be measured by the number of miles travelled by locomotives in switching service, either in the switching yards or by way-trains at various points. The number of *yard and train switching miles* is not as precise an estimate of work performed, in terms of physical energy expended, as the number of yard and train switching ton-miles would be. As an explanation of cost, however, it is superior since it reflects the complexity of railway traffic movement, and this, rather than the weight moved, is the cause of expenditure for switching service. Finally, some expenditure is probably due to the movement of trains rather than goods. To illustrate, if 100,000 tons is moved in twenty trains, less cost will be entailed in controlling train movements than there would be if the same goods were moved between the same points, in the same calendar time, but in fifty trains. The work which gives rise to these expenditures can be measured in *train-miles.*

In addition to these basic measurements of work there are a number of operations which occur, or conditions which exist, which may explain certain expenditures. For example, the cost of maintaining locomotives may be due to the miles travelled by locomotives, or the cost of maintaining roadway may be related to the nature of the terrain over which the road is built. These specific operations or conditions will be discussed in connection with the cost studies presented before the Commission.

Once the basic units in which work is measured, or by which expenditure is explained, called "output-units", have been decided, the relationship between these units and expenditures must be determined.

Some expenditures may relate only to the movement under study. With these there can be no problem. They can be entered directly from the accounts of the company as costs of the movement.

Those expenses which are related to more than one kind of movement are more difficult to analyse. As an example, we may consider expenditures caused by the maintenance of tracks and roadbed. One approach might be to argue that the track and roadbed are there, that they must be maintained and that, therefore, the costs of this work represent a fixed cost, at least in all but the very long run. There appears to be evidence that at a period around 1900 a theory very similar to this was held by most railway managements. At any rate it was commonly held that about half the total costs of a railway were fixed.[1]

At the other extreme, it can be argued that since the track exists to carry goods, the entire cost of maintaining it is due to the traffic over it. The maintenance expenditure would then be divided by the number of gross ton-miles. Each gross ton-mile would be assumed to cause this much expenditure. Observation would soon show that this figure varied widely. For example, the average experience in the years 1956 to 1958 of the line-haul divisions of the Canadian Pacific Railway varied from a low expenditure of $0.25 per thousand gross ton-miles in one division to a high of $4.84 per thousand gross ton-miles in another.

A third point of view could be argued, that each of the two extremes above has something of the truth and that a proper analysis should seek to assess both the influence of traffic and the possibility that some expense is caused by the existence of the track, that is, that there can be some expense caused by the necessity to preserve minimum standards of repair. Expenses which are common to more than one activity may be related to one of the output variables by observing how the expenses vary in relation to variations of the output variables. These observations may be carried out for a single economic unit, such as a firm, an industry, or a country—over a number of different days, weeks, months, or years. In this case, the analysis is known as time-series analysis. On the other hand, the observations may be of a number of economic units at the same point in time. This is known as cross-section analysis. Cross-section analysis has the advantage that changing prices and wages do not create as difficult a problem as they do in time-series analysis. On the other hand, if cross-section analysis is carried out, using various companies as the observations, differences in management practices caused either by differing viewpoints on sound practice, or by financial ability, may introduce variations in the cost-output relationships.

If one wishes to examine the manner in which an expenditure varies with some output unit such as train-miles, a simple procedure is to plot on a graph the observations of expenditure measured along one axis and train-miles measured along the second. A graph showing such hypothetical data is shown in Figure 1.

A glance at this graph indicates that those cases in which train-miles are higher have higher expenditures while those cases in which train-miles are lower have lower expenditures. Inspection of this graph indicates that a line drawn from the point where both train-miles and expenditures are zero

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[1] Cf. Healy, K. T., *The Economics of Transportation in America,* New York, The Ronald Press Co., 1940, p. 194-7.

(the origin) through the point where they are both five, would fall approximately in the middle of these points. Statisticians use a method known as "least-squares" to determine where the line would fall. They would describe such a line as representing the equation:

$$E = a + bM$$

This can be translated as "Expenditure in dollars is equal to a constant number of dollars, plus some number of dollars times the number of train-miles". This kind of analysis is known as regression analysis. Since the relationship between expenditure and train-miles has been represented by a straight line, the relationship is called *linear regression.*

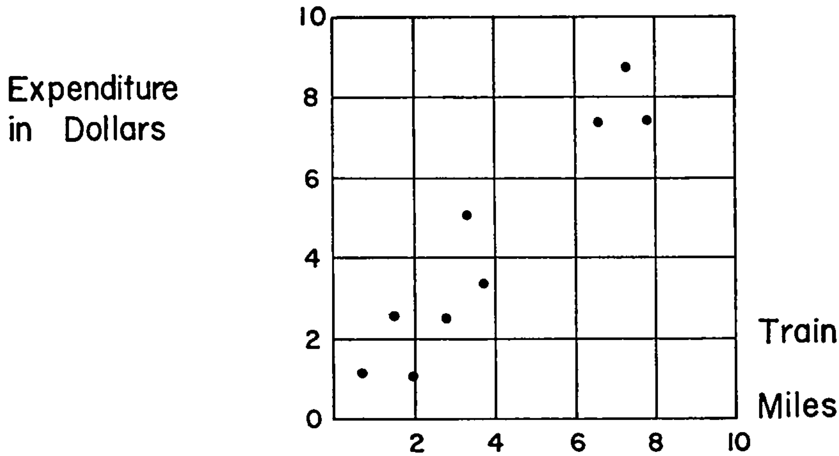

FIGURE I: Hypothetical Cost-Output Data

Returning to our example, the analyst who wished to examine track and road maintenance costs and who allowed the possibility that both traffic and the miles of road have an effect might now argue as follows.

"I know how many miles of road there are in each division of this railway. I also know the maintenance expense and the gross ton-miles in each division. If I divide the maintenance expense by the number of miles of road, I will be rid of the effect of miles of road, since in each division I will now be dealing with the maintenance expense per mile of road. By a similar treatment I can find the traffic density as gross ton-miles per mile of road. If I plot these on a graph, I can observe the effect of traffic density on road maintenance expense after compensation for the effect of miles of road."

Figure 2 shows such a graph. It is based on data for the Canadian Pacific Railway for the years 1956 to 1958. The straight line was "fitted"

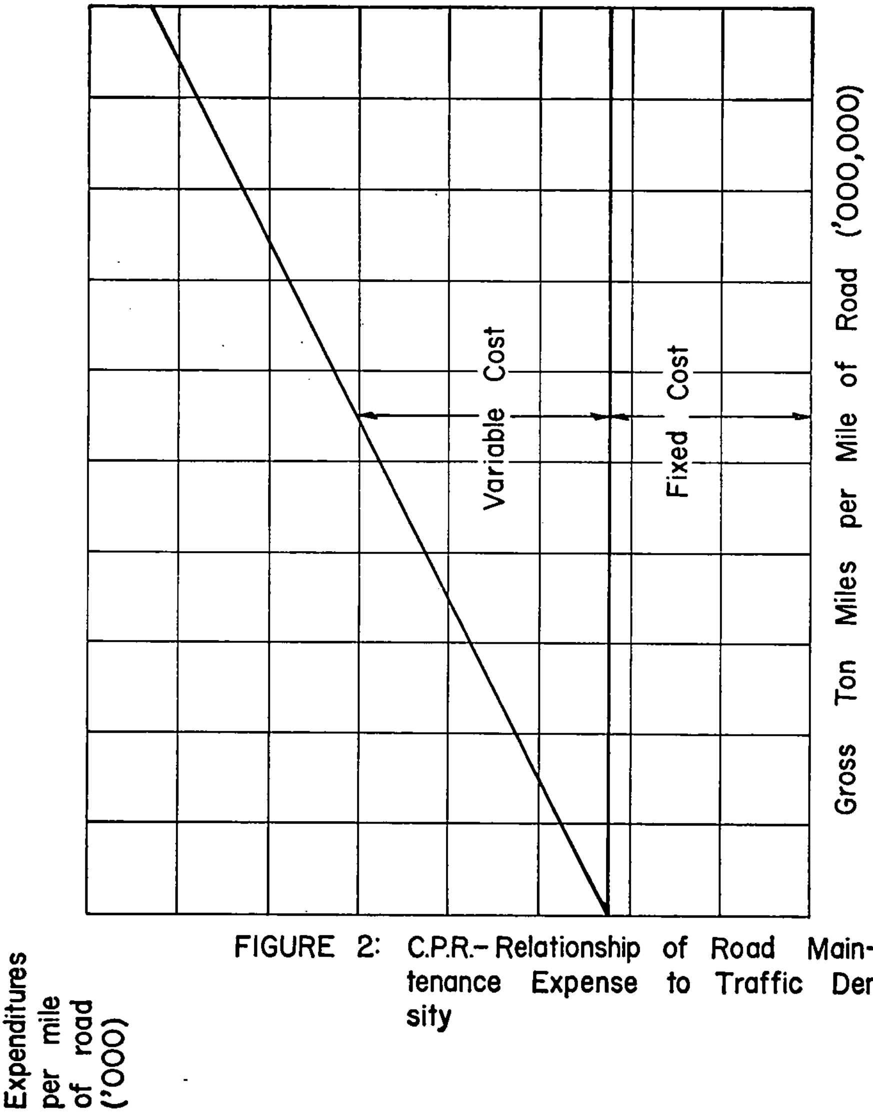

FIGURE 2: C.P.R.–Relationship of Road Maintenance Expense to Traffic Density

to the data by the method of least squares. The equation which it represents is "Expenditure per mile of road equals $2,216 plus $0.255,81 per thousand gross ton-miles per mile of road". Examination of Figure 2 shows that it is similar in form to Figure 4*a* of Chapter 2. The amount of $2,216 can be viewed as a fixed cost, the remaining amount below the line of regression may be viewed as the total variable cost.

Since both expenditures and traffic are expressed as amounts per mile of road, some means must be found to return to the original units—gross ton-miles. The Interstate Commerce Commission of the United States embodies in its rail-cost formula, known as Rail Form A, a method which the ICC refers to as a per cent variable. An analysis of the type illustrated in Figure 2 is carried out. The total cost is measured at the average density. (If a least squares analysis has been performed the line of regression passes through the point of average total cost and of average density.) The variable cost is then taken as a percentage of the total cost at this average density. In our example, the per cent variable (1441 ÷ 3657) is 39.4. On the average, it is then taken that 39.4 per cent of the expenditures vary with traffic density. Since the number of miles of roadway is assumed, for this analysis, to be fixed, this is tantamount to assuming that 39.4 per cent of the expenditures vary with gross ton-miles. By taking this proportion of the expenditure and dividing by the total number of gross ton-miles the variable expense per gross ton-mile is estimated. In our example, the total expenditure was $54,084,481. The variable portion of this (39.4 per cent) would therefore be taken as $21,309,285. Dividing by the number of gross ton-miles (75,564,756 thousand) one estimates a cost of approximately $0.28 per thousand gross ton-miles for the maintenance of track and roadbed.

Use of the per cent variable, measured at the average, is recommended by the ICC staff for problems of comparing costs of groups of railroads in different regions. In the case of the Canadian railroads this would be a suitable device to use in analysing the cost of traffic which moves over the whole system. As the ICC staff have noted, "at lower traffic densities the per cent variable would decrease while at higher traffic densities it would increase".[1] Therefore, if one attempts to find the cost of a movement which occurs only on a part of the railway account must be taken of the traffic densities in the divisions in which the traffic actually moves. The use of the "per cent variable" is inappropriate or at least needlessly time-consuming. An easier method is to deduct the "fixed cost" from the expenditures in each division and then to divide the remainder by the number of gross ton-miles for the division.

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[1] Interstate Commerce Commission, *Explanation of Rail Cost Finding Procedures and Principles Relating to the Use of Costs,* Washington, D.C., 1954, p. 73.

Technical objections to the ICC procedure have been raised.[1] Apart from these we may note that if we are interested in determining the effects on costs of variations in both the maintenance of miles of road and the traffic carried, the procedure of the Rail Form A gives only one-half the required information. It would, of course, be possible to carry out an analysis as outlined above and then to perform a similar analysis after dividing both the expenditures and the number of miles of road by the number of gross ton-miles. Unfortunately, although this would give estimates of the effects of both variables, there is no way of telling whether the estimate of the effect of variations in miles of road is consistent with the estimate of the effect of variations in traffic.

A procedure exists which frees us of much of the inconvenience of the foregoing type of analysis, meets the technical objections and gives consistent estimates. The method of "least squares" was mentioned on page 212, as a method by which an equation of the form $E = a + bM$ could be found to estimate the relationship between expenditures and the number of miles of road maintained. The same method can be extended to cover the cases where the expenditure is believed to depend upon more than one variable. In the present example, the relationship might be represented by the function:

$$E=a+b_1M+b_2(GTM)$$

This would be translated as "Expenditure in dollars is equal to a constant number of dollars, plus some number of dollars (b_1) times the number of miles of track, plus some number of dollars (b_2) times the gross ton-miles carried over the track". Graphically, the cost relationships would be shown separately as two lines, each of which would indicate the changes in expenditure which would take place in association with changes in one of the output variables if the second output variable were held constant. Where the expenditure is related to two or more output variables, and where the relationships are assumed to be straight lines, the analysis is known as *multiple linear regression.*

In certain cases it is assumed that the relationships can be best described by curved lines. In such cases, the analysis is known as *curvilinear regression.*

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[1] See, for example, Meyer, J. R., Peck, M. J., Stenason, J., and Zwick, C.: *The Economics of Competition in the Transportation Industries,* Cambridge, Harvard University Press, 1959, p. 275.

Although the ICC method is now criticized by many railway cost analysts, it is worth paying tribute to the great step forward which its origination, in 1938 by Dr. Ford K. Edwards, represented. Comments on the development and limitations of "Rail-Form A" are given in R. L. Banks and Associates: *Study of Cost Structures and Cost Finding Procedures in the Regulated Transportation Industries,* Washington, D.C., 1959, p. 2-23 to 2-29, 3-7 to 3-8 and 3-12 to 3-14.

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In addition to describing the relationships between the expenditure and the output variables, the analyst usually wishes to know how well he has accounted for variations in expenditure. For example, in the illustration of Figure 1, it appears that the points would fall fairly close to the straight line taken as exhibiting the underlying relationship. On the other hand, in Figure 3, it is clear that if a straight line were fitted to the data a relatively large number of points would fall far from the line. In fact, the average expenditure per division might give almost as close an estimate of the expenditure in any division as an estimate based on train-miles.

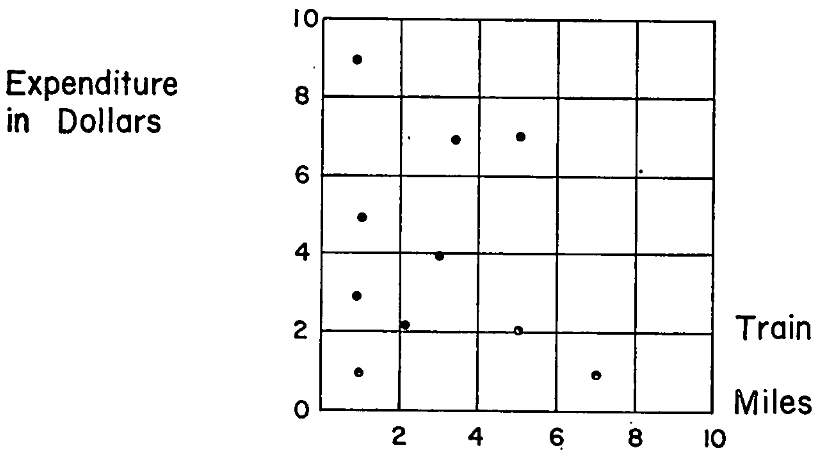

FIGURE 3: Hypothetical Cost-Output Data

To indicate the degree to which he has succeeded in explaining the variation between divisions the statistician uses measures known as the coefficient of correlation and the coefficient of determination. These are symbolized as r and r^2 in the case of simple linear regression, and as R and R^2 in the case of multiple linear regression. As the symbols indicate, the coefficient of determination is the square of the coefficient of correlation. In the next chapter we will make use of the coefficient of determination (r^2 or R^2) which can take values between zero and one. A value of zero indicates that there is no (linear) relationship between changes of the values of the variable to be explained and that used as the explaining variable. A coefficient of one indicates that there is a perfect linear relationship between the two variables.[1]

Since perfect correlation is rarely, if ever, attained in railroad costing, the relationship which is estimated between the expenditures noted and the output units will be an average relationship over the system. In some divisions or subdivisions the expenditure will be less than one would expect on the basis of the estimating procedure, in others it will be higher. One of the advantages of the statistical method is that estimates can be made of the probability that the observed expenditures will depart by more than a specified amount from the quantities which would be estimated by an application of the regression equations. Further, estimates can be made of the probable limits of error in estimating the regression coefficients, the "b's", of the regression equations. The most important use of these latter estimates is that of testing whether a regression coefficient reflects a true relationship between the variables or is the reflection of random influences in the basic data. Tests of this type are known as tests of statistical significance.

The logical nature of these tests can be illustrated by a simple example. Let us suppose that it has been suggested that the average height of boys of a particular age in a given school is 65.7 inches. Ten boys of this group, chosen at random, are measured. Their heights are found to be as given in the first column of Table I. The average height of the ten boys is 63.1

TABLE I—DATA FOR COMPUTATION OF STANDARD DEVIATION

Height (inches)	*Deviation from average*	*Square of deviation*
65	1.9	3.61
60	−3.1	9.61
61	−2.1	4.41
61	−2.1	4.41
63	− .1	.01
66	2.9	8.41
64	.9	.81
60	−3.1	9.61
62	1.1	1.21
69	5.9	34.81
63	0	76.90

[1] It should be noted that it is the relationship between *variations* in the values of the two variables which is measured. In the particular case where the relationship between the two variables could be represented by a horizontal straight line, the coefficient of determination will be zero since all possible changes in the variable measured horizontally will be accompanied by a change of zero in the variable measured vertically, *i.e.*, there is no relationship between changes in the two variables.

inches, but some are taller than 65.7 inches. Should we conclude that the average height is unlikely to be 65.7 inches? Or is it likely that the smaller average height of our sample is caused by the chance inclusion of a high proportion of smaller boys? To answer this we first ask how much variation there is in heights. The amount by which each boy varies from the average height is shown in the second column of Table I. The total of the deviations from the average is, of course, zero. It would be possible to ignore the signs and compute the total absolute variation of 23.1 inches and the average absolute variation of 2.3 inches. In fact, statisticians get rid of the negative signs by squaring the deviations as in the third column of Table I. This procedure also gives greater weight to the observations which are farthest from the average. Dividing by ten and taking the square root we arrive at a measure of the amount of variation of 2.77 inches.[1] This measure is known as the *root-mean-square deviation* or the *standard deviation.*

The reason for using this measure of dispersion or variation is that, provided the variations are random,[2] it is known how often deviations of a given *size,* measured in multiples of standard deviations will occur. For example, if a very large sample were taken, about 68 per cent of the observations would fall within one standard deviation of the mean, about 95 per cent within two standard deviations, and over 99.7 per cent within three standard deviations.

The deviation from the mean of an observation, divided by the standard deviation is known as the statistic "t". In the example we are discussing, the standard deviation is 2.77 inches. The standard deviation of the mean is found by dividing the standard deviation of the original observations by the square root of the number of observations. In this case, $2.77/\sqrt{10}=2.77/3.33=.83$.

A statistician will then ask the question: "If the average height of all the boys were, in fact, 65.7 inches, what chance is there that the average height of a random sample of ten boys from the group would be 63.1 inches, that is 2.6 inches less"? He finds the statistic "t" is $2.6/.83 = 3.1$. He would expect a deviation of this magnitude to occur less than one per cent of the time. The statistician could then be expected to say that, since he would expect such a result to happen only once in more than a hundred samples, he believes that the difference cannot be due to chance and that he therefore rejects the hypothesis that the average height of the larger group is 65.7 inches.

In this case, the statistician applied a "t-test" at the one per cent level of significance. If, for example, from general observation, he was con-

[1] For simplicity, the correction of dividing by (n−1), to correct for the bias in estimating the variance from a sample, has been ignored.

[2] That is, provided the variations may be presumed to be distributed according to the normal curve of error.

vinced that the average height of boys in the larger group (the population being studied) was, in fact, 65.7 inches, he might use a one-tenth of one per cent level of significance. He would then say that, "if this difference could have arisen by chance only once in a thousand times, I will assume that it arose because my hypothesis that the average height is 65.7 inches is wrong. Otherwise, I shall accept the 65.7 inch hypothesis as not disproven". On the other hand, if he had strong doubts of the possibility that the 65.7 inch hypothesis could be true—or if he felt that an error in accepting that hypothesis would be more costly than an error in rejecting it—he might use a five per cent level of significance. With this point of view, he would say, "If this difference could have arisen less than one time in twenty by chance, I will assume that it did not arise by chance and will not accept the 65.7 inch hypothesis".

Two points should be noted when considering this reasoning. The first is that the statistician does not prove a fact directly. Rather, he eliminates alternatives on the ground that they are unlikely. Having shown that the alternatives are unlikely, he accepts a hypothesis as the most plausible in view of the evidence available. The second point is that the level of significance is subject to the choice of the statistician: he must decide upon the degree of improbability of obtaining certain results which will persuade him that he is not observing the mere operations of chance.[1]

The computation of the standard deviations of various statistics differ according to the statistic being tested. The general philosophy of testing remains, however, that just outlined.

A most important group of tests, which will be referred to in Chapter 4, are those in which the statistician estimates the probability that a value derived from a sample could have arisen from a population (that is, the larger group of all possible cases of the kind being studied) in which the true value was zero. Thus, if a regression line of the type

$$E = a + b0$$

is fitted to a series of expenditures and the related series of output units, values will be found for the coefficients "a" and "b". The statistician will wish to assess the probability that, if, in the parent population, the true value was zero, the value which was found for the sample could have arisen by chance.

[1] An interesting example of this choice of significance level is the evaluation of experiments in extra-sensory perception. Some psychologists and biologists say that, even if statistical tests indicate that the results of such experiments could happen by chance only once in millions of times, they will not accept the possibility that these results indicate the existence of extra-sensory perception. These persons are using, in effect, a zero per cent level of significance in this case.

The probability that a value of "t" of a given size will arise by chance depends upon the number of observations or cases which were included in the sample studied and the number of parameters (or "constant values", such as "a" and "b" above) which are estimated from the data.

Most analyses assume that the relationships between expenditures and productive activities are linear. In the first place, linear analyses are much easier to perform. The arithmetic involved in dealing with curved lines is more laborious than that required for straight lines. In the second place, the curvilinearity which can be demonstrated in economic analyses is often very slight, or non-existent, so that straight lines give, at worst, good approximations of the demonstrable relationships.

A lack of apparent curvature in the relationship between expenditures and activity can be caused by limitations in the range of observations. For example, if engineering analysis has indicated that the average cost of a particular process drops quickly as the level of production is increased to some value, then shows little change through a particular range, and then rises quickly, there will be a strong tendency for all plants to fall in the mid-range. Observations of the costs and outputs of such an industry will show little if any sign of curvature simply because no plants are built in the range of decided curvature.

The logic of statistical tests of significance also militates against the adoption of curved representations. A common method of representing a curved relationship is by a power series, *i.e.*, by an equation of the form,

$$E = a + b_1 0 + b_2 0^2 + b_3 0^3 \ldots\ldots,$$

in which as many terms of increasing powers of the output units are taken as are necessary to describe the data adequately. Following the general method outlined above, the statistical test of significance is applied at each stage. Thus after the linear model is fitted ($E = a + b_1 0$), a second degree curve ($E = a + b_1 0 + b_2 0^2$) is fitted.[1] The new model will always describe the data more adequately than the simpler one which preceded it.[2] The statistician normally will not accept this improvement unless he believes that the improvement is not likely due to random influences after taking account of the automatic improvement. One authoritative study indicates this point of view in these words:

> "The Steel Study does not reveal whether any tests were made of the reliability of the selection of a linear regression between the twelve annual values for output and total costs. A cubic or higher order equation might have been more appropriate. The fact that a higher order equation must necessarily fit the observed values of cost and output within narrower limits

[1] The values of the coefficients a, b_1, etc., will normally change at each step.

[2] Until the number of coefficients is one less than the number of observations.

> does not, however, render the linear regression invalid. The difference in 'closeness of fit' of the linear and higher order equations must be large enough to be statistically 'significant'. Perhaps of even greater importance, the difference must be sufficiently large so that the higher order equation indicates more accurately the view of cost behaviour which figures in decision formation."[1]

This reluctance to move from linear analyses has ample backing in the well-established dictum of scientific investigation that the simplest explanation possible should be sought. However, it must be remembered that the level of significance chosen by the investigator reflects the strength of his opinion that the explanation being tested is likely. An analyst who is convinced that the curved relationships discussed in Chapter 2 are likely will demand that the evidence shows that they do not exist. On the other hand an analyst who believes that a large organization consists of a number of reproducible units will expect a linear relationship between cost and output and will demand proof that this is unlikely.[2]

While the arithmetic involved in estimating curvilinear relationships is more tedious than that involved in estimating linear relationships, it usually presents no serious analytical difficulties. Many non-linear relationships may be represented in linear form by means of transformations of one or more of the variables involved. For example, in the case of the power series which we have just discussed, the square and higher powers of the output variable are treated as new variables which have a linear relationship to the expenditures which are being explained. If a simple reciprocal is involved, a similar treatment is available. Suppose that it is believed that the price of a commodity at any given time depends solely and simply upon the supply available, and that it is believed that the relationship is such that when the supply is low the price is very high and that as the supply increases the price drops, quickly at first and then more slowly, to approach some minimum value, one of the forms which such a relationship may take can be represented by the equation:

$$P = a + b/S,$$

$$\text{or,}\ P = a + b(1/S)$$

Instead of attempting to deal directly with the values of "S", we first calculate the values of the reciprocal of "S", which we might term "R". It is then a straightforward job to fit the linear equation:

$$P = a + bR$$

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[1] Committee on Price Determination, *Cost Behavior and Price Policy,* New York, National Bureau of Economic Research, 1943, p. 99-100.

[2] Cf. Smith, C. A., *Review of Statistical Cost Analysis,* by J. Johnston in American Economic Review, June 1961, p. 419.

Two interesting types of non-linear relationship can be treated by similar transformations. In a linear system, successive increases of equal absolute value in the explaining variable are accompanied by successive increases of equal absolute value in the explained variable. It may be believed, however, that successive increases of equal absolute value in the explaining variable are accompanied by successive increases of equal percentage in the explained variable. This relationship can be written as:

$$X = ab^Y$$

Taking logarithms, this can be written:

$$\log X = \log a + Y \log b$$

Substituting, $Z = \log X$, one has:

$$Z = \log a + Y \log b$$

Since both "a" and "b" are constants in this equation, their logarithms will be constant. The equation is, therefore, linear.

A similar transformation can be applied when it is believed that the value of the explained variable varies as some power of the explaining variable. This may be expressed as:

$$X = aY^b,$$

or, using logarithms:

$$\log X = \log a + b \log Y$$

Substituting, $Z = \log X$ and $T = \log Y$, the equation becomes:

$$Z = \log a + bT$$

This transformed equation is linear in Z and T, log a is again a constant.

Of course, when transformations such as these are employed in order to develop a linear regression, the procedure must be reversed in order to make estimates in the original units.

Although a wide variety of non-linear relationships can be treated by means of transformations of the type which have just been discussed, grave difficulties do arise when the relationship between the cost and output units involves a mixture of additive and multiplicative terms which cannot be transformed into a simple linear equation. For example, it might be thought that wear and tear on track and roadbed, and therefore the cost of maintenance, depended upon the traffic over the road and upon some power of the speed. An experiment could be planned to attempt an examination of the relationship between these elements. If the equation to be examined were,

$$\text{Cost a} = \text{b(Traffic in Gross Ton-miles)} + \text{c(Speed in MPH)}^{d},$$

logarithms could not be used to transform the equation to a linear form. There seems to be no way in which such a suspected relationship can be examined in one step.

Empirical studies have not yet demonstrated that the expectations of economists' analytical models as outlined in Chapter 2 are universally realized in the industrial world. Some of the reasons have been outlined in the preceding paragraphs. Another important reason is likely that economic affairs are much more complex than the analysts have yet been able to reflect in their models. (This inadequacy will be evident in the following chapter when alternate specifications are discussed.) When an analysis of a particular industry is performed a greater or lesser amount of the variation in cost is left unexplained. Usually, at least as a working hypothesis, it is assumed that this residual variation is due to chance variations. When a large amount of variation is left unexplained, one is driven to the conclusion either that the role of chance is very large in economic affairs or that important elements of cost have so far eluded analysis. A single cross-section analysis will reveal only the amount of unexplained variation. Since random influences can be expected to have unequal impact on particular economic units in different periods of time, successive cross-section analyses of the same economic units should indicate the presence of persistent, and therefore non-random, effects. From the point of view of a regulatory body when it is deciding general questions which do not require precise cost estimates, the problems raised by these non-random effects may not be important. To a company management which may have to decide whether to lose business through failure to meet competitive prices or to lose money by accepting business at less than marginal cost, these problems can be of great importance when the disparity between the competitive price and the company's own marginal cost is small. So, too, they must be to any regulatory body which must rule on the rates so set.

To railway management, large variations of actual expenditures from those which would be expected from statistical analysis are important for another reason. It is to be presumed that, in setting up the statistical models of the railway cost structure, all activities or circumstances which it is believed might systematically influence the cost relationships have been taken into account. The amount of discrepancy between the estimated cost (as shown by the analysis) and the actual cost is a measure of the combined effects of efficiency of operation and of the insusceptibility of expenditures to managerial control. If one division, for example, has expenditures ten per cent under those which would be expected, and a second has expenditures ten per cent over those which would be expected, the management of the first may be considerably more efficient than the management of the second division. Alternatively, the discrepancies may be due to random effects, that is to conditions over which management does not have control and which are not predictable. Of course, if an independent measure of managerial efficiency could be devised, the insertion of such a measure into the analysis would resolve this ambiguity. If the discrepancies are sufficiently large that management believes that they cannot be explained on the grounds of differing supervisory abilities, and if, over a period of time they persist, the cost analyst must pursue further the identification of the causes of cost variation. If, however, it is decided that the causes of cost variation have been decided satisfactorily, a decision must be made as to the degree to which the discrepancies between actual and estimated cost reflect the resistance of costs to control (random effects) and the degree to which they reflect differing supervisory abilities.

To this point the discussion of this chapter has assumed that the choice of output units (variations of which are expected to explain variations in expenditure) is a simple one. This is not so. As we will discover in Chapter 4, usually there are no unquestionable technical (*i.e.*, engineering) reasons for assuming that many classes of expenditure (as given in the Uniform Classification) are related to particular output units. Without clear technical grounds for a choice of output units, the statistical evidence received from our observations must be the grounds of our choice. From a statistician's point of view, the only way of choosing output units as suitable explanatory variables is to choose those which explain the largest amount of variation in expenditures. Unfortunately many of the output units tend to vary together. For example, as the number of gross ton-miles increases or decreases, the number of train-miles tends to increase or decrease.

The algebraic problem to which this gives rise can be illustrated by considering the problem of a cost analyst who is asked to find the cost of lemons and oranges. Assume that he is told that two housewives have purchased (a) 4 lemons and 6 oranges at a cost of 67 cents, and (b) 6 lemons and 4 oranges at a cost of 63 cents, respectively. The analyst will then perform a few simple algebraic manipulations and reach the conclusion that the oranges cost 7½ cents each and that the lemons cost 5½ cents each. If, however, he is told that the two housewives bought (a) 4 lemons and 6 oranges at a cost of 67 cents, and (b) 8 lemons and 12 oranges at a cost of $1.34, respectively, he will not be able to answer the question of how much oranges and lemons cost. His best answer will be that a package of 2 lemons and 3 oranges would cost 33½ cents. This is because in the second example the number of oranges and lemons bought by one housewife was each an exact multiple (or fraction) of those bought by the other, as were the total amounts they paid.

Statisticians speak of two variables which vary in such a fashion that one is a constant multiple of the other as collinear; indeed, provided there is an *exact* linear relationship between the two variables of the form $X=a+bY$ they are known as collinear. (By exact we mean that one is precisely predictable from the other.) As two variables come closer to this exact relationship, they come closer to being changeable as far as the observing analyst is concerned and the effect of each becomes merged with that of the other just as the cost of the oranges and lemons became merged in the second example of the last paragraph. Regrettably, in dealing with random variables this confusion sets in before exact collinearity has been evidenced. Thus, for example, if gross ton-miles and train-miles exhibit a strong tendency to vary together, it may be quite impossible to disentangle the effects of one from the other with the methods of the statistician. Because of this indeterminacy, and because of the possible existence of non-linear relations, the analyst must often do a considerable amount of "fishing around" for reasonable cost-output relationships. It should not be surprising, then, if several analysts pursue different paths in their attempts to explain variations in a particular class of expenditures. What may be surprising is that beneath the arguments of the analysts lies a large measure of agreement upon the nature of the fundamental relationships involved and upon the proportion of the variation in expenditure which is explained by given sets of variables.

A difficulty of a different kind which arises in statistical cost analysis is that of separating the long- and short-run effects upon costs of changes in given variables. In fact, in cross-section analysis precise separation of these effects is probably impossible. The difficulty can be seen by reference to Figure 4. Here the outputs and expenditures per unit of a set of hypothetical firms are superimposed as dots, upon long- and short-run cost curves.[1] The dotted line indicates the average cost curve which would be found by statistical analysis. Since the nature of long-run average cost is that it is the lowest cost which can be achieved for a given output when all appropriate long-run adjustments have been made, the long-run cost can equal but never exceed the short-run cost. It follows therefore that the observations of cost and output which one can observe will seldom be on the long-run curve. More likely the observations will be somewhere above this cost curve.[2]

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[1] In Chapter 2, long- and short-run adjustments were discussed. Short-run cost curves show the variations in cost which will occur with variations in output of plants of given sizes. Long-run cost curves show the minimum cost of various outputs as plant size varies.

[2] Cf. Borts, G. H.: *The Estimation of Rail Cost Functions,* Econometrica, Vol. 28, No. 1, January 1960, p. 108-131. See also Meyer, J. R., and Kraft, G.: *The Evaluation of Statistical Costing Techniques as Applied in the Transportation Industry,* American Economic Review, Vol. LI, No. 2, May 1960, p. 321-327.

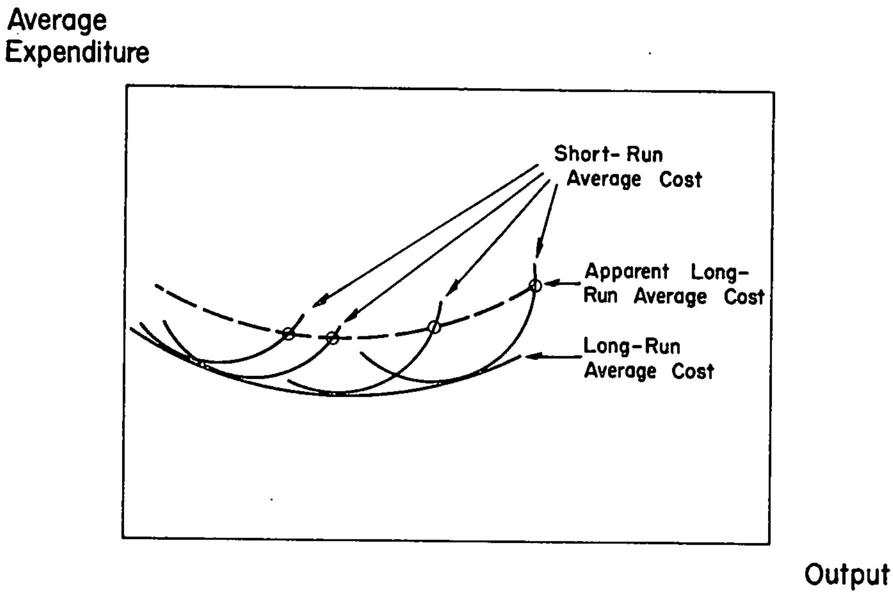

FIGURE 4: Effect of Short-Run Variations on Statistical Cost Curves

At first glance, this seems a crucial difficulty. However, there are mitigating factors. First, the upward bias which is caused by the movement along the short-run curve is a bias only in the estimation of long-run as opposed to short-run effects. It does not lessen the validity of the cost estimates and relationships as far as one is concerned only with the relationship in general between cost and output at a given moment of time, over the system. Second, if the range of outputs possible with adjustments of plant size is large compared to the range of outputs practical with any given plant size, the error will be small. Third, if the marginal cost is being estimated, the shape, rather than the absolute values, of the total cost curve, is the important characteristic. It is quite possible that the short-run characteristics of the industry are such that the shape of the long-run cost curves will not be affected.

In situations where one is employing marginal costs to judge rates, there seems, then, no reason to be unduly concerned with the problem of intermingled long- and short-run effects. We should, however, be on our guard to examine claims that "a long-run effect" has or has not been demonstrated.

If an error of the type discussed in the last paragraph is made, incorrect conclusions may be drawn as to the extent to which average costs will drop with increased utilization of plant.

When the analyst has decided upon the output units which he will examine and the relationship, if any, which they bear to expenditures, he must still decide upon the number of output units which are due to the specific movement or movements which he is analysing. Some can be taken directly from company records. For example, the weight of each shipment is recorded, as are the origin and destination. Provided the route is known, the weight of the shipment can be multiplied by the distance travelled to give the ton-miles generated by the movement. (Not all shipments are routed by the shortest available path between two points. Operating conditions may require a circuitous movement from time to time.)

Other output units must be assigned indirectly. Most trains do not carry one commodity only. Even if everything carried on that train has been shipped by carload lot, the expense caused by running the train must be apportioned to the various commodities carried. The problems encountered in assigning the output units can be as severe as those which are encountered in evaluating the impact of variations in output units upon expenditures. Obviously, if there is no traffic available trains will not run. But if some traffic is available, how many trains will run? If the traffic available drops or increases ten per cent, will the number of trains drop an equivalent amount? The methods of examining these problems must be the same methods used to discover the relationship between output units and expenditures, that is, observation and statistical manipulation of the data-including regression analysis where applicable.

The last few pages have recited some of the difficulties of cost analysis, with particular reference to railroads. To some it may seem that the uncertainties which beset cost analysts negate any contribution which they may have to offer. At times, those who are, by trade, professional cost analysts are undoubtedly among those who feel this way. Each, in viewing his own work at the moment of completion, may feel that this is as good a job of cost estimation as has ever been done. Yet each knows that, "When studying complicated joint product operations like railroading, there is likely to be no such thing as '*the* correct cost estimate' ".[1] If this be so, it may be asked, "why then bother to say anything"? The answer may be found in the words of an author who said:

> "As I understand it, statistics is not primarily for making objective statements, but rather for introducing as much objectivity as possible into our subjective judgements. It is only in limited circumstances that fully objective

[1] Meyer, J. R., Peck, M. J., Stenason, J., Kraft, G., and Brown, R.: *Avoidable Costs of Passenger Train Service,* Cambridge, Aeronautical Research Foundation, 1957, p. 5.

> statements can be made, although the literature of theoretical statistics is mainly concerned with such circumstances. The notion that it must all be precise is harmful enough to be worth naming. I shall call it the 'precision fallacy'. If we refuse to discuss problems in which vagueness is unavoidable then we shall exclude a large proportion of real-life problems from consideration. In fact every judgement involves vagueness, because when it becomes precise it is no longer called a judgement. Vagueness will not disappear if we bury our heads in the sand and whistle."[1]

There may be value in registering again that the purpose of a cost analyst, who is forced to resort to statistical (in the theoretical as opposed to the strictly numerical sense) argument, is to introduce as far as he can an objective orientation. The comments which appear in Chapter 4 of this report indicate some of the ways in which one can recognize the subjective or objective content in the report of a statistical cost analyst.

In the following chapters, there is an account of the presentation before the Commission of the costs and revenues of transporting grain from the Provinces of Manitoba, Saskatchewan and Alberta to export positions as given by the Canadian Pacific Railway Co. and the Canadian National Railways. The counter suggestions, given on behalf of the Provinces of Manitoba and Alberta and on behalf of the Alberta Wheat Pool, the Manitoba Pool Elevators, the Saskatchewan Wheat Pool and the United Grain Growers, are included *seriatim* as the various groups of accounts are discussed. Chapters 7 and 8 briefly discuss the passenger deficit and the costs of branch lines of low density.

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[1]Good, I. I.: *Significance Tests in Parallel and in Series,* Journal of the American Statistical Association, Vol. 53, No. 284, Dec. 1958, p. 799.

Chapter 4

The Variable Cost of the Grain Traffic

This Chapter comments upon the studies of variable cost presented by the Canadian National Railways, the Canadian Pacific Railway Company, R. L. Banks and Associates on behalf of the Province of Alberta and the Province of Manitoba, and by W. B. Saunders on behalf of the Alberta Wheat Pool, the Manitoba Pool Elevators, the Saskatchewan Wheat Pool and the United Grain Growers. Since most of the discussions before the Commission and in conferences with the Commission's consultants dealt with the presentation of the Canadian Pacific Railway, this Chapter will deal with the presentation of that Company in much greater detail than with the estimates of the Canadian National.

Section A of this Chapter deals with the estimation of the relationships between output units and expenditures, Section B with the estimation of the output units attributable to the movement of grain from Western Canada to export positions and Section C with some more general problems.

A. The Relations between Output Units and Cost

1. *Track Maintenance and Depreciation*

CANADIAN PACIFIC RAILWAY

Accounts Explained

202 Track and Roadway Maintenance	229 Roadway Buildings
208 Tunnels, Bridges and Culverts	266 Road Property Depreciation (part)
212 Ties	269 Road Machines
214 Rails	271 Small Tools and Supplies
216 Other Track Material	273 Public Improvements
218 Ballast	281 Right of Way Expenses

The Canadian Pacific explained the expenditures in these accounts by means of the following regression:

(1) Expenditures=		$1,208,385.00		(2.32)
	+	$1,136,811	per mile of track	(6.11)
	+	$0.16475	per thousand gross ton-miles	(5.29)
R^2=.83	+	$0.39053	yard and train switching miles	(2.19)

If this explanatory equation is compared with the explanation on page 214 of Chapter 3, it will be noticed that the estimated cost attributable to gross ton-miles has dropped from 28 cents per thousand gross ton-miles to 16 cents, and that estimates of the effect of miles of track and yard and train switching miles have been included on a consistent basis. The example of Chapter 3 was computed from the same data as that above (except that data for the four terminal divisions were not included in the former case). The figures in brackets are values of "t", on the assumption that the true value of the coefficient is zero.[1]

The Canadian National explained the same group of accounts with the exception that 266 (depreciation) was not included, and 270 (dismantling retired road property) was included. Their estimating equation was:

(2)	Expenditures=	$258,029		
		+ $866.17	per mile of road	(5.52)
		+ $187,888.2	per mile of tunnels	(3.54)
	R^2=.87	+ $0.75687	per yard locomotive mile	(4.28)

The Canadian National believed that the nature of the terrain through which a rail line passes has some effect upon the cost of maintaining the line. As there is no direct method of measuring all the aspects of the terrain which might affect maintenance costs, miles of tunnel were used to indicate rough terrain. Using the number of miles of tunnel in this fashion does not mean that the Canadian National analysts believed that the existence of tunnels, in itself, caused an expenditure of $187,888 per mile. It indicates that, in their opinion, conditions which do cause such expenditures arise, in a division, in a fairly direct ratio to the number of miles of tunnels.

R. L. Banks and Associates presented a second explanatory equation for the Canadian Pacific accounts.

(3)	Expenditures=	$1,319,000		(1.41)
		+ $0.05745	per dollar invested in tunnels, bridges and culverts	(2.48)
		+ $0.3896	per train-mile	(5.58)
		+ $742.52	per mile of track	

The inclusion of the investment in tunnels, etc., was an attempt on the part of Banks to include in the analysis of Canadian Pacific expenditures some variable which would perform the function of miles of tunnels in the Canadian National explanation. As an explanatory variable it should be superior to miles of tunnels since it reflects the existence of rivers as well as grades, and since it reflects less severe variations in terrain than do tunnels.

[1] The use of the "t" test is discussed briefly in Chapter 3.

Unfortunately, however, it also reflects the price level at the time of the investment. If the bridges, and so forth, were built at different times in different divisions, or if, for other reasons, the cost of similar structures varied between divisions, the investment in tunnels and bridges will reflect these price deviations as well as the differences in terrain. A measure in physical terms is to be preferred to investment if one is available.

W. B. Saunders and Co. used an index constructed on the basis of the tonnage ratings of locomotives on each section of road.

> "The tonnage rating of any given locomotive on different sections of the railway will vary inversely with the maximum adverse grade encountered. To a lesser extent, greater degrees of curvature will also cause lower tonnage ratings. Therefore, the reciprocal of the tonnage rating over each separate section of line was interpreted as an index of grades and curves for that section. For each section the lower rating in either direction for 1500 to 1800 horsepower diesel units was related to the estimated rating (5500 tons) for these units over level tangent track as a base. Wherever ratings for this class of unit were not given, the ratings for the class shown were converted to such a basis. To demonstrate the geographical distribution of grades and curves on lines which are important in the handling of statutory grain (Figure 2 was prepared) showing the indexes for the main line of the CPR from Vancouver eastward to the lakehead. This chart illustrates the non-random impact of grades and curves; but for costing purposes it was necessary to produce average indexes for each of the 31 divisions of the CPR. To this end, the individual sections making up each division were combined using the road mileage of the section as weights. The four terminal divisions were assigned an index of 100. The composite indexes for each division are shown in the Appendix."[1]

Like the Canadian National Railways' variable, miles of tunnels, this index is a physical, rather than a monetary measure of terrain. Like the R. L. Banks' use of investment, the index of grades and curves reflects more detailed variations in terrain than does miles of tunnels. It appears to be the best indicator of difficult terrain introduced in the hearings. After testing the index in its original form, the Saunders organization developed the following model:

(4) Expenditures = −$144,000			
	+$794	per mile of track	(4.6)
	+$480	per mile of track	
		× (the grade index − 100)	(3.9)
	+$0.165	per thousand gross ton-miles	(6.6)
$R^2 = .886$	+$0.709	per yard and train switching mile	(4.3)

Against the use of some variable to reflect the changing terrain, it was argued that:

> "Owing to the random distribution of topography in the Canadian Pacific system, the omission of an explanatory variable to reflect topography does

[1] Transcript of evidence, *Hearings,* November 11, 1960, Vol. 117, p. 19497.

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not bias the cost coefficients in the Canadian Pacific track maintenance model; the constant term absorbs the effects of topography. If a proper measure of topography was included in the regression, its effect would be to reduce the constant cost without significantly altering the coefficients of the other explanatory variables. That is to say, it would not significantly alter the cost of moving export grain. The reason for this is that there is no correlation between topography and the output or size variables as used in the Canadian Pacific regression model."[1]

The relevant question is not whether topography is randomly distributed across the Canadian Pacific system, but whether it is randomly connected with the expenditures in question. To illustrate by a homely example, suppose that a statistician were called upon to explain yelps of pain coming from various members of a crowd. Were he to discover that some mischievous small boy was distributing shots from a pea-shooter in random directions into the crowd, he would still investigate any correlation between the persons hit by peas and the yelps of pain. The latter part of the quoted paragraph suggests, of course, that it was this definition of randomness which we are invited to consider.

It is quite true that if there is no correlation between topography and the output and size variables used in the regression models, there will be no change in the coefficients of the other explanatory variables when a new variable to reflect differences in terrain is introduced into a linear model. The contention that there is no correlation was supported by the argument of this paragraph:

"Topography affects track maintenance and depreciation expense in several different ways. Amount and characteristics of curvature, extent of gradient, subgrade conditions, amount of precipitation, rivers, drainage patterns and frequency of highway crossings are all characteristics of topographical significance which have an effect on track expense. To develop any comprehensive basis for adequately measuring all of the various effects of these features on track maintenance would be most difficult, time-consuming and expensive. It is our view that such a procedure would not be warranted and would not alter the results of Canadian Pacific's track maintenance and depreciation regression model to an appreciable extent since there is an overall random distribution of topographical influences throughout the system. Although certain topographical features predominate in some areas, these are substantially offset by different topographical features which predominate in other areas. For example, in mountainous terrain somewhat greater expense is incurred for track lining and gauging and for depreciation of rails and ties as a result of the heavier curvature and gradients which prevail, as compared to other territories, but this is compensated for by the better subgrades provided which minimize the amount of surfacing and shimming required, the well defined drainage courses which reduce the incidence of subgrade erosion, the comparative lack of vegetation to control and the extremely low incidence of highway or road crossings to maintain. Where maintenance and depreciation of tunnels is incurred due to the presence of such structures, there are no

[1] Transcript of evidence, *Hearings*, January 23, 1961, Vol. 132, p. 22537.

bridges, culverts or highway crossings to maintain or weeds to destroy, and protection is afforded against the accumulation of snow, within the limits of the structures. On the other hand, in such areas as the Prairies, where curvature and gradient have a less pronounced effect and where tunnels are non-existent, considerably greater expense is incurred in restoring subsiding fills due to the less stable subgrades, repairing washout damage which results from the less well defined and inconsistent drainage patterns, control of vegetation which flourishes more freely, shimming of track due to greater frost disturbance, and maintenance of culverts and highway or road crossings which occur with much greater frequency than in the mountains."[1]

In 1908, the Canadian Pacific contended that "In the mountains the line was three times as costly to construct and almost twice as expensive to maintain and operate as on the Prairies. Bridges and trestles were more numerous in the mountains, tunnels and snow-sheds were necessary, and local traffic was light".[2]

In 1914, the Board of Railway Commissioners said that "beyond all question both the initial construction and railway operation through the mountains, are much more expensive than operations on the prairies".[3] The railways continued to hold this point of view until as late as 1948.[4] In view of this and in view of the fact that the Canadian National appear to hold this view at the present time, it would seem wise to accept that the effects of terrain are not balanced for the whole country until the development of a "comprehensive basis for adequately measuring all of the various effects of these features" has shown that the Canadian Pacific's current view is indeed correct.

The fact that in the Saunders' model the coefficient of yard and train switching miles jumps from $0.39 to $0.77 is sufficient indication that, with some sets of explanatory variables, the effect of introducing a measure of terrain variations does, in fact, cause differences in the coefficients.

One respect in which the explanatory equation presented by Banks differs from those presented by the other analysts is that it uses train-miles rather than gross ton-miles as the explanatory variable.

In the particular case of the grain trade this substitution is very important for if the appropriate variable is train-miles, and if, as has been claimed, grain travels in heavier trains than other goods generally (so that a ton-mile of grain represents fewer train-miles than a ton-mile of other commodities), the use of gross ton-miles inflates the cost of moving grain and deflates the cost of moving other commodities.

Train-miles were used on the ground that the wear and tear on track is related to the weight on the axles of the rolling stock passing over

[1] Transcript of evidence, *Hearings*, January 23, 1961, Vol. 132, p. 22534-22535.

[2] Currie, A. W., *Economics of Canadian Transportation*, Toronto, University of Toronto Press, 2nd ed., 1959, p. 53, reporting Coast Cities Case (1908) 7 C.R.C. 125.

[3] *Ibid.*, p. 59, reporting Western Rates Case (1914) 17 C.R.C. 225.

[4] *Ibid.*, p. 105.

the track, and that the unit with the heaviest axle-loading (the locomotive) controls the amount of wear and tear. This argument is appealing. In some places, regulations for trucks travelling on public highways restrict the axle-loadings, on the ground that heavier axle-loadings accelerate the breaking-up of the highways. It certainly seems reasonable to believe that there will be a greater maintenance cost with heavier axle-loadings.[1] Recently the Canadian Pacific shifted from steam to diesel locomotives. The axle-loadings of the diesel locomotives are higher, in three of the four classes used on branch lines, than were those of the steam locomotives.

TABLE I—CANADIAN PACIFIC RAILWAY STEAM AND DIESEL BRANCH LINE LOCOMOTIVE AXLE-LOADINGS

Steam		*Diesel*	
Class	*Weight per driving axle*	*Class*	*Weight per driving axle*
	(lbs)		*(lbs)*
D.10	52,000	DS.10	57,500
G. 5	50,667	DS.12	59,650
		DRS.106	45,250
		DRS.12	55,825

SOURCE: Letter, W. J. Stenason, Director of Economic Research, Canadian Pacific Railway, to D. H. Hay, May 6, 1961, Table 1.

According to the Canadian Pacific, this table shows "that the rail replacement program of Canadian Pacific has been associated with an increase in axle loadings".[2] It seems that there can be no dispute that heavy axle-loadings of locomotives cause track maintenance cost.

To jump from this conclusion, to the further conclusion that the miles travelled by locomotives as measured by train-miles should replace gross ton-miles as an explanatory variable is not, however, so simple. Even if it is true that the locomotive causes more maintenance than a single car, the movement of a number of cars may cause more maintenance than the locomotive which pulls them.

[1] New evidence on this point has recently been given by Mr. Donald Gordon, President of the Canadian National Railway.

"The CNR has some 4,500 miles of track laid with light rail which restricts the class of diesel power that can be operated by reason of axle loading . . . Because of the weight restrictions brought about by rail and bridge conditions, the CNR requires over 200 light axle road diesel units to handle traffic on these branch lines . . . The cost of upgrading these branch lines to make them fit for main line power is prohibitive (approximately averaging 30 to 50 thousand dollars per mile)." House of Commons, Sessional Committee on Railways, Airlines and Shipping, Proceedings and Evidence, No. 1, Thursday, June 15, 1961, p. 65.

[2] Stenason, W. J., letter to D. H. Hay, March 6, 1961. Note also the statement on page 22523 of the Transcript, "Canadian Pacific has been, and will be, faced for many years with the necessity of replacing considerable mileages of light rail, which is not yet worn out, owing to its inadequacy to withstand the heavier axle loadings which it is now required to accommodate".

One method of testing the effect of train-miles and gross ton-miles would be to use both in an explanatory equation. Unfortunately, there is a sufficient degree of collinearity between these on the Canadian Pacific that this approach is not satisfactory. However, in a number of models (to be discussed later) tested by the Commission staff train-miles were substituted for gross ton-miles. In each case, the explanation was slightly less satisfactory than when train-miles were used. In addition, some evidence is available from Canadian Pacific experience. On the main line of the Kenora division which is double-track, "train-miles in the eastward and westward division are approximately equal, but the gross ton-miles in the eastward direction are greater than in the westward direction. As can be seen from Table II, the average life of rail in the westward direction is 25.3 years as compared with an average life of 14.9 years for the rail in the eastward direction".[1] Until further evidence is received, gross ton-miles appear the better variable to explain road maintenance.

Finally, the Banks' explanation differs from others in the derivation of the $742.52 per mile of track in that it was not found through regression analysis. It was defended as reflecting "a magnitude acceptable on an engineering basis, using data publicly available from the Dominion Bureau of Statistics, as well as information supplied by the CPR Engineer of Track. This cost is our estimate of irreducible road maintenance and depreciation expense".[2] The phrase "irreducible road maintenance and depreciation expense", is an unfortunate one which was introduced by Canadian Pacific witnesses. The coefficient of approximately $1,150 per mile of track can be interpreted as the amount which the Canadian Pacific would spend on track which it was keeping fit for traffic, although no traffic was in fact moving over it. In defence of their figure, Canadian Pacific produced an engineering appraisal[3] which indicated that under these conditions, an expenditure of approximately $1,100 would be made.

The Banks' view, as expressed under cross-examination, was as follows:

> "It is our view that the deductions as to minimal maintenance that an engineer might make from a review of the Canadian Pacific maintenance of way rules would lead one to a higher standard of maintenance and to a greater expense for track maintenance than is actually required on a minimum irreducible track basis. And this is simply because Canadian Pacific, as a well run railroad, maintains its track more expensively and to a higher standard than some railroads which do not have the Canadian Pacific's financial resources."
>
> "Q. You mean by that that Canadian Pacific wastes money on its track?"
>
> "A. Oh, not at all. I am saying that what Canadian Pacific considers to be a deferred standard of maintenance is the normal operating routine

[1] *Ibid.*

[2] Transcript of evidence, *Hearings,* November 10, 1960, Vol. 116, p. 19264.

[3] Transcript of evidence, *Hearings,* January 23, 1961, Vol. 132, p. 22524.

of an engineer who does not know from one year to the next whether his budget is going to be $20,000.00 or $30,000.00."[1]

Thus, the figure produced by the Banks' organization was not presented as the expenditure which the Canadian Pacific made in fact, but as an estimate of what the expenditure might have been if the Canadian Pacific

TABLE II—AVERAGE LIFE OF RAIL IN MAIN LINE OF KENORA DIVISION (CPR)

Based on Age of Rail Last Removed

Age (Years)	*Westward Track*		*Eastward Track*	
	Miles	*Mile-years*	*Miles*	*Mile-years*
1	—	—	—	—
2	—	—	—	—
3	—	—	—	—
4	—	—	7.7	30.8
5	—	—	2.4	12.0
6	—	—	16.1	96.6
7	—	—	18.3	128.1
8	—	—	11.1	88.8
9	—	—	14.1	126.9
10	—	—	39.3	393.0
11	—	—	34.1	375.1
12	4.0	48.0	10.5	126.0
13	2.0	26.0	10.7	139.1
14	5.5	77.0	49.1	687.4
15	—	—	26.4	396.0
16	2.2	35.2	20.7	331.2
17	1.7	28.9	18.5	314.5
18	0.9	16.2	8.6	154.8
19	3.2	60.8	9.9	188.1
20	4.3	86.0	1.7	34.0
21	1.4	29.4	10.5	220.5
22	3.0	66.0	48.5	1,067.0
23	43.2	993.6	35.1	807.3
24	54.3	1,303.2	7.1	170.4
25	73.3	1,832.5	—	—
26	48.4	1,258.4	3.6	93.6
27	82.0	2,214.0	1.7	45.9
28	47.6	1,332.8	2.3	64.4
29	12.0	348.0	—	—
30	19.0	570.0	—	—
Total	408.0	10,326.0	408.0	6,091.5
Average age (years)		25.3		14.9

[1] Transcript of evidence, *Hearings*, January 16, 1961, Vol. 130, p. 22376.

had viewed its situation differently. If the Banks' argument were accepted, it would seem that $394.29 per mile of track (the difference between Banks' and Canadian Pacific estimates) would have to be charged to high maintenance standards. This course cannot be recommended. The regression approach seems preferable for our purposes.

The Saunders Co. presented fifteen explanatory equations of which one has been presented above. These were given in explaining the reasoning and testing which led to the presentation of two rather complex models as improved explanations of the track maintenance and depreciation expenditure. We need not present all these equations, but some comments upon the hypotheses which were being investigated might be in order.[1]

An initial attempt to separate the effects of freight from passenger gross ton-miles was abandoned when the results indicated that passenger ton-miles caused about thirty times the maintenance of freight ton-miles, and the coefficient for freight ton-miles proved to be not significantly different from zero—perhaps because of the close relationship between the two ($r=.90$).

A similar attempt was made to separate the effects of yard locomotive switching miles and road locomotive switching miles. Although statistically this produced a satisfactory explanation, the coefficient for road locomotive switching was too high to be accepted as realistic.

The effect of different types of track was examined by separating miles of track into miles of running track, main lines; miles of running track, branch lines; and miles of switching track. Then the effect of substituting miles of roadway for miles of track was examined. In each case, although interesting relationships were obtained, the models did not satisfy all the statistical tests.

Two models were developed which, it was felt, did not have statistical disabilities:

(5)	Expenditures=	$1,026,000	
		+$1,580 per main track-mile	(2.5)
		+$ 911 per branch track-mile	(4.4)
		+$0.126 per thousand gross ton-miles	(2.5)
		+$0.498 per yard locomotive-mile	(3.1)
	$R_2=.884$	+$3.749 per road locomotive-mile	(3.3)

and

(6)	Expenditures=	$778,000	
		+$1,092 per mile of roadway	(8.8)
		+$0.191 per thousand gross ton-miles	(8.8)
		+$0.585 per yard locomotive-mile	(4.1)
		+$3.830 per road locomotive-mile	(4.1)

[1] The full argument appears in Transcript of evidence, *Hearings*, November 11, 1960, Vol. 117, p. 19489-19506. The discussion from this point to the Canadian Pacific counter-argument is a summary of that presented by Saunders.

Following the examination of the effects of grades and curves which we discussed above (equation (4)), the Saunders Co. investigated the impact of grades and curves on the maintenance costs which are explained by variations in traffic. This was done by the application of an index of grades and curves, similar to that for track-mileage, but weighted in accordance with traffic densities.

Two further adjustments were made. The first of these was based on an opinion that passenger traffic caused (because of higher speed) twice as much wear and tear as freight traffic and that the standards of passenger traffic caused maintenance practices to be twice as costly as for freight services alone. The main body of their argument was as follows:

> "It seems self-evident that if a higher standard of structure and maintenance are established on a line because passenger trains must operate over it at passenger train speed, comfort and safety, then the freight trains that also use the tracks contribute to the wearing out and tearing down of that higher standard. The higher cost of the wear-and-tear of the freight trains on this passenger-standard line, in excess of what their cost would have been over a lower freight-only line is clearly chargeable to the passenger service.
>
> "The CPR system in 1958 produced about six billion freight gross ton-miles and about one billion passenger gross ton-miles. Thus, if passenger gross ton-miles had had exactly the same cost as freight gross ton-miles, passenger trains would have accounted for one billion out of a total of seven billion freight equivalent gross ton-miles. But with passenger gross ton-miles having a wear-and-tear equivalent of two freight gross ton-miles, the passenger service would have been chargeable with two billion out of a total of eight billion *freight equivalent* gross ton-miles, if all lines had been maintained to freight-only standards.
>
> "Actually, virtually all the passenger gross ton-miles and part of the freight gross ton-miles took place over lines maintained to passenger standards, which can be assumed to double the cost. Supposing that at least one-third of the freight gross ton-miles were on passenger lines, then four of the above eight billion total really represented eight billion freight equivalent gross ton-miles on passenger-standard lines, which, together with the remaining four billion gross ton-miles on freight-only lines, brings the total to twelve billion freight equivalent gross ton-miles. Of course, the actual six billion freight gross ton-miles can only be charged with six of these twelve billion. As a result, we can conclude that under these assumptions, the one billion actual passenger gross ton-miles on the CPR in 1958 were equivalent to six billion freight gross ton-miles. Thus it appears that a ratio of six-to-one would more nearly reflect the freight equivalence of passenger gross ton-miles than the ratio of two-to-one used by the CPR. If the fraction of gross ton-miles taking place over passenger lines is actually one-half or two-thirds, the ratio would increase to seven- or eight-to-one."[1]

The Canadian Pacific attacked both bases of this contention. With regard to the relative effects of speed they said:

> "To reflect the relative effects of passenger and freight traffic on maintenance-of-way expenses, the American Railway Engineering Associa-

[1] Transcript of evidence, *Hearings,* November 11, 1960, Vol. 117, p. 19504-19505.

tion employs equating factors of 1.0 for freight or passenger car gross ton miles, 2.0 for freight locomotive gross ton miles and 3.0 for passenger locomotive gross ton miles. Applying these equating factors to 1956, 1957 and 1958 traffic on Canadian Pacific lines, equivalent passenger gross ton miles amounted to 64.04 billion and equivalent freight gross ton miles amounted to 233.67 billion. Actual gross ton miles for passenger cars, as used in the grain cost study, were 32.64 billion and for freight cars and contents were 183.59 billion. The ratio of equivalent to actual gross ton miles, therefore amounted to 1.962 for passenger traffic and 1.273 for freight traffic. On this basis, the relative effect of passenger to freight gross ton miles would be 1.962 divided by 1.273, equalling 1.54, which is somewhat less than the factor of 2.0 used by Canadian Pacific but only about one-quarter of the factor of 6.0 suggested by the cost consultant for the Grain Handling Organizations.

"The equating factors employed by the American Railway Engineering Association were developed by representatives of major railways throughout Canada and the United States on the basis of their extensive practical experience in roadway maintenance. As pointed out by Professor W. W. Hay on page 29, Volume I, of his book entitled "Railroad Engineering" when referring to these equating factors, "the equating factors have been derived for steam locomotives whose reciprocating motion at high speeds is hard on the track. Where diesel-electrics or straight electrics with rotative drive are used, there may be justification for using values less than those given above". Since Canadian Pacific was largely dieselized during the cost study, a weighting factor of 2.0 is, if anything more than adequate. This appraisal of the weighting factor is substantiated by supervisory officers in direct charge of track maintenance on Canadian Pacific based on their experience."[1]

With regard to the effects of a higher standard of maintenance they said:

"Although some lines on Canadian Pacific are maintained in somewhat better surface and alignment than might be required for freight service alone, owing to the higher operating speeds of passenger trains using them, there are no higher standards of construction for lines carrying a substantial volume of passenger traffic than those which carry freight traffic exclusively. There is no difference in the size of rail or in the quantity or quality of ties and ballast used for freight service and for passenger service. Some lines which have light or moderate curvature and which carry passenger traffic have curves super-elevated somewhat in excess of that required for freight train speed in order to permit passenger trains to operate at higher speed. In heavy curve territory, however, where the effect of curvature on track maintenance is most pronounced, it is the practice of Canadian Pacific to limit the speed of passenger trains to the same as that authorized for freight trains. Accordingly, there is no appreciable amount of additional cost resulting from "higher standards of track structure" and any additional maintenance cost incurred in the preservation of better surface and alignment to provide satisfactory riding qualities for passenger equipment would be considerably less than double that required for freight train operation.

"There is no evidence to support the hypothesis that freight trains produce more wear and tear on tracks maintained for passenger traffic than on tracks maintained for freight traffic alone. There are no circumstances which would lead to such a result except, possibly, in the case of curves

[1] Transcript of evidence, *Hearings*, January 23, 1961, Vol. 132, p. 22532-22533.

> super-elevated in excess of freight train speed requirements which, as mentioned previously, is only applicable on Canadian Pacific where light or moderate curvature prevails. In fact, experience indicates that track deteriorates at an accelerating rate as the deterioration progresses so that it would be reasonable to expect that, on the contrary, freight traffic would incur less track maintenance expense on a line maintained for passenger traffic than on a lower standard freight line."[1]

In the models which the Saunders organization used, when freight and passenger gross ton-miles were introduced as separate variables, the resulting coefficients indicated a greater ratio than two-to-one. But as they, themselves, said, "Because of the high intercorrelation between passenger and freight gross ton miles, the multiple regression technique cannot be used to test this assumption or to derive the true ratio".[2] Further, when a six-to-one ratio was substituted in two of the Saunders' models, there was, from a statistical point of view, little improvement in one case and no improvement in the other.

In the face of the evidence that a six-to-one ratio is far from the value traditionally accepted and that it does not accord with what railway operating officials of the Canadian Pacific believe reasonable from their experience, it is difficult to accept the six-to-one ratio without firmer statistical backing. At the same time, it must be noted that what statistical evidence there is, is all in the direction of suggesting a ratio higher than two-to-one. It is to be hoped that if a situation arises, on either the Canadian Pacific or the Canadian National, when the high intercorrelation between freight and passenger gross ton-miles no longer exists, the railways will seize the opportunity for further statistical testing.

The last modification instituted by the Saunders' organization was to combine several sets of variables in one of their equations. Each of main track-miles, branch track-miles and gross ton-miles was combined with its counterpart attached to the grade and curve index. Thus part of one equation read:

$$527\,X_1 + 617\,X_1\,(X_{11} - 100),$$

where X_1 represents main track-miles and X_{11} represents the main track index. Dividing by 527 one finds the new composite variable

$$(X_1 + 1.170\,X_1\,[X_{11} - 100])$$

The three combined variables,

main track-miles variable $= X_1 + 1.170\,X_1\,(X_{11} - 100)$
branch track-miles variable $= X_2 + .146\,X_2\,(X_{12} - 100)$
gross ton-mile variable $= X_3 + .539\,X_3\,(X_{13} - 100)$,

[1] Transcript of evidence, *Hearings*, January 23, 1961, Vol. 132, p. 22531-22532.
[2] Transcript of evidence, *Hearings*, November 11, 1960, Vol. 117, p. 19504.

were substituted for separate variables in a previous equation.[1] This was done in an attempt to strengthen the "t" values of the previous equation. It was pointed out that because this substitutes coefficients already estimated from the data in the form of predetermined relationships the new "t" values are not susceptible to evaluation.

An interesting line of argument was introduced in this excerpt:

> "In certain of Mr. Saunders' track expense regressions, main line track miles and branch line track miles have been introduced as separate independent variables and independent coefficients of expense developed. There is no consistency in the various relationships between these coefficients: the coefficient for main lines is more than double that for branch lines in Equation 4,[2] is 73% greater in Equation 6 and less in Equations 11, 12 and 14 except on territories with relatively low tonnage ratings. This indicates that these coefficients may be absorbing some of the influences of traffic volume. Such a result can be expected in view of the fact that the distinction between main lines and branch lines is primarily a function of traffic density. Since a realistic coefficient of expense per mile of track should be free of any influences of traffic volume and the functions which it represents are just as much a reality on branch lines as on main lines, there is no justification for any difference existing between the coefficients for main lines and branch lines.
>
> "The breakdown of track miles into main line and branch line miles distorts the equation as the main line track variable absorbs costs which are truly chargeable to gross ton-miles. This is the result of the high intercorrelation between miles of main line track and gross ton miles... Canadian Pacific has tested this by developing a regression in which the minimum maintenance cost of $1,137 per mile of track has been deducted from the dependent variable, and miles of main line track added as an explanatory variable. The purpose of such a test is to determine whether miles of main line track add a significant factor to the regression or whether their effects is merely to distort the gross ton mile coefficient. It was seen that the latter is true, for the effect of introducing miles of main line track as an independent variable was to sharply reduce the value of the gross ton-mile coefficient."[3]

Empirically, this may be true for the Canadian Pacific. Its truth depends upon the high correlation between main track-miles and gross ton-miles. Even though main track is defined on the basis of traffic density, it is not necessary that main track-miles and gross ton-miles be highly correlated. A high traffic volume can exist in a division with either (a) a small number of high-density lines, or (b) a large number of low-density lines. Since the high correlation exists, the proportion of high- and low-density miles per division must be roughly constant. One might imagine a railway defining main track-miles as those having a traffic density of 300,000 gross ton-miles per mile or over. (The low figures of this example were chosen for ease in calculation.) Two divisions on this railway might then have the following track and traffic.

[1] Subscripts altered from original.

[2] Equation numbers refer to original Saunders & Co., submission and not to those of this report.

[3] Transcript of evidence, *Hearings*, January 23, 1961, Vol. 132, p. 22527-22528.

TABLE III—TRAFFIC DENSITY OF TWO HYPOTHETICAL DIVISIONS

	Miles	*Ton-miles (millions)*	*Density (hundred thousand gross ton-miles per mile)*
Division A	700	70	1
	300	150	5
Total	1,000	220	2.2
Division B	500	50	1
	500	170	3.4
Total	1,000	220	2.2

The explaining equation of the railway would treat these divisions as identical. The Saunders' equations discriminate between the two cases. Since the wear and tear caused by traffic depends upon the density on the particular segment of track rather than on the average density in the division, the Saunders' equations are a more precise formulation.

More interesting is the logical conclusion of this argument which is that, as far as running track is concerned, miles of roadway should be the relevant explanatory variable rather than miles of track. Passing sidings are added only to accommodate increases in traffic and, *a fortiori,* second track is a reflection of a high ton-mileage. Following the argument of the last quotation, one can contend that the use of miles of track, rather than miles of road, fails to remove important influences of traffic volume.

The Saunders Co. presented equations which utilized the miles of roadway. One of these was:

(7) Expenditures = —$32,000

	+$809	per mile of roadway	(2.7)
	+$253	(miles of roadway) (grade index —100)	(1.7)
	+$0.119	per gross ton-mile	(3.5)
	+$0.066	(gross ton-miles) (grade index —100)	(2.8)
$R^2 = .945$	+$0.769	yard locomotive-miles	(5.7)
	+$3.307	road locomotive switching miles	(4.2)

In view of the prominence which the treatment of this group of accounts had received, and in view of the complexity of the relationships between these accounts and the output variables, special attention was paid to this analysis by the Commission staff. As a first step, the expenditures by division were examined when plotted on graph paper against the estimated expenditures for each of the divisions. The residual amounts, unexplained by the estimates of the railway and by several of the consultants' models, were examined. It was suspected that the Vancouver division had characteristics differing from other divisions. "Examination of the dependent variable input data to Account 202, etc.," by the Canadian Pacific on request, "for the Vancouver Division shows amounts for the years 1957 and 1958 of $1,739,985 for extensive bridge work over that required in 1956."[1] This amount was removed from the accounts since both the statistical evidence and conversations with railway officials indicated that this was an expenditure of a different nature than occurred on other divisions. The treatment of this amount is discussed below.

The net relationships were then plotted, that is, for each division the effects (according to equation (1)) of gross ton-miles, and of yard and train switching miles, were subtracted from the actual expenditure. The remaining amounts can be attributed to miles of track and random effects. These net amounts were plotted against miles of track. Similarly the net amounts attributable to gross ton-miles and to yard and train switching miles were plotted against the appropriate output variables. Inspection of these various graphs indicated the possibility that at least one of the relationships was not linear.

Two possibilities suggested themselves. The first was that the relationship between expenditures and miles of track is either of the classic shape discussed on page 203 of Chapter 2 or a second degree approximation to this. (That is that it can be expressed as either $E = a - bX^2 + cX^3$ or as $E = a - bX^2$.) The second was that the relationship between expenditures and gross ton-miles is curvilinear. This latter idea was suggested by earlier findings in the United States. For example, Healy, studying the maintenance-of-way expenses of Class I railroads in the United States in 1927 and 1935 remarks:

> "In both cases there is a definite tendency for expense per mile of road to start at a certain minimum and increase consistently as density increases. The existence of a minimum, below which standards cannot drop, results in a rather high unit expense at the very lowest density, but by the time the range of density at which most railroads operate is reached, a relatively uniform unit expense is maintained. At the average density for the country, which was 4,000,000 gross ton-miles per mile of road, the expense is 0.04 cents per gross ton-mile. For double that density it drops only to 0.036 cents. The same trend is evident when density is expressed in terms of car-miles. At a density of 50,000 car-miles per mile of road per year, below which few Class I railroads operated in 1935, the maintenance-of-way expenses were 2 cents a car-mile. At double that density, which is approximately the average density for the Class I railroads, the unit expenses become 1¾ cents. Doubling the density again brings it to a level exceeded by only a few of the coal carrying roads, but the expense per car-mile drops only to 1½ cents."[2]

[1] Letter, W. J. Stenason to D. H. Hay, Jan. 3, 1961.

[2] Healy, K. T.: *The Economics of Transportation in America,* New York, The Ronald Press, 1940.

Elimination of the exceptional (in the sense that it applied to but one division) expenditure in the Vancouver division raised the general fit of the estimating equation, as measured by the coefficient of determination, R^2, from 83 per cent to 86 per cent. The attempt to fit a curved line to the relationship between miles of track and expenditures showed a similar improvement, a second degree equation raised R^2 to .90, a third degree to .92. In both cases linear relationships were preserved for gross ton-miles and for yard and train switching miles.

In an attempt to represent the apparent curvature of the relationship between gross ton-miles and expenditures, the logarithms of gross ton-miles were substituted for the original values while miles of track and yard and train switching miles were treated in the original fashion. The result was a drop in the amount of variance explained, R^2 went down to .80.

Examination of the working papers of W. B. Saunders and Co. confirmed the suggestion of Mr. Saunders that more needs to be known about the switching function.[1] In certain formulations, the four Canadian Pacific terminal divisions appeared to act as a group with different characteristics than the twenty-seven line-haul divisions. To test this, the Canadian Pacific ran a special model in which it was assumed that switching miles have a different character on line-haul divisions than they do on terminal divisions. Switching miles were split into two variables, the first having the number of switching miles for line-haul divisions, and zero entries in the case of terminal divisions, the second having zero entries for the line-haul divisions and the switching miles for terminal divisions. The results of this test were an indication of an appreciable but apparently not statistically significant difference between the coefficients of the switching variable for the two types of division.

A second problem which emerged from this examination was that although the variation in expenses was fairly well explained in general, in the case of certain divisions the discrepancy between the actual expenditures and those which would be estimated by the use of the equation was disconcertingly large. The estimated values for a number of divisions varied from the actual by from twenty to twenty-five per cent of the actual. In view of this it seemed wise to search for a new explanation which, even if it did little to improve the general fit, would lessen these large discrepancies. While plotting the graphs of the net effects for this stage of the analysis, it was noticed that the Kenora division was greatly over-estimated by the mile-of-track variable. Since this division has a great deal of double-track line, the hypothesis that the appropriate variable is miles of road, rather than miles of track, was again considered. Substitution of this variable raised the R^2

[1] Transcript of evidence, *Hearings*, January 10, 1961, Vol. 128, p. 22125-22126.

to .93. More important, it succeeded in reducing some of the large discrepancies.

Again, an attempt was made to solve the problem of the switching variables. Yard engine switching miles have a very high correlation with yard track-miles. This is to be expected since the size of yard can be adjusted (given time) to the amount of switching which is taking place. On the other hand, the tracks which are switched exclusively by road locomotives (the definition of road switching track), will often be little used, in comparison with yard track. It may exist primarily to give access to particular industries. It seemed possible that yard locomotive switching miles might be used as a variable explaining both the maintenance caused by yard switching, and that attached to the existence of yard switching track. Road switching miles and yard switching miles might then be used as separate variables. Neither this formulation nor any of the variations tried were successful in giving a better explanation of this account. At the present time it seems that the best explanation is given by using yard and train switching miles as a variable to explain both the maintenance costs associated (in fact) with the actual switching operation and those associated (in fact) with the existence of switching track.

Plotting the net expenditures against the explanatory variables again raised the question of curvilinearity. The introduction of a second degree term for gross ton-miles raised the coefficient of determination to .94, but more important was the fact that this improvement was largely due to a lessening of the larger discrepancies. In particular the estimate for the Kenora division, which consistently had estimated expenditures far over those actually experienced, was brought closer to experience. Equation 8 presents the results of this step.

(8) Expenditures = —\$55,533		
	+\$3,558.0 per mile of road	(.593)
	—\$3.6492 per (mile of road)^2	(—.469)
	+\$0.015604 per (mile of road)^3	(.439)
	+\$0.28217 per thousand gross ton-miles	(.695)
	—\$0.000,000,013059 per (thousand gross ton-miles)^2	(—.417)
R^2=.942	+\$0.70262 per yard and train switching mile	(.677)

NOTE: For both equations (8) and (9) the figures to the right in parentheses are partial coefficients of correlation and not "t" values.[1]

[1] The electronic computer programme available to the Commission staff did not include a provision for the computation of "t" values. The expense of including such a provision did not appear justified.

Finally, the residuals were compared with a new composite variable, miles of road multiplied by Saunders' index of grade and curvature (weighted by mileage). One hundred was subtracted from the original index in each case. This examination indicated a strong possibility that a relationship between terrain, as measured by this index, and expenditures on maintenance-of-way existed in sufficient degree to warrant the insertion of this variable in the explanatory system. This was the final adjustment made in the statistical model. This model was as follows:

(9)	Expenditures=	\$27,059.80	
		+\$1,288.1 per mile of road	(.223)
		—\$1.5140 per (mile of road)^2	(—.214)
		+\$0.0090402 per (mile of road)^3	(.292)
		+\$0.32000 per thousand gross ton-miles	(.777)
		—\$0.000,000,013338 per (thousand gross ton-miles)^2	(—.479)
		+\$0.69143 per yard and train switching mile	(.725)
	R^2=.957	+\$4,6334 per mile of road times Saunders' grade index	(.511)

It is interesting to note that the effect of introducing this new variable was to reduce the coefficients for miles of road to about half their previous values, while similarly lowering the explanatory power of these values. This suggests that a future programme of research might include an investigation of the weighting of miles of road and the grade index.

The coefficients for gross ton-miles and for yard and train switching miles remained stable when the new variable was added.

Despite lack of complete satisfaction with the strength of the miles-of-road coefficients, equation (9) has been accepted for this report.

The most satisfactory treatment, presently available, of the amount of \$1,739,985 deducted from the road maintenance accounts of the Vancouver division, appears to be to treat it as an expenditure caused by events for which some contingency allowance must be made. The amount can be prorated to the miles of road in the system as an allowance for unusual, recurrent expenditures.

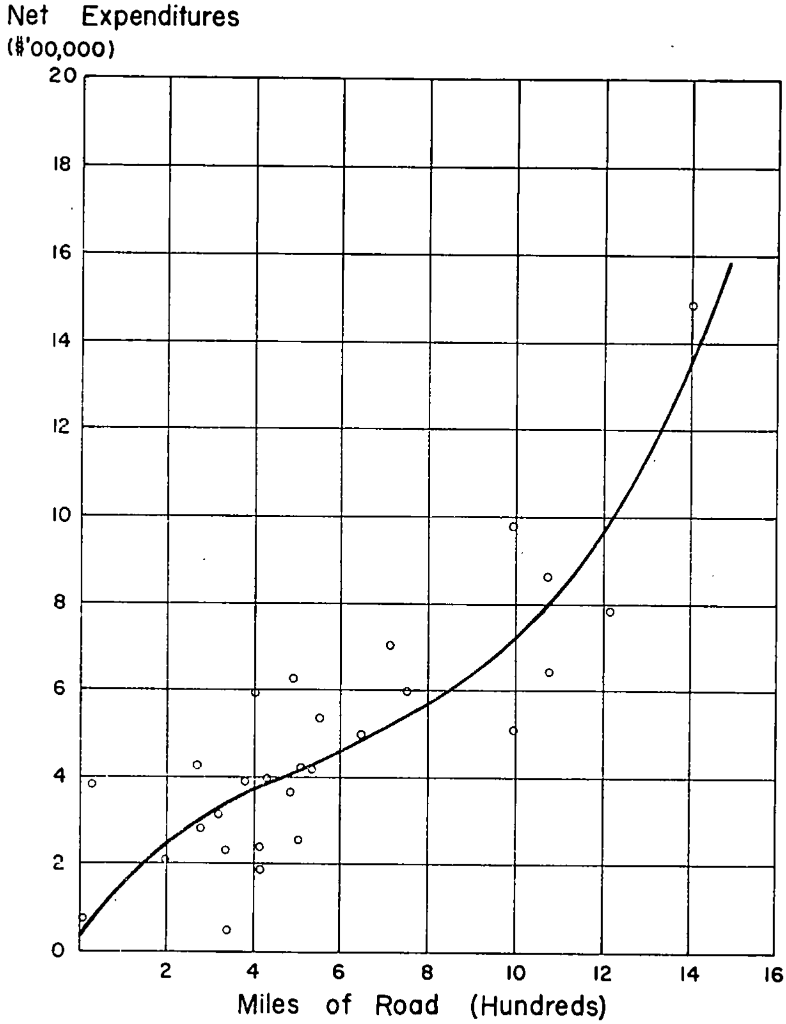

FIGURE I: Relationship between Road Maintenance Expenses and Miles of Road for Canadian Pacific Railway after Allowance for Effect of other Variables. Based on Equation 9.

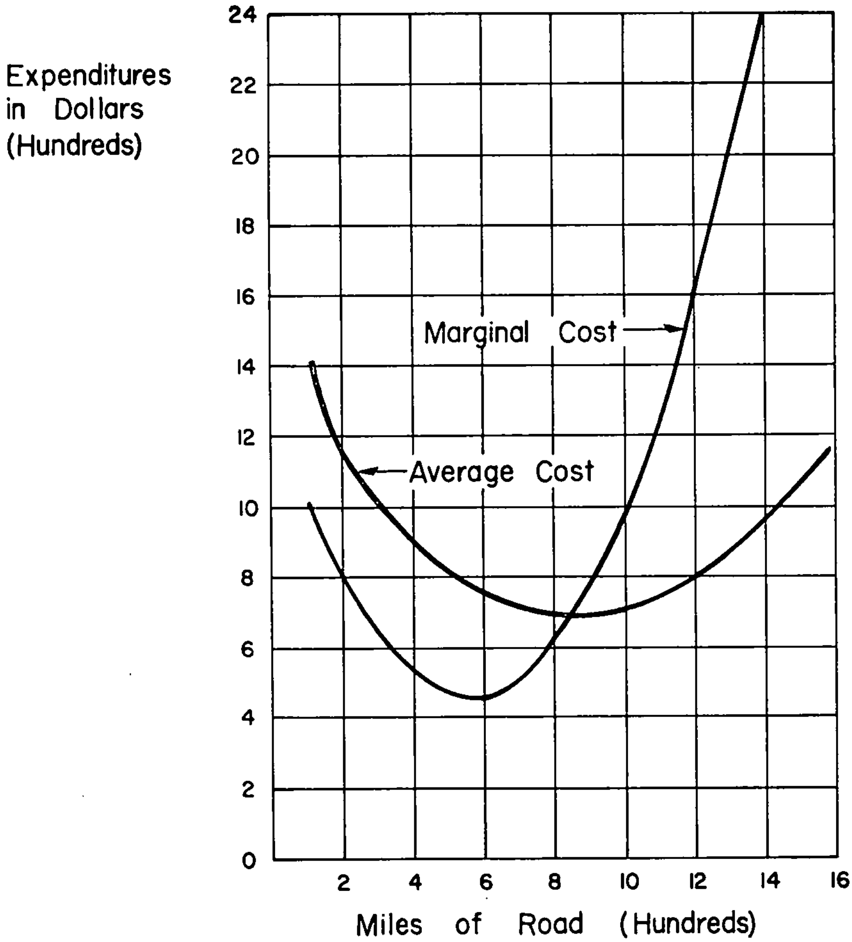

FIGURE 2: Average and Marginal Costs related to miles of road for Canadian Pacific Railway according to Equation 9.

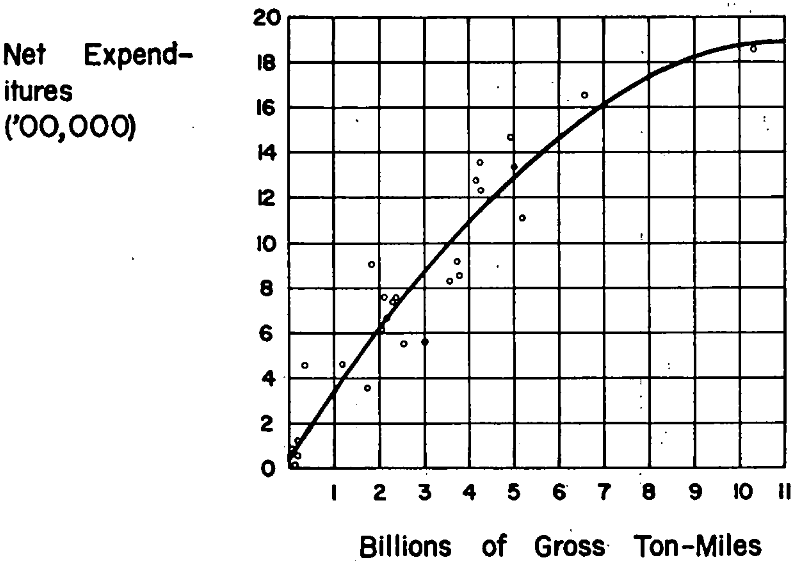

FIGURE 3: Relationship between Road Maintenance Expenses and Miles of Road for Canadian Pacific Railway after allowance for effect of other variables.
Based on Equation 9.

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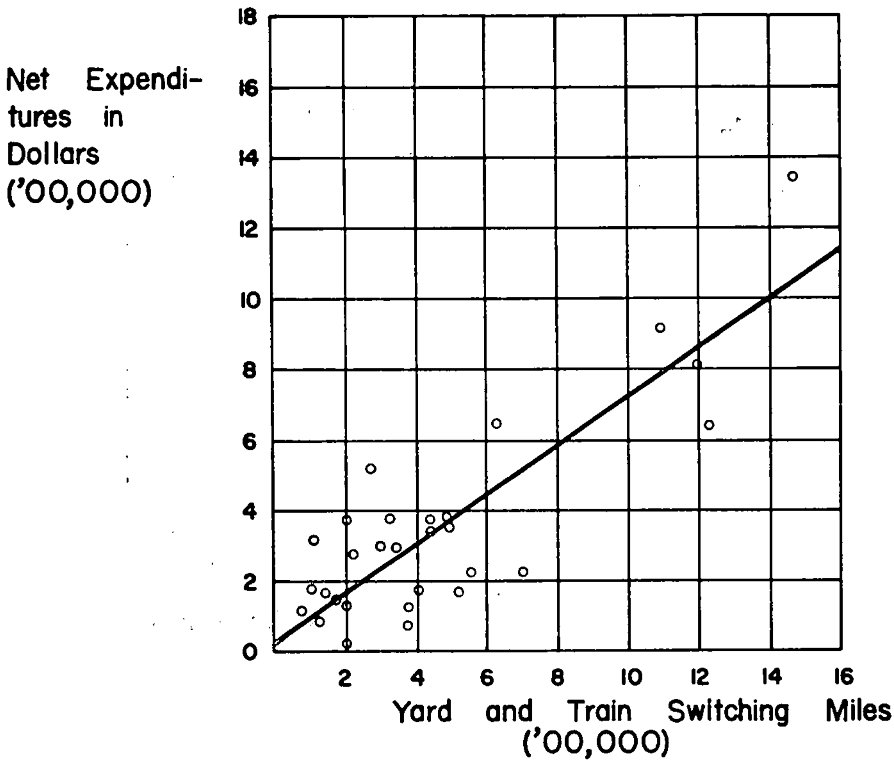

FIGURE 4: Relationship between Expenditures on Road Maintenance and Yard and Train Switching Miles for the Canadian Pacific Railway after allowance for the effect of other variables.
Based on Equation 9.

2. *Road Maintenance Superintendence and Overhead*

CANADIAN PACIFIC RAILWAY

Accounts Explained 201 Superintendence (Road Maintenance)
274 Injuries to Persons (Road Maintenance)
276 Stationery (Road Maintenance)
277 Other Expenses (Road Maintenance)

(10) Expenditures= \$1,083,445
+\$0.032888 per direct road maintenance expense (t=5.26)
R^2=.78 +\$43,92223 per mile of track (3.62)

CANADIAN NATIONAL RAILWAYS

Accounts Explained 201 Superintendence (Road Maintenance)
274 Injuries to Persons (Road Maintenance)
276 Stationery (Road Maintenance)
277 Other Expenses (Road Maintenance)
275 Insurance (Road Maintenance)

(11) Expenditures= \$65,318.66
R^2=.58 +\$0.060,005 per dollar direct road maintenance expense (6.17)

Both railways, it will be seen, explained at least part of the variation in superintendence and overhead expenses by relating these indirect expenses to the direct expenses. In order to relate these accounts to the output units, the amounts of expense attributed to the study traffic in each of the other road property maintenance accounts were multiplied by the coefficient for dollars of direct road maintenance expense in the equations above. An equivalent procedure would have been to multiply the coefficients of equation (10) or (11) by the relevant coefficients found in the analyses of the other road property maintenance accounts, then multiply the product by the appropriate output units assessed to the study traffic.[1]

Thus, with reference to the road maintenance accounts,[2] the explanation for the variable costs of superintendence might have been written:

(12) Expenditures= (\$1,136.81110)(0.03288) per mile of track
+\$43,92223 per mile of track
+(\$0.16475)(0.03288) per thousand gross ton-miles
+(\$0.39053)(0.03288) per yard and train switching mile

[1] Symbolically, Σ a(bc) is equivalent to Σ (ab)c.

[2] For illustrative purposes, equation (1), that is, the explanation of road maintenance expense suggested by the Canadian Pacific, has been selected for combination with equation (10).

Simplified, equation (12) would read:

(13) Expenditures = \$81.30058 per mile of track
+\$0.0054170 per thousand gross ton-miles
+\$0.012841 per yard and train switching mile

Following a similar procedure with each of the other groups of accounts studies for road maintenance, the similar terms could have been added together to give a single explanatory equation for road maintenance superintendence and overhead. Algebraically the methods are identical, only the order of the operations performed is different.

The method of the last two paragraphs is a complicated example of a procedure which was entitled by the cost analysts, who appeared before the Commission, "pyramiding". It was generally agreed that this is not the best procedure. Among the comments made about pyramiding were the following: "It is of little value to introduce a variable which cannot be directly related to a particular cost category by the use of an intermediary variable. Most likely the improved statistical results (if in fact there is an improvement) is not due to underlying relationships but to statistical mechanics." ". . . no method is readily available of testing the statistical significance of the coefficients in the final cost equation derived."[1]

The arguments of the last paragraph suggest that one should try to relate this group of accounts directly to the output variables. Since superintendence is one of the areas in which non-linearity, of the type discussed in connection with the track maintenance group of accounts, can be expected, an attempt was made to estimate the relationships directly using a non-linear system. For Account 201, etc., on the Canadian Pacific, the following equation was obtained and has been utilized in this report:

(14)	Expenditures = (Acct. 201, etc.)	−\$9,493.5	
		+\$3867. (miles of road)	(.651)
		−\$0.44167 (miles of road)^2	(−.531)
		+\$0.00018548 (miles of road)^3	(.482)
	R^2=.833	+\$0.0064720 (thousand gross ton-miles)	(.528)
		+\$0.052843 (yard and train switching miles)	(.582)

NOTE: For this equation the parenthesized values to the right are the partial coefficients of correlation and not "t" values.

[1] Transcript of evidence, *Hearings*, January 23, 1961, Vol. 132, p. 22545-22546. During the hearings, these arguments were advanced to counter a suggestion that higher "t" values obtained by pyramiding were meaningfully improved. In the present context, the last sentence quoted retains the full force it had in the original comment.

3. *Shops and Enginehouses, Maintenance and Depreciation*

CANADIAN PACIFIC RAILWAY

Accounts Explained 235 Shops and Enginehouses Maintenance
266 Depreciation

(15) Expenditures= \$81,200 (0.23)
+\$0.05230 direct equipment maintenance
R^2=.91 expense (9.13)

CANADIAN NATIONAL RAILWAYS

Accounts Explained 235 Shops and Enginehouses Maintenance

(16) Expenditures= \$73,582
+\$0.040388 direct equipment maintenance
R^2=.96 expense (477.88)

Again, the railways chose an explanation which depends upon "pyramiding". R. L. Banks and Associates suggested a second explanation which also depends upon pyramiding. Rather than relate these expenditures to equipment maintenance expense, they chose to investigate the relationship between maintenance expense and the size of the shops and enginehouses as measured by the amount of investment in these facilities. Presumably expense in this category is explained by a causal chain of the following type: work (measured in gross ton-miles and yard and train switching) causes a need for maintenance; maintenance work causes a need for shops and enginehouses (measured by investment in these buildings); shops and enginehouses need maintenance both because of wear and tear caused by the work done in them and because of the action of the elements.

The railways chose to jump to the amount of maintenance work done. R. L. Banks and Associates chose to move to the size of shops and enginehouses. In doing this, Banks estimated the following relationships for eastern and western line-haul divisions:

West

(17) Expenditures= \$5,436.40 (0.09)
+\$0.05815 per dollar investment
R^2=.89 in shops and enginehouses (10.11)

East

(18) Expenditures= \$17,271.00 (0.49)
+\$0.06763 per dollar investment
R^2=.92 in shops and enginehouses (10.50)

Following this, the relationship between investment in shops and enginehouses and output units was estimated for the system.

(19) Investment,
Shops and
Enginehouses= $657,100.00 (0.32)
R^2=.26 +$1.7643 per yard and train switching mile (4.09)

Equation (19) was then substituted into equations (17) and (18) to yield the following:

West

(20) Expenditures= $43,646.00
+$0.10259 per yard and train switching mile

East

(21) Expenditures= $61,711.00
+$0.11932 per yard and train switching mile

The Canadian Pacific pointed out that had these relationships been estimated directly for the 17 western divisions (15 line haul plus two terminals) the following equation would have resulted:[1]

(22) Expenditures=—$67,600 (—1.031)
R^2=.65 +$0.22343 per yard and train switching mile (5.293)

R. L. Banks and Associates replied that a direct estimation using the 15 line-haul divisions resulted in a coefficient of determination of .40 and a regression coefficient of $0.13966 for yard and train switching miles. The differences in these coefficients from those of the Canadian Pacific direct model, and the existence of a negative constant value in the latter were cited as evidence of heterogeneity caused by differences between line-haul and terminal divisions.[2]

None of the explanations put forward to explain these accounts can be accepted as completely satisfactory. On *a priori* grounds there appears to be no basis on which to choose between direct equipment maintenance expense and investment in shops and enginehouses. The investment variable has the disadvantage that prices of different time periods are included. The direct expense variable has the disadvantage that it reflects current activity but will not reflect the possible necessity of maintaining shops or enginehouses built for another level of activity. From the point of view of statistical measures, the coefficient of determination and the significance of the regression coefficients, there is little to choose between them.

[1] Memorandum: W. J. Stenason to D. H. Hay, November 29, 1960.
[2] Letter: R. L. Banks to D. H. Hay, December 23, 1960.

Improvement in the explanation of these expenditures is likely to come only from an examination of the direct estimates. For that reason, they are chosen in this report. Furthermore, because it is based on a slightly more complete sample, the 17 observation sample will be used. It is quite true that the shifts in coefficients indicate that further study is needed. It is also true that these shifts may be due to heterogeneity—but they may be due to incomplete specification. Perhaps another explanatory variable would remove these peculiarities. As well, it would be desirable to use a method of estimation using information from the whole system. For the purpose of this report, equation (22) has been accepted as the explanation for Accounts 235-266 for the Canadian Pacific, since it appears to give the best explanation presently available. In doing so the need for further exploration must be explicitly recognized.

4. *Power Plants, Maintenance and Depreciation*

CANADIAN PACIFIC RAILWAY

Accounts Explained 253 Power Plant Systems
266 Depreciation

(23) Expenditures= \$0.01546 per dollar expense Account 373 (9.04)
R^2=.74

The Canadian National treated this account as part of the fixed cost.

R. L. Banks and Associates examined the relationships between expenditures in this account and output units for the east and west separately. In the west they found that expenditures on maintenance and depreciation of power plants is significantly related to investment in power plants. In the east this relationship was not significant but that with dispatching and station employees expenses (Accounts 372-3-6) was significant. They, therefore, developed two explanatory equations.

West

(24) Expenditures= \$4,189.19 (0.32)
R^2=.80 +\$0.08702 per dollar investment in power plants (7.17)

East

(25) Expenditures= \$7,983.82
R^2=.50 +\$0.008413 per dollar expenditure dispatching and station employees (3.15)

These equations were, in turn, related to output units by other equations.

The necessity to turn to different explanations in the east and west suggests that the best explanation of this account has not yet been found. It is difficult to believe that the cause of this expenditure is different in east and west. This account also needs further work in order to develop a direct relationship. In the meantime the Canadian Pacific model has been accepted for this report.

5. *Dispatching and Station Employees Expenses*

CANADIAN PACIFIC RAILWAY

Accounts Explained 372 Dispatching
373 Station Employees
376 Station Expenses

(26)	Expenditures=	\$6,666,613	(1.22)
		+\$5,6149 cars C.L. originated	(1.53)
		+\$0,02336 passenger car-miles	(1.63)
	R^2=.54	+\$65.35356 cars L.C.L. originated	(3.97)

The Canadian National dealt with Accounts 373 and 376 only. Account 372 was included with another group dealing with train control.

(27)	Expenditures=	\$367,814.6	
		+\$52,053 carloads L.C.L.	(4.0)
	R^2=.64	+\$4,2352 carloads, other	(1.4)

Because of the low "t" values, R. L. Banks and Associates chose to relate these accounts to other output variables.

(28)	Expenditures=	\$439,862	(0.71)
		+ \$0.2839 per dollar investment in station and office buildings	(6.35)
	R^2=.79	+\$58.72 per car loaded L.C.L.	(5.46)

In turn, investment in station and office buildings was related to output units through the following equation:

(29)	Investment in station and office buildings=	\$2,766.771	(1.02)
	and	+\$0.19879 per thousand gross ton-miles (1 frt. + 2 passengers)	(2.52)

Substituting equation (29) into equation (28), the following explanation resulted:

(30)	Expenditures=	\$1,225,348
		+\$58.72 per carload L.C.L.
		+\$0.05644 per thousand gross ton-miles

In this case, the direct approach of the railways is clearly preferable to the "pyramiding" method. True, the "t" values are low, suggesting that the relationships are weak. Possibly this is because of the nature of the data available for analysis. For freight, only origination data has been used. For passenger traffic only passenger car-miles. On the face of it, these would not seem likely to be the best explanatory variables. While a part of the work of station employees is concerned with originating freight movements, part must be connected with freight terminations. For originations, a count of waybills issued would seem a likely candidate for an explanatory variable. Similarly, a count of shipments terminated would seem a likely explanatory variable. Passenger tickets sold might well account for both originations and destinations since in the case of passenger traffic these are likely to be roughly in balance. The data for these variables was not available at the time of these studies; we must rest content with equation (26) as a starting point in this analysis.

6. *Train Locomotive Supplies and Enginehouse Expenses*

CANADIAN PACIFIC RAILWAY

Accounts Explained 398 Train Locomotive and Supplies
400 Train Enginehouse Expenses

(31)	Expenditures=	\$161,051	
		+\$0.2124 per locomotive-mile (steam)	(1.94)
	R^2=.571	+\$0.12959 per locomotive-mile (diesel)	(1.87)

CANADIAN NATIONAL RAILWAYS

Accounts Explained 398 Train Locomotive and Supplies
400 Train Enginehouse Expenses

(32)	Expenditures=	\$376,190	
		+\$0.35094 per yard locomotive-mile	(11.83)
	R^2=.89	+\$0.05169 per train locomotive-mile	(2.2266)

R. L. Banks and Associates noticed when examining the scatter diagram for this account that the Quebec district obviously has a relationship between expenditures and output units which is not typical of the other districts. To correct this, they performed their analysis on the remaining nine districts. In addition, they dealt with all locomotive-miles taken together. This yielded the equation for the Canadian Pacific.

(33)	Expenditures=	\$726,630	(0.42)
	R^2=.82	+\$0.13410 (per locomotive-mile)	
		(steam and diesel)	(5.61)

On re-examination, the Canadian Pacific agreed that the Quebec district had an unusual relationship. An investigation of the process by which these accounts and output units are charged, showed that the locomotive-miles for trans-continental passenger trains are charged to the various districts, the expenses of Accounts 398 to 400 for these trains are almost entirely charged in the Quebec district. To correct for this, the Canadian Pacific removed the locomotive-miles attributable to these trains from the other districts and added them to those for Quebec. The regression analysis was repeated, yielding:

(34)	Expenditures=	\$29,944	
		+\$0.15512 per locomotive-mile (steam)	(2.55)
	$R^2=.89$	+\$0.18068 per locomotive-mile (diesel)	(5.35)

Canadian Pacific do not keep diesel unit mile statistics by division. However, Canadian National do. Attempts by the Canadian National to analyse this account using diesel unit miles resulted in a group of equations with utterly insignificant or negative coefficients for diesel unit miles.[1] It appears quite likely that the higher coefficient for diesel locomotives is due to the definition of locomotive as a single unit for steam and as the combined units on a train for diesel.

The Canadian National use of yard locomotive-miles was suggested by the fact that under steam practices enginehouses were situated where yard switching took place. Yard locomotive-miles were used as a proxy size variable.

While the railways' models (equations (32) and (34)) have been accepted for this report, the analyses of these accounts, carried out by the various parties, indicate that here again, the explanations of expenditures have not been satisfactorily related to the determinants of the expenditures.

7. *Gross Investment in Road Property*

CANADIAN PACIFIC RAILWAY

(35)	Gross Investment=	\$34,125,798	(2.67)
	(Road Property)	+\$15,130,387 per mile of track	(3.39)
		+\$4.35896 per thousand gross ton-miles	(5.11)
	$R^2=.75$	+\$12.66340 per yard and train switching mile	(1.87)

As noted below in Section C, the Canadian National could not perform this analysis.

[1] Unpublished study.

R. L. Banks and Associates could not accept the low "t" value of the coefficient for yard and train switching miles. To avoid this they constructed two models:

West

(36)	Gross Investment=	\$60,550,000	(2.76)
	(Road Property)	+\$3.4360 per thousand gross ton-miles (1 frt. + 2 passengers)	(3.68)
		+\$12,520 per mile of track	(2.28)

East

(37)	Gross Investment=	\$48,648,700	(2.14)
	(Road Property)	+\$6.6080 per thousand gross ton-miles (1 frt. + 2 persons)	(5.43)

Although these two models increased the significance of the coefficients, they did so at the expense of deleting miles of track from the eastern equation. It is difficult to accept an explanation of investment in road property which does not contain any variable representing the physical size of the railway.

Analysis of the type carried out for the Account 202, etc., complex might well prove to be more successful than the Canadian Pacific Equation which is accepted for this report.

8. *Other Regression Analyses*

The following groups of accounts were analysed by the railways using regression techniques. None was challenged by the consultants of the provinces or grain-handling organizations and none was examined critically by the Commission Consultants.

(a) Maintenance of Fences, etc.

CANADIAN PACIFIC RAILWAY

Accounts Explained 221 Fences, Snowsheds and Signs—Maintenance
266 Depreciation

(38)	Expenditures=	\$604,565	(4.42)
	R^2=.78	+\$34.61040 per mile of right of way fences	(9.34)

CANADIAN NATIONAL RAILWAYS

Accounts Explained 221 Fences, Snowsheds and Signs

(39) Expenditures= \$3,264.06
R^2=.67 +\$40.008 per mile of fence (7.43)

(b) Water and Fuel Stations

CANADIAN PACIFIC RAILWAY

Accounts Explained 231 Water and Fuel Stations—Maintenance
266 Depreciation

(40) Expenditures= \$285,035 (2.07)
R^2=.64 +\$0.01070 per dollar of fuel expense (2.88)
+\$0.45140 per dollar of water expense (4.92)

CANADIAN NATIONAL RAILWAYS

Accounts Explained 231 Fuel and Water Stations

(41) Expenditures= \$10,284
R^2=.43 +\$0.010915 per total locomotive-mile (steam) (2.81)
+\$0.006481 per total locomotive-mile (diesel) (2.21)

9. *Expenses Assigned Directly*

Both railways obtained the costs for grain doors, including the costs of repair (part of Account 402), and the claims for loss and damage (part of Account 418), directly from company records. From these figures, the portion applicable to domestic grain shipments was removed.

The Canadian Pacific submitted figures based upon the average experience for the years 1956-58.

In the case of grain doors the Canadian Pacific argued that:

"the purchase of grain doors in any one year cannot be related directly to the use of grain doors in that year. Consequently, a three-year period averages out variations from year to year in the purchase and in the use of grain doors."[1]

R. L. Banks and Associates presented the following data:[2]

TABLE IV—COMPARISON OF GRAIN SHIPMENTS AND GRAIN DOOR EXPENSE

Year	*Waybills at statutory rates*	*Per cent of 3 yrs.*	*Grain door expense–CPR*	*Per cent of 3 yrs.*
1958	2,400	29.6	\$ 761,808	30.1
1957	2,572	31.8	764,580	30.3
1956	3,129	38.6	1,000,347	39.6
Totals	8,101	100.0	2,526,735	100.0

SOURCE: Board of Transport Commissioners for Canada, "Waybill Analysis Carload All-Rail Traffic, 1958; CPR".

[1]Transcript of evidence, *Hearings*, January 16, 1961, Vol. 130, p. 22507.
[2]Transcript of evidence, *Hearings*, November 10, 1960, Vol. 116, p. 19227.

The data is evidence that, although grain door expense cannot be related precisely to the use of grain doors in a given year, the expenses for that year can be expected to give a better estimate for that year than will an average of that and the two preceding years. Therefore, in this report grain door expense has been taken as that for 1958.

In the case of loss and damage, the three-year average presented by Canadian Pacific was contained in Exhibit 132. This was a revision of the original estimate. In presenting this revision, the Canadian Pacific stated that the adjustment was made "to make (this) consistent with other parts of the study".[1] The Canadian Pacific also argued, "Obviously a three year average reflects better claim experience than a one year figure, because claim payments are not necessarily paid in the year in which the loss or damage was incurred."[2]

This claim could well be tested in future research by the use of a lagged time series regression analysis of, say, net ton-miles of grain against loss and damage payments: that is, to explain the loss and damage payments in a given year, the revenue ton-miles of that and successive previous years could be used as variables in a multiple regression.

The extent to which payments of claims for loss and damage are deferred until future years is the determinant of the degree to which averages over years should be used rather than the costs for a given year. It may be placing too much emphasis upon the precision of the language of the statement quoted above but, nevertheless, in this report the costs for 1958 have been used because of the language of that statement—that claim payments are not *necessarily,* rather than usually, paid in the year in which the loss or damage occurred.

In both of these cases the Canadian National used the costs for the year 1958.

10. *Expenses Allocated*

Certain accounts were allocated to grain according to the number of the relevant output units attributed to grain. This procedure assumes that the average expense is constant over any range of output units. Put another way, it assumes that the relationship between the expenditures and the output units can be represented by a straight line through the origin. In some cases there may be statistical evidence that this relationship does, in fact, exist. In other cases, the procedure is resorted to because, although the relationship cannot

[1] Exhibit 132, Canadian Pacific Railway, Revision to Results of Cost Study for Moving Grain and Grain Products at Statutory and Related Rates to Export Positions in Western Canada, Arising from Suggestions and Tests Proposed by Commission Staff, Consultants of Grain Trade and Provinces, and Canadian Pacific, p. 6.

[2] Transcript of evidence, *Hearings,* January 23, 1961, Vol. 132, p. 22508.

be demonstrated statistically, it seems reasonable to believe that the expenses will vary according to the particular output units chosen, and no more accurate representation of the relationship can be found.

For this report, the allocations performed by the railways have been accepted. Some of these allocations were challenged by other consultants. There were not, however, clear demonstrations that superior methods of allocation had been found. The choice between methods had to be made on an arbitrary basis. The railways' estimates for these accounts have been accepted essentially because this was the simplest procedure for the Commission staff. The decision to proceed on such a basis was made easier by the knowledge that the amounts involved in the choice between methods of allocation are small.

The attached lists show the methods used by the two railways to assign expenditures. The order of presentation was different in the two cases. This difference in order of presentation has been preserved. The number of cases in which a different method was used by the two railways for the same account is very small, so that the lists are almost interchangeable. Although these differences should be kept in mind, those who wish to examine the treatment of specific accounts will find the list prepared by the Canadian Pacific of greater value. Those who wish to examine the application of particular methods of analysis will find the list prepared by the Canadian National of greater value.

Exhibit No. 61

CANADIAN PACIFIC RAILWAY

GROUPING OF EXPENSE ACCOUNTS IN THE COST STUDY AND METHODS USED TO DETERMINE COST

Account Numbers	*Name*	*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 and 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

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GROUPING OF EXPENSE ACCOUNTS IN THE COST STUDY AND METHODS USED TO DETERMINE COST—*Cont.*

Account Numbers	*Name*	*Method*
Equipment Maintenance—Conc.		
326-331	Work Equipment Repairs and Depreciation	Allocated
328-331	Other Equipment Repairs and Depreciation	Not applicable
Traffic		
351, 352, 353, 354, 356, 357, 358, 359	Superintendence, Agencies, Advertising, Associations, Industrial and Immigration Bureaus, Insurance, Stationery and Other Expenses	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	Train Enginemen, Train Loco. Fuel and Power, Trainmen	Direct
397	Train Locomotive Water	Direct
398, 400	Train Enginehouse Expenses and Train Locomotive Other Supplies	Regression Analysis
402	Train 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
418	Loss and Damage—Freight	Direct
419	Loss and Damage—Baggage	Not applicable

GROUPING OF EXPENSE ACCOUNTS IN THE COST STUDY AND METHODS USED TO DETERMINE COST—*Conc.*

Account Numbers	*Name*	*Method*
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	Misc. Joint Facilities	Not applicable
General		
451, 452, 453, 454, 455, 457, 458, 460, 461-462	General Officers, Clerks and Attendants, Office Expenses, Law 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

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CANADIAN NATIONAL RAILWAYS
METHODS OF ANALYSIS[1]

Expense Accounts Analysed by Statistical Regression Methods

Road Maintenance	*Railway Expense Account Numbers*
Track and roadway	202, 208, 212, 214, 216, 218, 229, 269, 270, 271, 273, 281
Fences, snow sheds and signs	221
Station and office buildings	227
Fuel and water stations	231
Shops and enginehouses	235
Power plant systems	253
Removing snow, ice and sand	272
Superintendence and miscellaneous	201, 274, 275, 276, 277
Transportation	
Superintendence and miscellaneous	371, 374, 410, 411, 414, 415, 416, 420
Train control	249, 372, 404
Station employees and expenses	373, 376
Yardmasters and yard clerks	377
Yard locomotive enginehouse and other expenses	386, 388
Yard other expenses	389
Train locomotive other supplies and enginehouse expenses	398, 400

Direct Expenses and those Expenses to be Analysed by Special Studies

Road Maintenance	
Rail communication systems, maintenance and operation	247, 407
Road property—depreciation	266

[1] Exhibit 57, Precis of evidence of Canadian National Railways, Sect. IV and VII, Statutory and Related Rates on Grain and Grain Products in Western Canada, p. 25-28.

Direct Expenses and those Expenses to be Analysed by Special Studies—Conc.

Equipment Maintenance	*Railway Expense Account Numbers*
Diesel locomotives	311A
Freight train cars	314
Work equipment	326
Shop and power plant machinery	302
Superintendence and miscellaneous	301, 306, 329, 332, 333, 334, 335
Other equipment and machinery—depreciation	305
Rolling stock and vessels—depreciation	331
Traffic	
Total traffic expenses	351, 352, 353, 354, 356, 357, 358, 359
Transportation	
Yard trainmen and enginemen	378, 380
Yard switchmen	379
Yard locomotive fuel and power	382
Train enginemen and trainmen	392, 401
Train locomotive fuel and power	394
Train other expenses	402
Loss and damage—freight	418
General	
General officers, clerks and others	451, 452, 453, 454, 455, 458
Pensions	457
Railway Tax Accruals	
Other railway taxes	468
Others	
Joint facilities	278, 279, 336, 337, 390, 412, 413, 465, 466

Expense Accounts which are not Affected by the Movement of Western Grain Traffic or are Related to Steam Operation

	Railway Expense Account Numbers
Road Maintenance	
Grain elevators	237
Wharves	241
Other structures	265
Equipment Maintenance	
Steam locomotives	308
Other locomotives	311B
Passenger train cars	317
Vessels	323
Other equipment	328
Transportation	
Coal and ore wharves	375
Yard locomotive fuel and power	382
Yard locomotive water	385
Train locomotive water	397
Operating sleeping and parlour cars	403
Crossing protection	405
Drawbridge operation	406
Operating vessels	408
Loss and damage—baggage	419
Miscellaneous Railway Operations	
All expenses	441, 442, 443, 446, 447, 448
Equipment Rents	
All expenses	463, 464
Express, Commercial Communications and Highway Transport (rail) Operations	
All expenses	470, 471, 472, 473, 474, 475, 480, 481, 482, 483, 484, 490, 491, 492, 493, 494, 495

B. The Estimation of the Output Units

1. *Revenue Ton-Miles, Loaded Car-Miles, Number of Carloads, Loaded Car Handlings*

Both the Canadian Pacific and the Canadian National searched waybills to determine the revenue, the number of tons of the study traffic, and the number of cars of export grain which originated at each station. Field studies determined the routes over which this traffic is moved to export positions and the percentage of this traffic which travelled by each route. From the results of these studies, the mileage travelled by each carload could be determined. These mileages were then multiplied by the number of tons and cars originated to determine the number of revenue (net) ton-miles and the number of car-miles.

2. *Gross Ton-Miles, Loaded*

Gross ton-miles were found by multiplying the average tare weight of box cars used in grain service to give tare ton-miles. This was added to the net ton-miles to produce gross ton-miles. In each case the average tare weight was found by examination of the records for a sample of the cars actually used in the grain trade.

3. *Gross Ton-Miles Empty, Empty Car-Miles, Empty Car Handlings*

Each railway studied a sample of the box cars which were used in the grain trade in 1958. The movements of these cars were traced from the point at which the grain shipments originated back to the point from which they had been dispatched, empty, to receive grain. The information found by this tracing was treated in the manner described above, to develop these output units.

4. *Active Car Days*

The records on freight cars include the dates at which the cars were at various points. For their respective samples, the railways calculated the total time which the cars carrying grain were under load plus the time of related empty movement. The results of this study were then "blown up" to give a figure for the total study traffic.

To allow for the extra time which would be required for "back-shop" repairs, the Canadian National increased their total active time by a factor of 2.4 per cent. This represented the proportion of cars in the shop for repairs at a sample time. The Canadian Pacific excluded all storage and repair times.

In a revised statement (Exhibit 132), the Canadian Pacific recalculated the number of car days chargeable to the grain trade. A new method was used involving the use of calendar car days. For the box car fleet as a whole this would be simply the average number of box cars in the fleet times 365. A sample of 300 box cars was examined to find the proportion of active and idle car days. Approximately one-half of this sample was composed of cars which had been included in the original study of grain cars. The other half were cars which were drawn from the entire box car fleet. The ratio of idle car days to active car days was then applied to the active car days found by the procedure outlined above.

To take account of the fact that Canadian Pacific cars are sent to other railways, the "off-line" days of the cars in the sample of 300 were removed from consideration. This had the effect of reducing the number of days in which a car was considered to belong to the Company's fleet, from 365, by the number of days which the car was off-line. An allowance of ten per cent of the off-line days was also deducted as an allowance for idle time connected with off-line movements. In justification of this procedure, it was pointed out that the per diem rate for car-hire, which the Canadian Pacific receives, includes an allowance to cover an assumed rate of non-utilization of approximately ten per cent.

Observation of the Canadian Pacific's car service records shows no way in which one could decide whether or not off-line service causes any different amount of idle time than does on-line service. The procedure which the railway followed does assume that off-line service causes a lower amount of idle time than does on-line service. This was justified on the grounds that the railway is paid only for the days included in the ten per cent allowance and that therefore the costs which arise out of the remaining idle days which can be attributed to off-line service must be recovered from traffic carried on-line. Nobody can deny that if the per diem allowance for car rental is insufficient to cover the costs of providing the cars, the excess cost must be covered by on-line service. This, however, does not justify a procedure which attributes a cost arising out of off-line service to an on-line service. (In fact, no evidence was brought forward to indicate whether the per diem allowance was reasonable and whether it covered more or less than the ten per cent idle time allowed.)

The Canadian Pacific procedure charged 58 days idle time for each 100 days of active on-line time. Had the charge to off-line days been made consistent with that to on-line days, this would have been reduced to 44 days; that is, a reduction of almost 25 per cent in the idle days charged, or of almost 9 per cent in the days chargeable to on-line traffic would have been made.

W. B. Saunders and Company argued that the largest part of the idle time experienced by the Canadian Pacific is due to the need to hold cars in readiness for peak shipping periods. Since this need is related to loads originated rather than to the number of days the average car remains under load, it was argued that originations rather than active car days is the appropriate measure by which idle car days should be allocated. This procedure would have the unfortunate effect of placing the burden of providing cars for peak periods upon traffic which has many short trips and relieving traffic which has few long trips. To give a simple example, consider a railway which has four box cars, of which, over a thirty-day period two remain idle, one is active for thirty days carrying two loads of grain, and one is active for thirty days carrying thirty loads of newsprint. Under the Saunders' procedure the car carrying grain would have assigned to it just slightly over six per cent of the time of the two idle cars, while the car carrying newsprint would have slightly under 94 per cent assigned to it. While, under these simplified conditions, it might be argued that one of the idle cars was standing by in case of repairs to the newsprint car or in case a few extra loads were offered, it seems difficult to accept that over 90 per cent of the idle time would be due to the newsprint trade.

An alternative procedure is to admit frankly that the provision of idle time causes an overhead cost which is difficult to assign meaningfully. Costs arising from the necessity of idle time would not then be included in the variable or marginal costs of specific movements. This is the procedure followed by the Canadian National (except that that railway allowed for time in back-shop repairs).

A second method which might be applied stems from a modification of the Saunders' argument. Since the preponderant majority of idle time appears to come from the existence of idle capacity to provide for peak periods, observations might be made during the month of greatest box car utilization. Idle time for the year might then be assigned on the basis of the active car days for that month. Such a procedure would necessitate the collection of no data which the railways did not collect during the present study and would call for few additional calculations.

Both R. L. Banks and Associates and W. B. Saunders and Company asserted that, in performing their second analysis, the Canadian Pacific had calculated the number of active car days in a different way than they had calculated them in the original study. Since the results of the second study were applied to the active car days of the first study, such a procedure would obviously result in an error. The two consulting firms argued that the error was such as to increase the car days chargeable to grain. This topic was discussed at length, both verbally before the Commission staff and in correspondence. It became evident that the only way in which the question could be decided finally would be by means of a repetition, by the Commission staff, of a great deal of the second Canadian Pacific study. This, time would not allow.

Since it was impossible to make a re-evaluation of the counting methods employed by the Canadian Pacific, and since their adjustment for off-line active days had been rejected, an alternative method of estimating the number of car days attributable to grain on the Canadian Pacific had to be found. The Canadian National estimated that it required 3,547,084 car days for the transport of 5,957,631 thousand net ton-miles of grain, that is, .59538 thousand car days per ton-mile. Application of this ratio to the net ton-miles carried by the Canadian Pacific yields an estimate of 4,189,930 car days. This may be compared with the original Canadian Pacific estimate of 3,257,123 car days and their subsequent estimate of 5,073,742 car days.

Quite obviously this method of estimating costs upon the Canadian Pacific is far from satisfactory. We console ourselves with the knowledge that the absence of an allowance for back-shop repair time made the first estimate too low (although one would not expect it to be 20 per cent too low for this reason): the allocation of idle time presumably allocatable to off-line movements made the second estimate too high. A better estimate should lie between these extremes. Further, it is not unbelievable that conditions and technical ability on the two railroads would lead to the need for a similar number of available cars per ton-mile of transportation supplied for the same commodity.

5. *Train-Miles*

In order to compute train-miles the railways first estimated the number of trains which would be required to carry grain on each train-run. To do this they made adjustments to the gross weight of grain cars and trains to allow for the fact that the tractive effort to pull an empty car, compared to a loaded car, is greater than a simple comparison of their gross weights would indicate. The weights of trains and grain shipments were, therefore, measured in equivalent gross tons (Canadian Pacific) or equated gross tons (Canadian National). These two terms merely indicate that the two railways follow different formulae to allow for the different tractive efforts required with different weights of loading. In the remainder of this section weight will mean equivalent or equated weight unless otherwise stated.

The Canadian Pacific estimated the number of trains by multiplying the average weight of train, by train-run by direction, by the proportion which the weight of grain was to total traffic for that train-run.

The Canadian National estimated the number of trains on way-freight runs by multiplying the number of trains on each run by the ratio of the number of grain carloads originated to the total number of carloads originated. For through train-runs, the Canadian National divided the total weight of grain shipments by the average weight for the run.

The methods employed by the railways assume that trains are infinitely divisible, that is, that if there is sufficient traffic for two trains per week and the available traffic is halved, one train per week will be run. If the available traffic is again halved one-half train per week (one train every two weeks) will be run, and so forth. The Canadian Pacific defended this assertion through an examination of the flexibility of way-freight scheduling, and a check of the average weights of way-freights on runs varying from service of four or more trains per week to service as and when required. The results of this examination persuaded them that there is a rough constancy in the trailing weights of way-freights.[1]

As a further check upon this assumption, the Commission staff performed a regression analysis of the relationship between freight gross ton-miles (but not equivalent gross ton-miles) per division and freight train-miles per division. Three-year averages (1956-1958) for the Canadian Pacific were used for the 28 divisions for which these data are available. If train-miles per division are not directly proportional to gross ton-miles, this may be due to the fact that if a line is in existence there will be pressure upon the railway company to provide a minimum frequency of service. There will, therefore, be a tendency of those divisions which have light density to have relatively more train-miles per division than those which have heavy density. (The higher the density per mile of road, the greater will be the opportunity to make up full-tonnage trains without seriously lessening the speed of service.) To test this hypothesis, miles of road were inserted as an explanatory variable. The resulting equation was:

$$\begin{aligned} \text{Train-miles} = {} & 228{,}380 \\ & +.34637 \text{ gross ton-miles ('000)} \qquad (t=20) \\ & +171.33 \text{ miles of road} \qquad (19) \\ R^2 = {} & .945 \end{aligned}$$

For the system as a whole, for this period, there was, on the average, one train-mile for each 2,000 gross ton-miles. Yet this regression indicates that train-miles are added or subtracted with changes of traffic volume at the rate of one train-mile for each 2,900 gross ton-miles. It appears that the assumption of complete divisibility of trains overstates the marginal cost of traffic. (In this case, the constant appears to be a reflection of the inability of a linear model to follow a curved function which would go through the origin. See Figure 5 which shows the train-miles, after adjustment for miles of road, plotted against gross ton-miles.)

A better test of the relationship between train-miles and gross ton-miles would utilize the records of equivalent or equated gross ton-miles. Further, data are available which could be adapted to test this relationship,

[1] Transcript of evidence, *Hearings*, May 11, 1960, Vol. 117, p. 11905.

not only on a divisional basis but also upon a train-run basis both by direction and without regard to direction. Such a test might shed valuable light not only upon this problem but also, as a corollary, upon the problems of the railways in maintaining light-density lines.

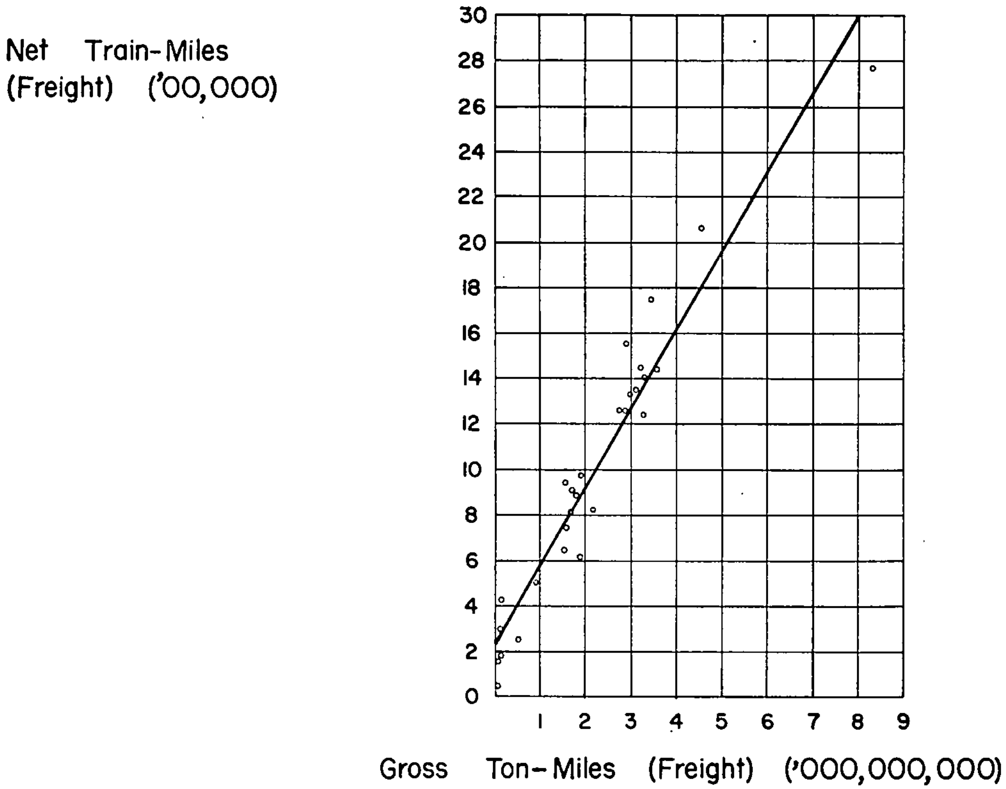

FIGURE 5: Relationship between Train-miles (freight) and Gross ton-miles (freight) for Canadian Pacific Railway after allowance for the effect of miles of Road.

It was argued by the consultants who appeared on behalf of the Provinces of Alberta and Manitoba and of the grain organizations, that grain is carried on heavier trains than other traffic, and that, therefore, grain requires fewer trains than other traffic in relation to the equivalent gross ton-miles carried.

W. B. Saunders and Co. analysed the contents and weight of 119 trains studied by the Canadian Pacific, in three sample periods totalling 23 days, on the Winnipeg-Fort William run. Their conclusions follow.

> "The average weight of all trains in the study was 4,302 equivalent gross tons. This is the equivalent of the train weight that CPR imputed to eastbound grain loads on this train run in 1958. The total weight of non-grain traffic, including empty cars, was 274 thousand equivalent gross tons. On a prorata basis, train for train, this traffic was assigned 73.4 trains, which produces an average weight of 3,733 equivalent gross tons, or 13 per cent less than the average. In contrast, the 238 thousand equivalent gross tons of grain, accounting for the remaining 45.6 trains, averaged 5,219 equivalent gross tons per train, 21 per cent more than the average. This is the train tonnage properly assignable to grain on this train run, and suggests that, if the study period is representative of 1958, the CPR overstated eastbound train miles by 21 per cent. It should be noted that the Kenora division, of which the portion from Winnipeg to Fort William is overwhelmingly the most important part, accounted for 33 per cent of the total grain study gross ton-miles.
>
> "The above study exposes the fallacy of the assumption that because many, if not most, trains carry some grain, an average train weight is proper. It showed that 89 of the 119 trains carried some grain. For 47, grain made up less than half of their consist. These trains averaged 3,684 equivalent gross tons. The other 42 trains had more than 50 per cent grain, and averaged 5,406 equivalent gross tons. The higher the proportion of grain, the heavier the train, seems to be a good generalization. The latter group of trains, in fact, while fewer than half the total trains, carried 85 per cent of the grain!"[1]

In order to compensate for this overstatement, R. L. Banks and Associates estimated the train-miles which would have been required if all grain moved in full-tonnage trains between Alyth, Alberta, and Vancouver and between Moose Jaw and the Lakehead. After computing the train-miles which would be required in the loaded direction, they assumed that an equal *saving* in train-miles could be made in the opposite direction. Since the Canadian Pacific had estimated the train-miles required in the empty direction separately, the Banks' estimates probably under-estimate the train-miles required. This error will be more or less compensated by conservative elements in their calculations, in particular that no new estimates were made for main-line traffic from Moose Jaw to Alyth, and that they assumed that all trains were hauled by 1600-1800 H.P. diesel units and ignored the possibility that the Canadian Pacific might employ their 2400 H.P. units on these runs. The Banks' amendments are therefore accepted as fair revisions.

The Canadian National method of attributing way-freight miles to cars rather than to ton-miles appears to have considerable merit. If one thinks of a way-freight which has a run of thirty miles and which collects thirty cars, each of fifty gross tons, one each from points one mile apart, some 23,250 gross ton-miles will have been generated of which 1,500 or

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[1] Transcript of evidence, *Hearings*, November 11, 1960, Vol. 117, p. 19509-19510.

about 6½ per cent will have been generated by the last car. Since, in fact, carrying the furthest car caused an extension of only one mile in the train's run, slightly over 3 per cent would appear to be a fairer charge. To take another case, if those cars which are heavily laden happen to be carried a shorter distance than those which are lightly laden, the heavier cars could be charged more than the lighter even though they cannot call for the train to travel as many miles. These are, of course, simple examples which leave most of the complications of actual way-freight operations out of the picture. They do, however, lend support to the view that since the function of way-freight operations is to collect and distribute cars, the train-miles generated in these operations might better be allocated over the cars handled rather than over the weight and distance travelled by these cars.

6. *Yard and Train Switching-Miles*

Each of the railways conducted field studies at representative yards to determine the switching time necessary for the grain traffic. The yards studied account for 74 per cent of the western terminal operations in the case of the Canadian Pacific and 83 per cent in the case of the Canadian National.

Argument on the switching studies centred about the desirability of making an allowance for the tendency of grain to move in strings of cars which require less switching than traffic generally, and the allowance to be made for switching under the difficult conditions of the winter months.

The Canadian National made no allowance for the fact that grain moves in multiple car lots but argued that as they had made no allowance for winter conditions, the error in one direction was compensated by an error in the other.

The Canadian Pacific argued that the savings from multiple car cuts are quite small, and that in any event traffic generally does not have a significantly smaller number of cars per cut than does the grain traffic.

The Canadian Pacific argument that there is little effect on costs was contained in the following paragraphs:[1]

> "An analysis of the operations performed in classification yards shows that the elements of classification should be broken down into six categories. In only one of these elements of classification, that is in the "Kick Cut to Clear", is there any operating reason to believe that size of cut would influence classification time. Most of the elements are simply a function of handling a train or of moving an engine for work which must be done to an entire train. The elements are as follows:
>
> (a) *Light Movement*
>
> This element of classification involves the movement of the light engine in preparation to begin work or after the completion of an assignment. The light movement is not related to the size of the cut

[1] Transcript of evidence, *Hearings*, January 23, 1961, Vol. 132, p. 22583-22587.

since the distance that the engine must travel depends entirely on the point from which it starts and the distance it must travel before coupling on to the string of cars to be handled.

(b) *Bleed Cars*
This element entails the releasing of air from the brake cylinders of cars to be handled. The time required depends entirely on the number of cars in the string of cars to be handled. The size of cuts in the string has no bearing on the time required for performing this element. Bleeding is accomplished by the yardman walking alongside the string of cars and pulling a lever on each car which releases the air from the brake cylinder.

(c) *Initial Pull to Classify*
This element consists of pulling a string of cars from the point where they were to the point from which switching will commence. The time required to perform this function is related to the distance the cars must be pulled as well as the number of cars in the string of cars. It has no relationship to the number of cars in the individual cuts in the string.

(d) *Kick Cut to Clear*
This element involves the actual kicking of the cars from the string of cars and permitting them to roll freely to their destination. The time required for this element of classification is that time elapsing from the time the signal is given to the engineman to kick the car until the car has cleared the fouling point of the lead or the engine is given the subsequent signal to move. It is in this type of switching movement where size of cut might affect classification time.

(e) *Trim Ladder Tracks*
This element of classification involves the shoving of cars into their respective tracks when they have stopped on the lead track, or fouled on the lead track, or when they have not entered the track sufficient distance to permit following cars to be placed in the track clear of the lead. This element of classification is not related to the number of cars in the cuts.

(f) *Walk and Couple Tracks*
This element involves the coupling of cars in tracks. Since the yardman is required to walk the entire distance of the track if all the cars on that track are to be coupled up, the number of cars in cuts will not affect the distance required for him to walk. The presence of automatic couplers on freight cars results in cars automatically coupling when they are kicked into tracks in almost all cases. The time to adjust couplers which did not automatically operate is not the effective time element.

"Thus in examining the six elements into which classification switching may be segregated, in only one of these elements, the "kick cut to clear" element, can classification time be affected by size of cut.

"As the only measurable influence of multiple car cuts on classification time is in the element "kick cut to clear", Canadian Pacific used the results of an exhaustive study in a flat switching classification area in Winnipeg terminals, in which trained yard analysts have timed the work which is involved in the "kick cut to clear" element of classification. The relative importance of the kick cut to clear element in classification time was also determined.

"The percentage of total classification time of the six elements of classification time in the study area was found to be as follows:

(1) Light Movement	7.30%
(2) Bleed Cars	0.02%
(3) Initial Pull to Classify	38.38%
(4) Kick Cut to Clear	26.73%
(5) Trim Ladder Tracks	6.33%
(6) Walk and Couple Tracks	21.24%
Total	100.00%"

From this argument, the Canadian Pacific concluded that only 26.73 per cent of classification time is affected by multiple cuts.

In discussions with consultants who appeared before the Commission, and with others who have knowledge of switching operations, the Commission staff discovered that the following arguments can be raised.

(a) *Light Movement*
When there are a larger number of cars in each cut, there will be a tendency to move larger strings of cars. While each light movement will be of the same length, there will be fewer movements. Therefore, with larger cuts there will be less light movement.

(b) *Bleed Cars*
No arguments were advanced to support the idea of savings in the time to perform this element.

(c) *Initial Pull to Classify*
Savings in this element can arise for reasons similar to those of light movement—there will be fewer trips with larger cuts.

(d) *Kick Cut to Clear*
It is agreed that there are savings in this element.

(e) *Trim Ladder Tracks*
The kick necessary to have cars clear the lead track depends upon several factors. Some of these are the weight of load in the car, the type of car and the weather conditions. Cars will be left on the lead track, or will be insufficiently far down their own track if the combined effect of these factors is misjudged. With larger cuts, there will be fewer cuts for the same size of train. There will therefore be less chance of needing the ladder tracks trimmed because of misjudgement. Thus there can be a saving in this element with multiple car cuts.

(f) *Walk and Couple Tracks*
When a yardman does have to couple cars which have not coupled automatically, the job can be very time-consuming. Again, with larger cuts there will be fewer cuts for trains of the same size and, therefore, less need of that part of this job which can vary.

Thus, it can be argued that 99.98 per cent of classification work is susceptible to savings because of larger cuts.

R. L. Banks and Associates attempted, with the data which was made available to them, to evaluate the savings which could be expected because of larger cuts in grain service than on average service. Although they admitted that this data did not allow them to present estimates which were as accurate as they would prefer, it is true that their estimates are the only ones which were presented to the Commission which have an empirical base for the switching function as a whole.

The Banks' organization quoted results of Mr. W. B. Wright who studied a flat yard of the Chesapeake and Ohio Railway. In Table V, the first three columns are from that evidence, the last two columns are from Canadian Pacific evidence, and refer only to the "Kick Cut to Clear" element.

TABLE V—FLAT YARD SWITCHING DIRECT YARD ENGINE MINUTES PER CAR

	Wright			Canadian Pacific	
Number of cars per cut	*Wright scale engine minutes*[1] *per cut*	*Average engine minutes per car*[1]	*Average engine minutes per car as % of single car switch*	*Average classification time per car*[2]	*Average classification time per car as % of single car switch*
1	3.16646	3.1665	100.00	.68	100
2	3.45606	1.7280	54.57	.37	56
3	3.74566	1.2485	39.43	.28	41
4	4.03526	1.0088	31.86	.25	36
5	4.32486	0.8650	27.32	.21	31
6	4.61446	0.7691	24.29	.19	28
7	4.90406	0.7006	22.13	.19	28
8	5.19366	0.6492	20.50	.17	25
9	5.48326	0.6092	19.24	.16	23
10	5.77286	0.5773	18.23	.14	21

[1]Transcript of evidence, *Hearings*, November 10, 1960, Vol. 116, p. 19157.
[2]Transcript of evidence, *Hearings*, January 23, 1961, Vol. 132, p. 22587.

The Banks' organization applied the percentage savings to Canadian Pacific data. It is clear that for at least one element, that of "kicking to clear", the Wright scale does in fact approximate Canadian Pacific experience.

For hump yards, a scale developed by Mr. E. C. Poole of the Southern Pacific was adopted by the Banks' organization.

It is now generally recognized that multiple car shipments do result in savings in switching time. For example, in deciding a recent case (though one in which much larger cuts were involved), the Interstate Commerce Commission recently remarked, ". . . the protestants' assigned cost ignores the movement of this traffic in multiple-car shipments, and obviously results

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in an overstatement."[1] Since the Banks' estimates appear reasonable, and since there is not other empirical evidence on the costs of the entire switching function, these estimates have been accepted here.

In their revised estimates of Exhibit 132, the Canadian Pacific included an increased estimate of yard switching miles to reflect the fact that some grain shipments are switched under the more difficult conditions of winter. In making this adjustment, the fact that the Kenora yards were under winter conditions, at the time when they were studied, was overlooked. A small readjustment therefore had to be made.

C. Some General Problems

1. *The Adjustment Factor*

The railways worked, as far as possible, with accounts at the divisional level. Some expenditures are made and accounted for at district or system levels. In addition certain credits, for example for salvage, are made at district or system levels. In order to balance their estimates with the total system expenditures, the ratio of total expenses for the system to expenditures accounted for at the division level, was applied to the estimates for expenditures at the divisional level.

This procedure assumes that expenditures, or credits, which are accounted for at district or system levels will vary in the same fashion as do expenditures, or credits, which are accounted for at the divisional level. In most cases the adjustment factor was relatively small, so that any inaccuracies which might result in the use of these adjustment factors would be relatively small. In the case of the superintendence and overhead accounts, however, the adjustment was quite large. In addition, the nature of the system and district accounts for superintendence suggest that the amounts involved will tend to vary less slowly at district and system levels than at divisional levels, with given changes of traffic. In these cases, then, there may be some overstatement of the marginal cost.

2. *Depreciation*

Certain depreciation accounts are carried only at the system level. The Canadian Pacific distributed these accounts over divisions by prorating the depreciation according to gross investment in the division. The amounts so

[1] Interstate Commerce Commission, Investigation and Suspension Docket No. 7256, Limestone in Trainloads—Prairie du Rocher, Ill., to Baton Rouge, La., December 22, 1960, p. 19.

prorated were then added to the divisional expenditures as recorded in the operating expenses. As the Canadian National does not have investment recorded at the divisional level, it found it necessary to prorate according to expenditures in the operating accounts, and the ratio of depreciation to operating expenditures was applied to the results of the estimation procedure based upon the divisional accounts.

Quite obviously the railways adopted these procedures because of the limitations of the accounts which they have inherited from years past when different problems were faced. It is well, then, that we should emphasize that criticism of the methods employed does not constitute criticism of the analysts who were forced to adopt these methods.

Proration of depreciation by gross investment is apt to penalize those divisions which are older, for these divisions are apt to have a greater proportion of their gross investment fully depreciated. They will, however, be charged with depreciation on the investment which no longer exists.

Proration of depreciation by expenditure on operating account is apt to have an error of another kind. To the extent which investment has taken place in labour saving devices, this method of proration will place the burden of depreciation on those divisions which have less investment, but a greater labour cost, and relieve those divisions which have more investment, but less labour cost.

As far as the Canadian National is concerned, there appears to be no solution to this difficulty until such a time as investment may be accounted for by divisions. The only alternative course of action would be to treat depreciation as a constant cost. Most people seem to feel that investment, and therefore depreciation, is controlled by the same factors as control operating expenditures. The Canadian Pacific regression model for investment in road property gives support to this view. The method adopted by the Canadian National appears to be preferable to treating depreciation as constant cost.

The Canadian Pacific method of prorating depreciation according to investment leads, as we have noted, to certain difficulties. These could be avoided by prorating on a basis of net investment. Inaccuracies would still remain, since different kinds of property carry different depreciation rates, and since these different kinds of property are unlikely to be present in the same proportions in every division. When these prorated values of depreciation are added to the values of the operating expenses, the inaccuracies of proration cause "errors of observation". These will tend to cloud what might otherwise be clearer relationships. It is therefore recommended that in future analysis attempts be made to secure relationships for operating expenditures and depreciation separately. It is to be hoped that the former will be stronger than any which have so far been developed for the

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respective categories of expense.[1] That the relationship will be lower for depreciation may be expected because of the difficulties with the prior proration. Different specifications of the two models may increase the combined validity of the explanatory models.

3. *The Grouping of Accounts and Specification of Models*

Certain accounts were grouped differently by the Canadian Pacific and Canadian National, and for certain groups of accounts different explanatory variables were specified. Since the technology of the two railroads, the climatic and geographical conditions under which they operate and their extent all appear to be roughly similar, it seems that this difference may be (a) because of differing views of the cost analysts, (b) because less than the best grouping was used by one group or both, or (c) because the nature of the available figures makes it impossible for one or other groups to act in any other way. In some cases, the first possibility was true. In some, the third was true. Whether the second possibility was true, only further research can demonstrate.

To aid in examining this question it is suggested that an examination of the data for each railway be made, using the methods of factor analysis, as, for example, centroid analysis or the method of principal components.[2] These are statistical methods of demonstrating which, and to what extent, different variables form groups. In addition they enable the creation of new and, if desired, independent composite variables, with a known relationship to the original variables. Among the more important insights into cost relations which might be gained from such an analysis is the degree, if any, to which categories of cost, removed from each other in the Standard Classification of Accounts, vary together.

In the following schedules, the estimates of variable cost for the Canadian Pacific are presented with the modifications discussed in this chapter. Considerations governing constant cost and the cost of money are discussed in the following chapters. In the case of the Canadian National, for reasons given earlier, no modifications have been made in variable cost. It is recommended, however, that future cost presentations of the Canadian National be modified in the same fashion, when those modifications apply to the estimates of that railway.

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[1] During discussions with W. B. Saunders and Co. regarding their models for track maintenance expense, this experiment was tried. The strength of the relationships, as measured by R^2 was in the expected direction. Certain other difficulties which emerged with the explanatory equations for depreciation may have been due in part to the difficulties discussed here, or may have been due to the fact that the specifications of the models examined were suitable for the operating accounts but were less so for the depreciation account.

[2] Cf. Meyer, J. R., and Kraft, G.: *The Evaluation of Statistical Costing Techniques as Applied in the Transportation Industry,* American Economic Review, Vol. LI, No. 2, May 1960, p. 327-333.

TABLE VI-a—CANADIAN PACIFIC RAILWAY
MARGINAL ROAD MAINTENANCE EXPENSE APPLICABLE TO THE STUDY TRAFFIC

	Account	Group of accounts	Independent variable	Unadjusted coefficient or unit cost	Adjustment factor	Adjusted coefficient or unit cost	Output unit of study traffic	Applicable to study traffic
1	201	Road Maintenance Superintendence	Gross Ton-Miles	$0.0064720	1.59587	$0.01033	12,233,795	$ 126,375
2	274	and Overhead	('000)					
3	276		Yard and Train					
4	277		Switching Miles	$0.052843	1.59587	$0.08433	844,556	71,221
5	202	Track Maintenance and	Gross Ton-Miles			See text and		
6	208	Depreciation	('000)	←		following note 1.	→	$ 2,211,685
7	212							
8	214		Yard and Train					
9	216		Switching Miles	$0.69143	1.01430	$0.70132	844,556	$ 592,304
10	218							
11	229							
12	266							
13	269							
14	271							
15	273							
16	281							
17	227	Station and Office Buildings	Carloads	$1.33237	1.06861	$1.42378	175,203	$ 249,451
18	266	Maintenance and Depreciation						
19	231	Water and Fuel Stations	$ of Fuel Expense	$0.01070	1.00285	$0.01073	2,464,262	[2]$ 26,441
20	266	Maintenance and Depreciation	$ of Water Expense	$0.45140	1.00285	$0.45269	60,496	[2]$ 27,384
21	235	Shops and Enginehouses	Yard and Train	$0.22343	1.31299	$0.29336	844,556	$ 247,759
22	266	Maintenance and Depreciation	Switching Miles					
23	249	Signals Maintenance and	Train-Miles	$0.04772	1.06483	$0.05081	2,538,683	$ 128,990
24	266	Depreciation	Main Line					
25	253	Power Plants Maintenance and	$ of Station	$0.01546	1.23230	$0.01905	885,043	$ 16,860
26	266	Depreciation	Employees					
27	275	Insurance and Joint	$ of Road Maintenance	$0.01060	1.00000	$0.01060	3,698,470	$ 39,203
28	278	Facilities						
29	279							
30								$ 3,737,673

[1]Since the relationship between gross ton-miles and expenditures is not linear, a simple multiplication will not yield the marginal cost. For each "grain-division" the expenditures attributable to the number of gross ton-miles carried by the division, less the gross ton-miles of grain, was subtracted from the expenditures attributable to the number of gross ton-miles of grain, including the gross ton-miles of grain. The resulting marginal cost was then multiplied by the adjustment factor to yield an estimate of the marginal cost of transporting grain. A minor (it is believed) inaccuracy results from the fact that total gross ton-miles were estimated as the three-year average. This means that the starting point along the cost curve was in error by the difference between the actual 1958 total gross ton-miles and the three-year average gross ton-miles.

[2]Since the explanation of this account was based on fuel and water expense, and since these, in turn, were estimated on locomotive miles or on an apportionment of these by train-run, an adjustment in the output units of study traffic was required when the basic estimates were adjusted.

TABLE VI-b—CANADIAN PACIFIC RAILWAY

MARGINAL EQUIPMENT MAINTENANCE EXPENSE APPLICABLE TO THE STUDY TRAFFIC

	Account	Group of accounts	Independent variable	Unadjusted coefficient or unit cost	Adjustment factor	Adjusted coefficient or unit cost	Output unit of study traffic	Applicable to study traffic
1	301	Equipment Mtce	$ of Direct Equip.	$ 0.04990	2.00526	$ 0.10006		
2	302	Suptce and Overhead	Mtce, Excl. Deprec.				6,378,694	$ 638,252
3	305							
4	306							
5	329							
6	332							
7	333							
8	334							
9	335							
10	336							
11	337							
12	308	Road Locomotive	Train-Miles	0.39718	—	0.39718	3,513,951	$ 1,395,671
13	311	Repairs	Train Swg. Miles	0.34653	—	0.34653	244,029	84,563
14		Yard Locomotive	Yard Loco-Miles	0.20762	—	0.20762	600,527	124,681
15		Repairs						1,604,915
16	314	Freight Train	Car-Miles	0.01712	—	0.01712	213,831,793	3,660,800
17		Car Repairs	Car Days	0.25363	—	0.25363	4,189,930	1,062,692
18								4,723,492
19	326	Work Equipment	$ of Road Maintenance	0.01352	—	0.01352	3,737,673	50,533
20		Repairs	Expense					
21	331	Road Locomotive	Train-Miles	0.16496	—	0.16496	3,513,951	579,661
22		Depreciation	Train Swg. Miles	0.26799	—	0.26799	244,029	65,397
23		Yard Locomotive	Yard Swg. Miles	0.14384	—	0.14384	600,527	86,380
24		Depreciation						731,438
25	331	Freight Train Car	Car-Miles	0.00427	—	0.00427	213,831,793	913,062
26		Depreciation	Car Days	0.22957	—	0.22957	4,189,930	961,882
27								1,874,944
28	331	Work Equipment Deprec.	$ of Road Mtce Ex.	0.00437	—	0.00437	3,737,673	$ 16,334
29								
30								9,639,908

TABLE VI-c—CANADIAN PACIFIC RAILWAY
MARGINAL TRANSPORTATION EXPENSE APPLICABLE TO THE STUDY TRAFFIC

	Account	*Group of accounts*	*Independent variable*	*Unadjusted coefficient or unit cost*	*Adjustment factor*	*Adjusted coefficient or unit cost*	*Suptce*	*Total coefficient or unit cost*	*Output units of study traffic*	*Applicable to study traffic*
1 2 3 4 5 6 7	371 374 410 411 415 416 420	Transportation Superintendence and Overhead	$ of Transportation Expense	$0.02442	1.79756	$0.04390				
8 9 10	372 373 376	Dispatching and Station Employees and Expenses	Carload	$5.61490	10.1101	$5.67672	$0.24649	$5.92321	175,203	$1,037,764
11	377	Yardmasters and Clerks	Yd. Switching Miles	$0.46992	1.09439	$0.51428	$0.02063	$0.53491	600,527	$ 321,228
12 13 14 15 16 17	378 379 380 382 385 389	Yard Expenses	Yd. Switching Miles	$2.37435	1.00498	$2.38617	$0.10423	$2.49040	600,527	$ 1,495,552
18	386–388	Yard Other Expenses	Yd. Switching Miles	$0.14389	1.01193	$0.14561	$0.00632	$0.15193	600,527	$ 91,238
19 20	392 394	Train Enginemen, Train Loco. Fuel and Power, Trainmen	Direct[1]							$ 5,019,463
21	401	Train Switching	Direct[1]							$ 225,931
22 23	398 400	Train Enginehouse Expenses & Train Loco. Other Supplies	Locomotive-Miles[2]	$0.17221	1.02378	$0.17631	$0.00774	$0.18405	4,358,507	$ 802,183
24	397	Train Locomotive Water	Locomotive-Miles	$0.01331	0.99913	$0.01330	$0.00058	$0.01388	4,358,507	$ 60,496

TABLE VI-c—CANADIAN PACIFIC RAILWAY

MARGINAL TRANSPORTATION EXPENSE APPLICABLE TO THE STUDY TRAFFIC (*Conc.*)

	Account	*Group of accounts*	*Independent variable*	*Unadjusted coefficient or unit cost*	*Adjustment factor*	*Adjusted coefficient or unit cost*	*Suptce*	*Total coefficient or unit cost*	*Output units of study traffic*	*Applicable to study traffic*
25 26	402	Train Other Expenses	Car-Miles Grain Doors	$0.00382			$0.00017	$0.00399	213,831,793	$ 853,189 681,198
27			Train-Miles	$0.09093			$0.00399	$0.09492	3,513,951	$ 333,564
28	404	Signals Operation	Train-Miles (Main Line)	$0.01146	1.06483	$0.01220	$0.00050	$0.01270	2,538,683	$ 32,241
29 30	390–391 412, 413, 414	Joint Facilities & Insurance	$ of Transportation Expenses	$0.01206	1.00000	$0.01206	$0.00053	$0.01259	11,261,534	$ 141,783
31	418	Loss & Damage—Freight	Direct							$ 307,487
										$11,403,317

[1]The Canadian Pacific estimate has been revised in accordance with the revision of locomotive-miles.

[2]Regression analysis indicated separate coefficients for steam and diesel locomotive-miles. A weighted coefficient was calculated based on the relative number of locomotive-miles for steam and diesel on the Prairie and Pacific Region in 1958.

TABLE VI-d—CANADIAN PACIFIC RAILWAY

ALLOCATION OF TRAFFIC AND GENERAL, COMMUNICATIONS—RAIL, AND TAX (OTHER THAN INCOME TAX) EXPENSE TO MARGINAL COST OF STUDY TRAFFIC

A. Percentage Relationships that Traffic and General, Communications—Rail, Rents and Taxes (other than Income Taxes) is to Total Freight Operating Expense—Year 1958

Traffic and general	12.423%
Communications—rail	1.965%
Rents and taxes	2.819%
Total	17.207%

B. Base Relationship—Variable Cost Study Traffic

Roadway maintenance—marginal	$ 3,737,673
Equipment maintenance—marginal	9,639,908
Transportation—marginal	11,403,317
	$24,780,898

C. Applicable to Study Traffic

Traffic and general	12.423%	$ 3,078,531
Communications—Rail	1.965%	486,945
Rents and taxes	2.819%	698,574
Total	17.207%	$ 4,264,050

TABLE VI-e—CANADIAN PACIFIC RAILWAY

SUMMARY OF ESTIMATED MARGINAL COST OF STUDY TRAFFIC

Roadway maintenance	$ 3,737,673
Equipment maintenance	9,639,908
Transportation	11,403,317
Traffic and general	3,078,531
Communications—rail	486,945
Rents and taxes	698,574
Total	$29,044,948

Chapter 5

The Constant Cost of the Grain Traffic

In Chapter 2 we noted the possibility that some of the costs of railway transportation are fixed. When fixed costs are present, the sum of the marginal costs of all movements will almost never be equal to the total cost. For example, if we are studying the cost of a certain train of ten cars, if the marginal costs of the tenth car is calculated, and if it is applied to each of the ten cars in turn, the sum of these ten marginal costs will seldom equal the total cost. If the average cost can be represented as a curve of the type presented in Chapter 2, Figure 6*b*, that is as falling as output increases from zero to some point and then increasing, the marginal cost will be less than the average cost at outputs between zero and the output of minimum average cost. At outputs greater than that of minimum average cost, the marginal cost will be higher than the average cost.

In Chapter 2 we noted that for individual movements the marginal cost is the bench mark against which the traffic's worth to the railway should be measured. If the output of the railway is such that it (the railway) is operating in that range where average cost is increasing, pricing all movements at the marginal cost will result in profitable operation since all movements will be carried at more than the average cost. If, however, the railway is operating in the range of declining average costs, pricing all movements at the marginal cost will result in losses, since all will be carried at rates below the average cost.

The necessity (if privately owned), or desirability (if publicly owned) of operating a railway in such a manner that it returns at least a normal profit, has led some to believe that railways should base their rates upon average or "fully-distributed" cost. (It is usually assumed that railways are operating in the range of declining costs. Such evidence as we have indicates that this is true for the Canadian railways.) Dr. Ford K. Edwards illustrated this type of pressure. Fortunately the sense of his remarks comes through despite some obvious difficulties in the transcript.

> "One of the reasons I have laboured as hard as I have on the subject of interpreting the fully developed [distributed?] costs is that one of the first studies that came from the ICC on grain was taken by a great many persons who said: 'Now we have no problem on rate-making. Here are the full costs. You don't need your costs of the value of service.' I was immediately thrown on the defensive by the efforts of a great many parties to use them as a guide.

> "Three or four years ago, even the Presidential Advisory Committee on Transportation came out with a statement—with the proposal—that the ICC should have no authority to set rates below fully distributed costs, which is an astonishing thing and got nowhere; but at least it offered this proposal."[1]

Although these pressures are easily understood, they are based on an argument which neglects a very important difficulty. If one considers a railroad which carries only one commodity between one point of origin and one destination, the average cost per ton moved is obviously the total cost divided by the number of tons moved. Similarly the average cost per ton-mile is the total cost divided by the number of ton-miles. There is no need to worry over which definition of average cost is used, as long as revenue on a tonnage basis is a given percentage of cost on a tonnage basis it will hold the same relationship to cost on a ton-mile basis. However, as soon as the situation is complicated by the addition of a second commodity, point of origin or destination, the idea of average cost becomes more difficult, although the mechanical procedure remains the same. The cost can be fully-distributed over the traffic by any of a number of methods. Since the fixed cost is a cost of being in business, it is not attached in any meaningful way to any of the measures by which it may be divided.

Some of the difficulties in choosing a method of distributing these costs were recently given by Mr. Samuel A. Towne, Chief, Cost Finding Section, Bureau of Accounts, Interstate Commerce Commission, who gave five methods of dealing with fixed costs.

> "First, they may be determined as a lump sum. This is of little help to the rate-maker or rate judge because it only shows that [what?] they are in the aggregate.
>
> "Second, they may be added to the out-of-pocket costs on the basis of a dollar distribution. This results in the higher cost traffic being assigned a relatively greater proportion of the constant costs than the lower cost traffic. The fully distributed costs thus obtained give no consideration to demand or non-cost factors, such as competition among modes of transportation, among markets, among commodities, and the value of commodity, social considerations, or any other factors which have played a part in rate-making in the past.
>
> "Third, there are those who raise the question, Why is it not proper to distribute the constant costs on a car and car-mile basis? It has been considered, but we find that, if such a method were used, the light-loading traffic would be asked to share a greater proportion of the total constant costs than the heavy-loading traffic. There is no convincing evidence to indicate that the light-loading traffic can assume this burden.
>
> "Fourth, the revenue dollar has been suggested as a method of distributing the constant costs. Such a procedure introduces revenue into the picture and makes it impossible to establish a standard for measuring rates without the influence of the factor that is being judged. This is wholly undesirable.

[1] Transcript of evidence, *Hearings,* May 30, 1960, Vol. 71, p. 12640.

"Fifth, constant costs should be recovered from kinds and classes of traffic based upon their respective abilities to 'bear burden'. This is a characteristic for which there has been little or no measurement data developed. . . . Since this field is almost totally unexplored, we have resorted to a uniform pro-rata apportionment per revenue ton and ton-mile of all carload traffic without distinction whatsoever. Obviously, full costs containing constant costs of this nature cannot serve as a guide to what a rate ought to be but rather they (full costs) become a reference point or norm which measures only differences in direct costs, while ignoring value-of-service measures".[1]

The lack of objective standards by which to choose between differing methods of distributing the fixed cost leads to difficulties illustrated by the hypothetical example of Tables I and II. Table I presents a simplified set of cost and revenue relationships for three movements. Table II shows the variable cost plus the fixed cost distributed according to three different methods.

TABLE I—HYPOTHETICAL EXAMPLE OF COSTS AND REVENUES

	Gross ton-miles of traffic	*Variable cost*	*Revenue*
Commodity A	100	$100	$150
Commodity B	200	250	500
Commodity C	300	275	500
Total	600	$625	$1,150
Fixed Cost	$500	Total Cost $1,125	

[1] Towne, S. A.: *Cost Evaluation and Cost Criteria* in Economic Costing of Railroad Operations, Chicago, Railway Systems and Management Association, 1960, p. 59-60.

Cf. Bonbright, James C.: *Fully Distributed Costs in Utility Rate Making* in American Economic Review, Vol. LI, No. 2, May 1961, p. 306:

". . . the question at issue concerns the economic significance of the apportioned total costs, not the weight to be given to a specific cost that must be covered unless the service is to be supplied at an outright loss.

"Mindful, perhaps, of the absence of any convincing answer to this fundamental question and mindful, also, of the notorious disagreements among the experts as to the most rational method of overhead-cost allocation—disagreements which defy resolution in default of any accepted objective standard of rationality—most state commissions have not made full-cost apportionments mandatory as a prelude to a decision on rate structure. Thus, in 1953 and again in 1957, when the Commonwealth Edison Company of Chicago filed an application for a general rate increase, the Illinois Commerce Commission declined to order such an apportionment despite the request of intervenors that the Company be required to submit one. In partial support of its refusal, the Commission referred to an exhibit, introduced by one of the Company officials, disclosing the existence of twenty-nine rival formulas for the allocation of capacity costs alone—formulas each of which had received some professional sponsorship."

TABLE II—FULLY-DISTRIBUTED COSTS OF HYPOTHETICAL EXAMPLE

	Costs Distributing According to		
	Gross ton-miles	*Variable cost*	*Revenue*
Commodity A	$183	$180	$166
Commodity B	417	450	467
Commodity C	525	495	492
Total	$1,125	$1,125	$1,125

In the case of Commodity A, it may reasonably be said from this evidence that the revenue of $150 does not cover the fully-distributed cost. In the case of Commodity B, the revenue of $500 appears to be greater than the fully-distributed cost. In the case of Commodity C, the revenue of $500 is greater or less than the fully-distributed cost, depending upon the measure by which one distributes the cost.

The ambiguities present in this example lead to conclusions similar to those which, in another connection, R. L. Banks has quoted, in modified form, from a statement given by Allan S. Olmstead, 2d, in 1916.

> "These (cost-finding) computations, then, consist of two processes. One is (the determination of variable cost) which is the ascertainment of facts; the other is apportionment (of fixed cost) which is the determination of policy. The former concerns itself with what is; the latter with what should be. One process consists of untwisting the intertwined but distinct strands of particular causation; the other of splitting the homogeneous fibres of a single cost . . . (Variable expense measurement) aims to find what each service costs; (constant cost) apportionment aims to determine what each service *ought to pay*.
>
> "Combining the two figures seems like adding quarts to feet. The desirable course would seem to be to resolve the total "cost" into its constituent elements, one marked "Matter of Fact— . . . (Marginal) Cost of Service" and the other labeled "Matter of Opinion—Mathematical Photograph of Witness's Sense of Justice. . ."[1]

Objections to the simple use of average-cost pricing do not rest solely upon the theoretical ground that the distribution of fixed costs is an exercise in the arbitrary assignment of costs which are not assignable. The practical difficulties which can be encountered can be illustrated by assuming that, in our hypothetical example, the railway lost the transportation of Commodity A. The costs and revenues would then be as in Table III.

[1] Banks, R. L., & Associates: *Study of Cost Structures and Cost Finding Procedures in the Regulated Transportation Industries,* Washington, D.C., 1959, p. 4-17.

TABLE III—REVISED HYPOTHETICAL EXAMPLE OF COSTS AND REVENUES

	Gross ton-miles of traffic	*Variable cost*	*Revenue*
Commodity B	200	$250	$ 500
Commodity C	300	275	500
Total	500	$525	$1,000
Fixed Cost	$500	Total Cost $1,025	

Thus although when revenues are compared with fully-distributed costs, Commodity A appears to be carried at a loss, the railway makes a profit of $25 when Commodity A is carried and a loss of $25 when it is not.

Since the response of the railway to this situation will be to raise the rates on Commodities B and C, average-cost pricing will be to the detriment of the shippers of these commodities. Since, if the railway has correctly estimated the demand for its services, a second result will be lower net revenues than in the situation of Table I, the railway will also be worse off. (See the Note to Chapter 5—A Possible Effect of Differential Pricing.)

The difficulties in the use or attempted use of fully-distributed costs have led many analysts to the belief that it would be better were the fixed costs given only as a lump sum. Regulatory bodies or ratemakers would then be left free to use any method which they wished to devise to cover these costs. Others, who do not feel as strongly, believe that "the rate-maker can ignore *neither* the existence of the constant costs (or burden) nor the necessity of the traffic in question making a proper contribution to such costs. However, the measure of such contribution rests on value-of-service [demand] considerations and not on cost considerations. Any other concept could not be reconciled with the fundamental nature of transportation costs".[1] When this viewpoint is held, the constant costs may be distributed in one or several ways in order to give a point of departure in deciding upon a reasonable rate.

Neither of the railways argued that average-cost pricing should be used for all commodities. Rather, it was argued (by one of the railways) that the transportation of grain to export positions was a special case and that, "if the level of rates set for statutory grain traffic did not recover full cost there would be a burden placed on other traffic or the railways".[2] This view was presented by witnesses through statements such as: "In view of the

[1] Interstate Commerce Commission: *Explanation of Rail Cost Finding Procedures and Principles Relating to the Use of Costs*, Washington, D.C., 1954, p. 21.

[2] Transcript of evidence, *Summations and Arguments*, Vol. 3, p. 99.

large volume of western grain moving to export positions in relation to total traffic, it is apparent that unless a substantial burden were to be placed on other traffic or on the railways, the just and reasonable rate must meet the total cost of transporting the grain traffic."[1] The same witness stated that "no one can seriously suggest that grain traffic in Western Canada bears any resemblance to a mere increment, that is that other traffic provides the basic volume and that grain traffic is incremental".

On cross-examination another witness put the question of basic or incremental traffic differently as is shown in the following interchange.

> "Q. And if you look at the output units per [for?] passenger, they are 10,222,000,000 . . . and I will stop there . . . gross ton-miles, and for grain, 11,768,000,000.
>
> Now, those two output units, to look at, I put it to you that you cannot validly regard passenger as incremental and grain, western grain moving to export positions, as basic to the plan [t]."
>
> "A. Well, that is my position, and I see no reason to change it. Passenger service is incremental or incidental, if you will, because under today's conditions there are alternative modes for transportation of passengers which are being used to an ever-increasing extent."[2]

A slight modification of the answer gives essentially the most common view of the way in which fixed costs are related to rates. As the ICC staff has said: "The apportionment of the constant and joint costs is fundamentally based on a weighing of the effect which the rates themselves would have upon the movement of the traffic and the carriers' revenues."[3]

With this in mind, the quoted evidence on passenger costs might be modified to read: "Passenger service must be considered incremental, or incidental if you will, because under today's conditions attempts to recover any of the fixed costs of the railway will result in alternative modes for the transportation of passengers being used to an ever-increasing extent." Since the railways have not been able to derive even their variable costs from passenger fares, distribution of part of the fixed cost to the passenger service would obviously be of no significance for ratemaking purposes. It would be of use only for certain studies of the extent to which passenger service fails to provide for overhead costs when these are distributed in some consistent fashion. There is nothing in the nature of passenger train service which makes it incremental or incidental. Rather, *management has decided* to treat it as incidental. All the evidence given to the Commission indicates that in making this decision, the railway management reflected properly the facts of the market for passenger service.

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[1] Transcript of evidence, *Hearings,* January 21, 1960, Vol. 21, p. 3409.

[2] Transcript of evidence, *Hearings,* November 8, 1960, Vol. 114, p. 18904.

[3] Interstate Commerce Commission, *op. cit.,* p. 26.

The argument that the grain traffic is "basic to the plant" contains difficulties which can be inferred from the comments on passenger train service. The mere fact that a sizable proportion of the railways' traffic is the movement of grain to export positions has no immediate relevance to the recovery of fixed costs. Suppose that one movement accounts for 60 per cent of a railway's traffic but that competitive conditions, or the ability of the shipper to pay, dictates that while covering something more than the variable costs which can be attributed to it, the traffic under consideration will cease if it is charged with fully-distributed costs (distributed according to any measure). The railway management, realizing that it is better off with the traffic than without it, will consider the traffic as "incremental", just as the managements of the Canadian National and Canadian Pacific consider passenger traffic as incremental.

What of the argument that since the grain traffic is such a large proportion of the railways' business, it must bear "its share" of the fixed costs because the remaining traffic cannot do so. Historically, the fact that the Canadian National has recurrent deficits lends validity to this argument on its behalf. Similarly, the fact that the Canadian Pacific has consistently operated at a profit (although equally consistently below that judged fair and reasonable by the Board of Transport Commissioners), reduces the validity of this argument in its case. But evidence, placed before the Board in application after application for rate increases, shows that as rates have been increased various other categories of traffic have been withdrawn from the railways. It is, therefore, fair to believe that if the grain trade has not borne its full share of the fixed costs (however defined), the attempt to recover these costs from other segments of traffic has resulted in at least the accelerated loss of some of these other segments. Since this causes the distribution of the fixed costs over a smaller total traffic, the problem of the railways is increased in a spiral fashion. But it would be equally fair to reach the same conclusion if the railways were losing other segments of traffic while the grain segment paid its full share, or even two or three times its full share of the fixed costs. For if the railway cannot retain other traffic at higher rates, and if it is possible to obtain needed revenue by having grain return a greater revenue, it is in the interests of the railways to charge grain a higher rate—no matter what proportion of the fixed charges grain is presently contributing. To carry this argument to its ultimate conclusion: if the railway must have increased revenues to exist, and if it is impossible to increase the revenue from other traffic, grain must be charged a sufficient rate to allow the existence of the railway, no matter what multiple of fully-distributed costs that rate may be. Inevitably we are led back to the conclusion that the demand for rail services must be considered in setting a rate for grain, and that the simple, mechanical application of any fully-distributed cost can serve as no more than one guide.

For a certain class of "constant costs", one of the difficulties disappears. These are constants which emerge because a linear model has been used to represent what are, in fact, curved relationships. Suppose that the cost relationships are of the type illustrated by the curve 0A of Figure 1. If a linear model is used, the relationships estimated by the statistical process may be those represented by the line BC. In this case, 0B would be presumed to be a fixed cost.

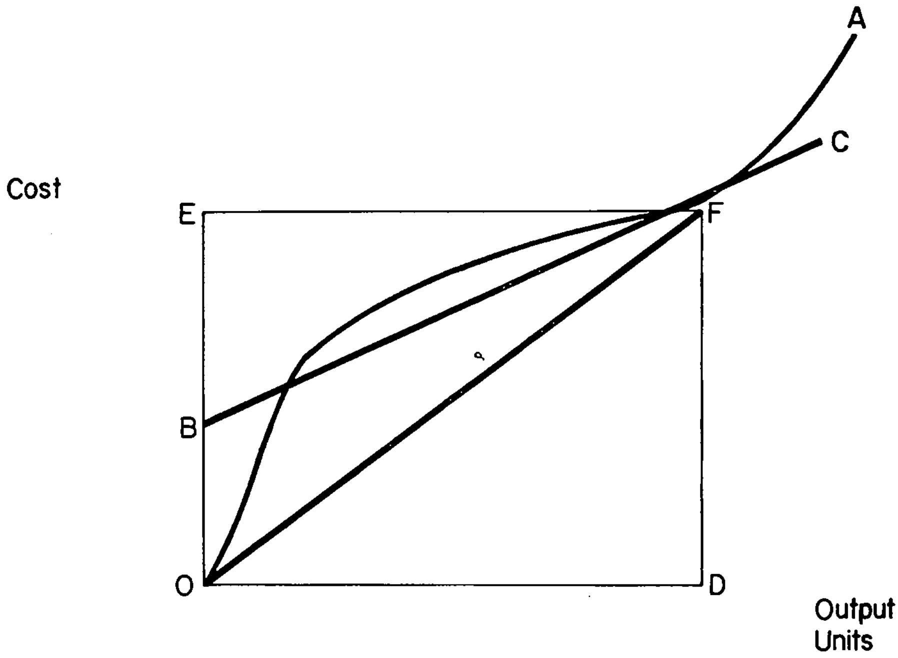

FIGURE 1: Hypothetical Cost Relationships

Of course, 0B is not a true fixed cost since it arises only because the straight line which best fits the data as a whole will not go through the origin. The constant cost so indicated might be referred to as a "pseudo-fixed cost".

In the case of pseudo-fixed costs or in cases when a curvilinear analysis indicates that there are no true fixed costs, one of the basic difficulties in estimating the average cost disappears since there is an average cost which can be related directly to a particular output. If a particular division is operating at an output level, D, the average cost will be represented by the slope of line 0F, that is by 0E divided by 0D. This average cost will be meaningful because it can be attached to a particular output. The use

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to which it can be put still suffers from one of the limitations which affect fully-distributed cost. In the presence of conditions which make it desirable to differentiate the rates for different commodities, the average cost—even if all costs are variable—bears no necessary relationship to a particular commodity or movement. Still, to the extent that average costs of the kind we are now discussing can be computed for a large portion of total railway costs, a more meaningful point of departure will exist for rate regulators than are costs distributed on a completely arbitrary basis.

As the analysis of Chapter 4 indicates, we are not in a position, as yet, to make such an analysis for more than a small proportion of rail costs. However, the analysis which has been made indicates the possibility that the proportion which could be so treated, with further study, might be of significance.

It is to be hoped that later analyses of costs on the Canadian railways will attempt to produce such averages—especially for cases of maximum rate regulation of specific rates. For example, in the case of maintenance-of-way expenditures, examined in Chapter 4, the average and marginal costs for a division with traffic of three billion gross ton-miles are approximately 28 cents and 24 cents respectively. But when the traffic has risen to ten billion gross ton-miles, the average and marginal costs are 19 cents and 5 cents respectively. While the marginal cost remains the relevant cost for minimum rate regulation, it seems evident that, at least in the latter case, the average cost is a more realistic and meaningful point of departure for maximum rate regulation.

If the argument of these pages is accepted, the task of the Commission is not one of estimating the fully-distributed cost of moving grain. Rather it is one of deciding upon a fair contribution which grain should make towards the fixed (or, at any rate, presently unassignable) costs of the railways. It is not the function of this report to make such an assessment. But it may be helpful to the Commission to indicate the extreme positions which might be taken in assessing a fair contribution by grain.

In the absence of subsidies, it can be argued at one extreme that grain need make no contribution to fixed costs whatsoever. If the transport of grain covers the variable costs exactly, the railways are neither better nor worse off carrying grain than they would be if they did not carry grain. Under these circumstances, it cannot be argued that the carriage of grain throws a burden upon anyone. For if the burden were due to the carriage of grain, it could be removed by ending the grain trade. But under the circumstances where all variable costs are met, ending the grain trade will not remove, either from the railway or from any other shippers, any burden.

The difficulty with this point of view is that, to accept it, one must believe that the grain trade is incapable of paying more than the bare variable costs, that all the fixed costs can be borne by other segments of traffic, or that the fixed costs which cannot be borne by other segments of traffic represent costs of portions of the railway plant which are socially unnecessary or undesirable. For, in the long run, many, if not most, fixed costs are escapable with sufficient decreases in output. Hence, an insistence on grain rates which paid only variable costs would see a railway (free to make such decisions) gradually withdraw from the business of hauling grain and making, as time allowed, appropriate reductions in the size of its plant.

At the other extreme, it can be argued that none of these conditions is true. In that case, one would conclude that the transportation of grain to export positions should make a sufficient contribution to bring the railways' earnings up to the point sufficient to keep all their present facilities in existence. In the case of the Canadian Pacific, this would presumably be an amount sufficient to bring earnings into the region of the permissive level established by the Board of Transport Commissioners.

In the absence of subsidy, certain checks might operate to indicate the correctness or otherwise of the assessment made. If the remuneration were set at too low a rate, the railway would attempt to withdraw from service socially desirable portions of lines in an attempt to reduce expenditures. On the other hand, if the remuneration were set at too high a rate, either the shipment of grain will be transferred to highway trucking, or farmers finding that transportation (plus other) costs make grain farming unprofitable will begin to withdraw from grain production. In the latter case, as the railway's net revenues are reduced one would expect it to reduce its rates.

The railways suggested, however, that the increased remuneration should come from the Government as a subsidy to the grain trade. The basis for this suggestion was the statement that to charge an increase in rates to the grain farmers would cause undue hardship to these farmers. Quite obviously there is a sense in which any increase in rates to any shipper constitutes a hardship. No evidence was offered to the Commission to indicate the degree of hardship which would be involved. It is also quite obvious that an attempt to make such an evaluation is not within the scope of this report.[1] But it is within the scope of this report to suggest that the

[1] Apart from the issue of hardship, no evidence was presented to show the effect which increased freight rates might have upon grain shipments. Evidence for Canada, such as that for the United States of America contained in the United States Department of Agriculture, Technical Bulletin No. 1136, *The Demand and Price Structure for Wheat*, would have contained information which would have helped the Commission evaluate the effects of rate changes upon grain shipments, and consequently the effects upon rail revenues.

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adoption of a government subsidy will remove the possibility of one of these checks. There will be no point, other than that at which the resources of the Government itself become over-extended, at which the net revenues of the railways will decrease with an increased rate of remuneration. The upper limit to the subsidy will presumably be decided by the willingness of the country to perpetuate rail lines through this device.

Within these broad limits, the apportionments suggested by the Canadian Pacific Railway and by R. L. Banks and Associates will serve as adequate points of reference on which to base a decision. A short examination of the composition of these estimates is, however, desirable, particularly since such an examination reveals that judgement may be involved even in what appears to be a mechanical application of an apportionment formula.

The Canadian Pacific estimates were derived from the components shown in Table IV. (Columns or rows may not add to the totals shown because of rounding.) Assignment to grain was based upon the ratio of the variable cost of the grain trade to the variable cost of all freight service.

TABLE IV—CANADIAN PACIFIC RAILWAY

COMPOSITION OF CONSTANT COST[1]

	Size related	*Non-size related*	*Total*
Expenditures	$4,900,000	$8,400,000	$13,300,000
Interest	3,000,000	3,700,000	6,700,000
Total	$8,000,000	$12,000,000	$20,100,000

[1] As assigned by the Canadian Pacific.

The amount shown in the column labelled "size related" are amounts which reflect the fact that certain expenditures appear to vary in accordance with changes in the miles of track, or of road, which must be maintained. (The existence of this relationship was discussed in the earlier portion of Chapter 3.) These amounts do not include an allowance for the maintenance of those lines which were labelled "solely-related" or "substantially-related". Costs associated with the substantially-related lines are discussed in Chapter 7.

The Canadian Pacific divided the constant cost in two steps. In the first step, the coefficients for miles of track (found in their regression analyses of road maintenance expenditures) were multiplied by the miles of track in the system, after excluding the mileage of those lines which had been labelled "solely-related". In the second step, the remaining costs which had not been shown to vary with traffic volume were apportioned.[1]

Underlying this procedure, there would appear to be an argument somewhat as follows: "We have identified the cost of maintaining certain lines as a cost which should be attributed to grain. We will remove the cost of maintaining these lines from further analysis. The remaining costs which do not appear to vary with traffic volume should be apportioned, in some consistent manner, among all the various kinds of traffic."

The method followed by the Canadian National Railways[2] appears to have a different order in the argument underlying it: "Certain expenditures cannot be shown to vary with traffic volume. These expenditures should be apportioned, in some consistent manner, among all the various kinds of traffic. Included, in the costs which will thus be assigned to grain, will be the cost of maintaining certain lines. These maintenance costs have already been attributed to grain. We will, therefore, remove these costs from the mechanical assignment to grain and charge them to grain under a specific label."

If the Canadian Pacific had followed this line of argument, their assignment of constant cost to grain would have been approximately as shown in Table V.

TABLE V—CANADIAN PACIFIC RAILWAY

COMPOSITION OF CONSTANT COST, FIRST REVISION

Expenditures	$10,400,000
Interest	4,600,000
Total	$15,000,000

Still another line of argument might be produced. In the particular circumstances of this traffic, which is not carried further east than the Lakehead, it can be said that there must be many miles of track in Eastern Canada over which none of the traffic being studied is carried. These miles of track could be termed "solely-related to 'non-grain' traffic". Let us suppose that, in the Canadian Pacific system, there are 5,000 miles which could be so designated. Since the maintenance costs of those miles of track

[1] See Exhibits 69 (Revised) and 70 (Revised) in Appendix A.
[2] See Exhibit 57 BBB in Appendix B.

which are substantially related to grain are to be charged to the grain trade, it seems reasonable that the maintenance costs of those miles of track which have no connection with the grain trade should not be charged to the grain trade, even in part. In that case, the apportionment should begin by multiplying the coefficients for miles of track by the number of miles of track in the system, after deducting the miles of track which have been found to be solely- or substantially-related to grain, and after deducting the miles of track which have been found to have no use for the grain trade. In this case, the Canadian Pacific estimates would appear, approximately, as shown in Table VI.

TABLE VI—CANADIAN PACIFIC RAILWAY

COMPOSITION OF CONSTANT COST, SECOND REVISION

	Size related	*Non-size related*	*Total*
Expenditures	$3,600,000	$8,400,000	$12,000,000
Interest	2,250,000	3,700,000	5,950,000
Total	$5,850,000	$12,100,000	$17,950,000

R. L. Banks and Associates, as had the Canadian Pacific, apportioned constant cost in accordance with the ratio of the variable cost of the grain trade to the variable cost of all freight traffic. They, further, presented a number of possible alternative formulations of the appropriate estimate of the total constant cost and of the method of assigning it.

In estimating the total constant cost, Banks first used the constants found in the regression equations as a basis for his calculations. This method was one which had been presented originally by the Canadian Pacific. It was abandoned by the Canadian Pacific when it was found that the total costs estimated in this manner did not equal the recorded total expenditures of the railway for 1958. Among other reasons, this was so because the regression equations were based on the average experience of the three years 1956 to 1958. Total costs estimated with the aid of the regression equations would be expected to equal those recorded for 1958 only if the 1958 experience happened to equal the three-year average experience. Since this was not the case, the Canadian Pacific abandoned its attempts to measure the constant cost by this method. For the same reason, these estimates will not be discussed further here.

The alternate method presented by Banks was also employed by the Canadian Pacific. That is the method, shown in Appendix A, of deducting the identifiable expenses from the total expenditures of the railway and labelling the remainder, "constant cost". In Table VII these apportionments are presented.

As Table VII indicates, Banks also presented alternative assignments based, first, upon the assignment of part of the constant cost to passenger-train service, and, second, without the assignment of any part of the constant cost to passenger-train service. If one were attempting to assess the degree to which the economic difficulties of a railway stem from the inability of certain segments of traffic to contribute income to the same degree as other segments, there would be much to be said for the view that, "those analyses which attach a share of constant cost to the passenger services are of greater validity than those which do not. This follows from the fact that comparisons of like with like—in this case of two allegedly deficit traffics—should be developed and computed in a uniform manner if they are to provide a sound basis for governmental assessment of national transport problems."[1] On the other hand, in a study which attempted to form a basis for a decision on the reasonable level of remuneration for all, or a part of, the freight-train service, it seems unrealistic, as was indicated above, to expect the passenger-train service to contribute to constant costs at the present time. Therefore, one would accept, as more realistic, the apportionments made without assignment to passenger-train service.

Views on the nature of these constant costs will also affect the decision as to whether a part of the constant costs should be apportioned to the passenger-train service. Those believing that the constant costs are true fixed costs will accept the position that no adjustment in the services offered by the railway can affect such costs (except for the drastic adjustment of going out of business entirely). But it may be believed that the great majority of these expenses are of a kind which are not truly fixed, that the level of these expenditures will vary with sufficient long-run adjustment in the railway's operations. In this case, it can be said that the apportionments of "constant" cost are estimates of the level of costs which can be changed with severe changes in the amount of service offered, albeit estimates on a much more approximate basis than those discussed under the heading of "variable cost". If it were believed that large adjustments will be made in passenger-train service in the coming few years one would then lean towards the apportionments which include an assignment to passenger-train service, on the grounds that these indicate the assignment which would be made to grain were the analysis repeated after the modifications in passenger-train service.

[1] Transcript of evidence, *Hearings*, November 10, 1960, Vol. 116, p. 19238.

TABLE VII—CANADIAN PACIFIC RAILWAY

COMPOSITION OF CONSTANT COST[1]

	With assignment to passenger-train service	*Without assignment to passenger-train service*
Non-size related		
Expenditure	$5,016,649	$7,037,995
Interest	1,908,920	2,742,753
Sub-total	$6,925,569	$9,780,748
Size related		
Expenditure	$3,249,967	$4,575,038
Interest	458,355	658,878
Sub-total	$3,708,322	$5,233,916
Totals		
Expenditure	$8,266,616	$11,613,033
Interest	2,367,275	3,401,631
Grand total	$10,633,891	$15,014,664

[1] As assigned by R. L. Banks, see transcript of evidence, *Hearings*, November 10, 1960, Vol. 116, p. 19258-19259.

The assignments of R. L. Banks and Associates differ from those of the Canadian Pacific, even where the same methods of apportionment were followed, because of different estimates of the variable cost, because the costs of certain facilities which are substantially related to certain non-grain services were deducted, and because interest charges were computed on a different basis. The computation of interest charges is discussed in the next chapter. It is sufficient to note, here, that the position taken in this report approximates the interest computations of R. L. Banks.

Finally, it must be noted that a recommendation by the Commission, on the amount of constant cost which should be covered by the remuneration for grain, cannot be considered in isolation from other recommendations made by the Commission. For example, if the permissive level of earnings which is allowed the Canadian Pacific, should remain unchanged, and if the railway should be allowed increased remuneration from various sources sufficient to bring its earnings above the permissive level, the economic pressure on the railway to rid itself of uneconomic services would be removed. At the same time, part of the payment for these services would be transferred from the users of the services to grain shippers. (Since presumably the effect of earnings above the permissive level would be a reduction in other rates.)

In view of the various distributions of constant cost which have been presented above, it seems unlikely that one could claim that an assignment to the grain traffic of $11,000,000 would be inequitable to the grain trade. But if the Commission wishes to direct the attention of the railways and the regulatory authorities to the desirability of effecting economies in other areas, if it is believed that a curtailment of uneconomic light-density lines and passenger services will bring reductions in the total "constant cost", and if it is prepared to recommend measures to cover losses in these last two areas during the period of adjustment, a lower assignment would be justified. An assignment to grain of between $7,000,000 and $11,000,000 would appear reasonable for a short period of years during which the railways were making their initial adjustments in these fields. At the end of that initial period a reassessment should be undertaken, both to estimate the total amount of the "constant cost" and to review the appropriateness of the assignment to the grain traffic.

Examination of the assignments made by the Canadian National Railways, (see Appendix B), indicates that a much higher level of constant cost prevails than is the case for the Canadian Pacific. Insofar as higher costs on the Canadian National represent higher depreciation charges, these higher costs may be a reflection of the conditions under which the Canadian National acquired certain properties. If such be the case, it seems evident that the appropriate remedy would be a review of the accounts of the Canadian National to remove capital charges which may reflect unrealistic prices assessed against the Canadian National at the time various properties were placed in its charge. Insofar as these costs may represent greater difficulty on the part of the publicly-owned road to divest itself of uneconomic lines and services, the appropriate remedy would appear to lie in the direction of equalizing these opportunities. In fact, whatever reason one may think of for these differences, it appears inappropriate that the higher costs should be assessed to the grain traffic. It is, therefore, suggested that upon recommending an amount as an assignment of constant costs for the Canadian Pacific, the Commission recommends an amount for the Canadian National such that the total remuneration (per net ton-mile of grain traffic) recommended is approximately equal to that recommended for the Canadian Pacific.

Note

A Possible Effect of Differential Pricing

The following note is the result of certain statements made before the Commission. Although somewhat remotely connected to the material in the main body of Chapter 5, it derives its *raison d'être* from an assumption which seemed to underlie some of the arguments heard. That assumption was that differential pricing (either between commodities or between geographic regions) is necessarily against the interests of the shipper who pays the higher rate.

Under certain conditions of demand for transportation, and with a limit to the earnings allowed the railway, this need not be so. Let us take, as an illustration a highly simplified case of a railway which has offered to it only three commodities, which charges rates which always result in a net revenue which can be expressed in an exact number of cents per ton-mile, which has the same costs per ton-mile for each commodity, and which is limited by a regulatory authority to a net revenue of $222. Table I presents a hypothetical demand schedule.

TABLE I—SCHEDULE OF HYPOTHETICAL DEMAND FOR RAIL TRANSPORT

Net revenue per ton-mile	*Ton-miles shipped*		
	Commodity 1	*Commodity 2*	*Commodity 3*
1 cent	4,000	3,000	2,000
2 cents	3,550	2,100	900
3 cents	3,300	1,400	450
4 cents	3,100	1,000	300
5 cents	3,000	700	225
6 cents	2,950	500	185

With these schedules of demand for transportation of the three commodities, the total net revenue available to the railway at various levels of net revenue per ton-mile will be as given in Table II for each of the three commodities.

TABLE II—SCHEDULE OF HYPOTHETICAL RETURNS FROM RAIL TRANSPORT

Net revenue per ton-mile	*Total net revenue in dollars*			
	Commodity 1	*Commodity 2*	*Commodity 3*	*Total*
1 cent	40.00	30.00	20.00	90.00
2 cents	71.00	42.00	18.00	131.00
3 cents	99.00	52.00	13.50	164.50
4 cents	124.00	40.00	12.00	176.00
5 cents	150.00	35.00	11.25	196.25
6 cents	177.00	30.00	11.10	218.10

Under the conditions which are outlined above, the railway would charge a rate sufficient to yield a net revenue of five cents for Commodity 1, three cents for Commodity 2, and one cent for Commodity 3. The total net revenue to the railway would then be ($150+$52+$20) $222. If now the railway were required to equalize the rates charged these three commodities, it would charge a rate which would yield a net revenue of six cents per ton-mile. The resulting total net revenue would be $218.10. Under the drastic simplifying assumptions which we have adopted in this example, equalization of rates would result in a lowered net revenue to the railway and higher rates to each of the shippers.

Under the complex conditions of Canadian economic life, it is impossible to estimate the extent to which effects such as these occur. If one believes, however, that in negotiating, for example, agreed charges the railways have secured the greatest net revenue that they believe possible, and if they have contracted for freight rates which contribute something to the fixed charges of the railway, one must be very cautious in suggesting that these lower rates are not in fact indirectly beneficial to other shippers who pay higher rates. Equally, there seems reason to question whether, in fact, an enforced equalization of rates between different geographic areas will necessarily redound to the economic benefit of those whose rates are thus lessened. (The case where local shippers are subsidized in order to equalize or lower rates is clearly without the bounds of this argument.)

Chapter 6

The Cost of Money

Regulatory commissions or boards must, in almost all cases, decide what amount of profit it would be proper to allow those companies they regulate to earn. (In this chapter profit will be defined as the difference between revenues on the one hand and operating expenses including taxes on the other.)

One method of determining the amount of profit to be allowed is to ascertain the amount of capital invested in the firm, to decide upon a fair percentage return on the capital invested and where necessary, to translate this into an amount of money. This is known as the "rate base-rate of return" method of determining a fair profit. In determining the rate base, the first decision which must be made is whether to use original value less depreciation (net investment), reproduction value, or some combination of the two. A decision must also be made as to the desirability of allowing a return upon investment upon that part of the plant or equipment which was purchased out of retained earnings. It appears to be generally agreed that investment paid out of retained earnings should be allowed the same return as investment paid from ordinary stock unless the retained earnings were part of an unduly high rate of return. In the latter case, some authorities apparently hold that to allow profit on that part of previous earnings which was above a fair rate of return would be to reward the investor for an earlier unreasonable profit. Following the decisions on the rate-base, a criterion for the fair rate of return must be found.

The greatest difficulty which regulatory bodies have experienced with the rate base-rate of return method appears to have been that after going through the calculations, the allowable earnings resulted, or would have resulted in a rate which was unfair to the shipper or impractical for the railroad. Fair and Williams cite the following causes of the decline of valuation as a principle of rate regulation in the United States.[1]

"1. The application of valuation formulae assumed that the railways had such a high degree of monopoly over transportation that an exact regulation of maximum and specific rates could be assured by use of a formula.

2. The application of a formula failed to take account of the recurrent risks which occurred because of the impact of new competition and repeated economic crises.

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[1] Fair, M. L. and Williams, E. W., Jr.: *Economics of Transportation*, New York, Harper and Brothers, Revised Edition, 1959, p. 570-1.

3. Valuation formulae did not take into account the effect of rates on the movement of traffic or the financial needs of the railways.

4. The proponents of valuation erroneously believed that valuation can give a firm and precise formula to evaluate the reasonableness of rates rather than a judgement based upon a set of facts which must be considered in relation to the purpose of the study.

5. Valuation strove for precision at the sacrifice of realism. Hadley pointed out years ago that neither estimates of historical investments nor cost of reproduction with depreciation are values in the economic sense. Rather they are only estimated 'assessments', market value being the only true concept of value."

Similar conclusions were reached by the Royal Commission on Transportation under the chairmanship of the Honourable W. F. A. Turgeon which said:

"The task of the Board in fixing, determining and enforcing just and reasonable rates, involves a duty to both the railways and to the public; the Board must therefore be in a position that will enable it to determine, in so far as possible, the balance which will bring about this desired end. But since economic conditions may be such that different considerations exist under one state of affairs than under another, it is not proper to lay down the priority which should be given to the principles which guide the Board. The Canadian Pacific by its proposed amendment, asks that priority be given to the principle of a fair return on investment; yet experience has shown that such a factor may not be the guiding factor, it may be one which in times of economic depression must give way to other considerations. The procedure of rate making must be left flexible and this flexibility now exists under the Railway Act.

"If the proposed amendment submitted by the Canadian Pacific Railway were adopted it would tend to make the Board mere computers of a rate base and a rate of return, and calculators of the amount of increases necessary to bring about that return. The Board should not be so atrophied. The Board's duty is to consider the justness and reasonableness of rates not only as a whole, but in particular as well. Fair return on property investment may be one of the tests; it must not be either the sole or guiding test."[1]

Like reasoning is evident in the judgement of the Board of Transport Commissioners which said:

"Without purporting to summarize all the reasons previously set out, the following three reasons have particularly influenced us in deciding, as we do, that we will not under existing circumstances adopt the rate base-rate of return method for Canadian Pacific which, within the meaning of this application, would be the sole method of determining a permissive level of rates for all railways in Canada subject to our jurisdiction:

(1) The fundamental nature and nation-wide expense of the railway enterprise in Canada as presently constituted do not lend themselves to an automatic translation of railway costs into rates—both freight

[1] Royal Commission on Transportation, *Report,* Ottawa, The King's Printer, 1951, p. 70.

and other rates—based on any preconceived return. This inherent factor is in contrast with the single or multi-service local monopolistic utilities . . .

(2) The economic impact of freight rates is such that they should not be made the product of any automatic formula. This is particularly so where 100 per cent of the cost, or the increase in cost, is sought to be automatically applied in general rate increases to a much lesser percentage of the revenue producing business and in particular to that narrowing section of the non-competitive and non-statutory rate structure where the economic leverage and consequences are the greatest.

(3) The expression of net railway earnings as a rate of return encompasses certain component elements over which this Board has little or no direct control. Apart from the policies of government of which taxation is the most readily apparent, the component elements include the following:

(a) fluctuations in traffic both as to volume and consist;

(b) policies and demands of railway labour, and

(c) policies and efficiency of railway management.

We believe it would be both unsound and unrealistic for the Board now to attempt to pre-determine for nation-wide rail transportation any net return which in the end result is only the expression of the effect of the above-noted elements in conjunction with other factors when, in a composite sense, they are beyond the power of any single agency to regulate. We further believe that on psychological grounds alone it would be conducive to a weakening of the barriers, which now at least to some degree hold in check certain costs to create any illusion of a pre-determined net return for nation-wide rail transportation. Furthermore, on similar grounds, it could well be that the term 'financial requirements' would carry the connotation of a more searching scrutiny of all requirements for which funds are necessitated than would the automatic acceptance of the rate base-rate of return method which has been described at times, albeit in error or at least in over simplification, as reducing the Board to mere 'computers'.

In summary, therefore, the Board is of the opinion that, in the long run, it would be disadvantageous to the interests of the public, the railways and investors alike to give, through the implementation at this time of the Canadian Pacific proposal, any appearance or inference of certainty of solution of a nation-wide rail transportation problem for which, under present conditions, no certainty exists."[1]

Rather than use this method the Board has expressed its ruling on the proper level of profit for the Canadian Pacific as the amount of "permissive earnings", a specific amount. To find this amount the Board takes into account all the factors enumerated above. It then expresses its judgement on the amounts which the railway should be permitted to earn to cover payment of interest on bonded indebtedness, dividends or ordinary and

[1] Board of Transport Commissioners for Canada, *Judgment, Rate Base-Rate of Return*, Judgments, Orders, Regulations and Rulings, Vol. XLVIII, No. 16A, November 15, 1958, Ottawa, Queen's Printer, p. 55-6.

preferred stock, and in addition it includes an amount of "permitted" retained earnings. Calculations using the rate base-rate of return method are used by the Board as *one* of the end checks of permissive earnings. It will be obvious that once the permissive level of earnings has been established, although the route taken is different the end result can be expressed as a "permissive rate of return on net investment".

The cost of money developed by the railways was used by them as a rate of return which was applied to the base of net rail investment in property and equipment devoted to the grain trade. In addition, an amount was computed similarly, based on the unassignable investment. These amounts were presented as a part of the estimated cost of moving grain in 1958. The Canadian Pacific argued that the cost of money and the rate of return are not the same thing. This is correct, and the differences will be marked below. Nevertheless, the procedure followed by the railways was precisely that described by the Honourable Mr. Justice Kearney as the rate base-rate of return method.[1] The only exceptions were the use of the term "cost of money", and the application to the export grain trade alone.

In the light of the discussion above and the similarity in method, we must examine the claims that, the "cost of money is a fact", and that this fact was determined. To justify this contention, the witnesses for one railway argued that "the cost of capital is just as much a cost as the cost of labour", and "the cost of money is similar to the cost of wages". The first of these contentions is the weaker since it simply asserts that the cost of obtaining money for investment is a real cash outflow. The second contention may mean only that, or it may contain the stronger assertion that the cost of money has the same characteristics as wages. If the latter is the proper interpretation of the second contention, and if this contention were correct, there could be no doubt that the figures presented by the railways should be accepted as a component part of the cost of moving grain to export positions. There are, however, important differences which have been overlooked.

The cost of labour is a precisely measurable quantity once the quantity and kind of labour required are known. Present day wage rates are known; past payments of wages are recorded. The cost of money must be estimated. In contrast to a simple statement that the cost of train enginemen, train locomotive fuel and power and trainmen was $6,378,621 for the export grain trade in 1958, some twenty-one pages of text, supported by twenty-four pages of schedules and charts were required to demonstrate the process by which the estimate of 6½ per cent for the cost of money was reached. This is because in the cost estimates, the amounts actually paid to labour were presented at least for the system as a whole. In the case of the cost of money

[1] Board of Transport Commissioners for Canada, *op. cit.*, p. 15.

an attempt was made to estimate the amount which would have to be paid if the Canadian Pacific were to attempt to raise, in the market today, a sum equal to the issued value of its ordinary stock and retained earnings, while continuing to maintain payments on its present debt.

What are historical facts and what can be determined, are the return which the company has obtained on *its* investment and what yield the investor has obtained on *his* investment. For any year, the first of these is simply the sum of the interest paid on bonds, debentures and other debt instruments, the dividends on preferential and ordinary shares, and retained income. Expressed as a percentage, the sum of these is divided by the net investment of the company. The yield to the investor is most usefully defined as the interest or dividend which he receives from his investment. As a percentage it is usually divided by the *market value* of the bonds or shares.[1] Had the actual payments been given (including retained earnings as a "payment" to shareholders) the entry would have been very simply one of dividing net rail income by net rail investment (both recorded figures about which there is no dispute). This figure could have been presented as the historical cost to the railway in 1958 for the capital which it employed.

Instead, the railways chose to present the cost of money in terms of the yield which the railways would have to provide investors in order to attract capital today. This can be estimated but it can only be determined by an attempt to issue new securities; only then can one be certain what in fact a company would have to pay in the way of interest or what price they could obtain for stock when they attempted to raise new capital.

The cost of money at any time is a result of the interaction of the company's return on investment, the yield to investors, the history of both of these and of a host of other factors which can be summed up as "the current attitude of the market". The yield to investors depends upon the return to the company, since the first must be paid out of the second. While it would seem logical that the cost of money would be a reflection of the yield to the investor, this is only true in part. Since some of the return to the company can be retained, the relationship between the return to the company and the yield to the investors is also important. In evaluating corporate bonds a figure frequently quoted is the number of "times interest earned". This figure indicates the ability of the corporation to maintain interest payments in the face of a possible worsening in its fortunes. In the case of ordinary stocks the number of times the dividends have been earned after payment of interest or of dividends with a higher priority is often quoted. The pay-out

[1] Retrospectively, a particular investor may include any capital gains which he has obtained during the life of his investment. Prospectively he may include expected capital gains. Since these will depend upon the period and duration of ownership they are not easily available for quotation.

ratio, that is, the percentage of earnings which was paid out as interest or dividends, indicates the ability of the company to finance growth in investment from internal sources.

In addition to these measurements, the value of ordinary stock is frequently judged by the growth in the company's sales, earnings and investment, by the degree to which growth in investment has been financed by the issuance of ordinary shares (thus reducing the relative participation, in earnings per share, of former owners), the stability of the company or industry—that is its ability to withstand depressions, or to perform better relative to other companies or industries during recessions, even if perhaps not performing relatively as well during periods of high economic activity. The last two are not entirely independent, for if a firm has obtained a high proportion of its capital through debt, the heavy fixed charges will place it in a relatively vulnerable financial position.

Finally there is "the attitude of the market". From time to time investors in general turn to or away from common stocks as a class for a variety of reasons. During the years following World War II, for instance, a trend towards buying common stocks and away from securities with fixed interest was rooted, in part, in the belief that common stocks offered a measure of protection against inflation. It was believed that, in general, the prices and perhaps the yields of common stocks would increase at least in step with the general price level. At the same time, many investors felt that growth was a much more important criterion when evaluating a stock than the current yield. For reasons such as these, many common stocks sold at prices which, in terms of the analysis which would have been performed in the years before World War II, were almost unbelievably high.[1]

Despite the forthright statements in the preceding few paragraphs the estimation of the cost of money is neither simple nor usually completely accurate. Were it so the underwriters of bonds would be able to estimate the selling price to the market which would call forth exactly the amount of subscription desired. But examples are present of subscriptions falling short of offers (under-estimated cost of money) and exceeding desires (over-estimated cost of money). Nor is there complete unanimity in theory on the factors which determine the cost of money. For example, there has been a dispute, on the theoretical level, over the effects of a firm financing by means of different proportions of debt and equity.[2] A recent empirical study of the differences at one point of time in the price earnings ratios of a sample of corporations in the United States concluded that the most

[1] Presumably a particularly wide-spread example of the investors' inclusion of expected capital gains in their evaluation of expected future "yield".

[2] See Rose, J. J., Durand, D., and Modigliani, F., with Miller, M. H.: *The Cost of Capital and the Theory of Investments, Comments and Reply*, in American Economic Review, Vol. XLIX, No. 4, September 1959, p. 628-669.

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important determinants of a low cost of money appeared to be large size and stability of earnings, and also concluded that as far as could be demonstrated from this study, the evidence that the debt-equity ratio was important was inconclusive.[1] This last finding is in direct opposition to one of Durand's given in the last reference.

Notwithstanding these complications, it is certainly true that where earnings per share are low, the cost of money will tend to be high and that with an additional absence of marked growth the cost of money may be very high. As earnings per share increase, the cost of money will decrease to the point where it approximates a "normal profit". Where the return to the company is very high this approximation of normal profit to the investor will be accomplished by an increase in the market price of the securities.

The cost of money differs from the cost of labour in another important respect. If some wages are not paid, the labour which would have been paid will be withdrawn. In the case of some part of the investment, however, even if the cost of money is not paid the investment will not be removed. A part of the investment in railways is composed of the costs of grading the terrain, constructing bridge abutments, building tunnels, and so forth. If the cost of money is not paid on this investment the grading will not be undone nor will the bridge abutments necessarily be destroyed. Furthermore, even if there is no return on investment, that is, if the cost of money is not paid at all, the enterprise may continue to function for an indefinitely long period of time. It is sometimes thought that, because bonded indebtedness carries a fixed interest charge, there is a difference in kind between the obligations of paying dividends on ordinary stock and the obligation to pay interest on bonds. From a legal and accounting point of view this is so. From the point of view of the cost of operations, the difference is merely one of the priority of payment. J. M. Clark has made this point as follows:

> "For our purposes, the chief issue is the true nature of fixed charges, because they are often confused with 'constant costs'. Fixed charges represent a minimum limit on the net earnings of operation below which they cannot go without insolvency. Nevertheless, they frequently do go below this level, with the result that there is a reorganization and the bond holders accept stock in place of part of their bonds, or some other adjustment is made that reduces the fixed charges, and the business goes on. Fixed charges obviously may cover a very large or a very small part of the capital invested. Two companies may have exactly the same investment, but one of them may have two-thirds of its capital covered by fixed obligations and the other may have no fixed obligations at all. For purposes of the financial records, the income account and the balance sheet, there is an important difference between the two cases; but for purposes of cost accounting there is—or should be—none."[2]

[1] Benishay, H.: *Variability in Earnings—Price Ratios,* American Economic Review. Vol: II, No. 1, March 1961, p. 81-94.

[2] Clark, J. M.: *Studies in the Economics of Overhead Costs,* Chicago, University ot Chicago Press, 1923, p. 46-7.

Although the cost of money is real, it must be concluded that it does not stand on the same footing as the cost of labour or materials because it is not known, except at the moment of appealing to the market, and so cannot be presented with the precision with which wages and the costs of materials can be presented (at least in total). There is, however, another approach which can be fruitful. This approach was taken by another railway witness who defined the cost of money as "the return which should be earned if invested in a similar enterprise". This witness appears to have been alluding to the idea, which was discussed in Chapter 2, of "normal profit". Locklin remarks that "in discussions of economic theory, a return on capital, *or so much of it as is a normal return,* may properly be considered as a cost of production. This is so because capital must in the long run receive its reward, or additional capital will not be forthcoming when needed".[1] (emphasis added). This definition, however, reminds us that the relevant rate to apply where a subsidy is in question is the rate which will be just high enough to encourage the investor, through the railway management, to stay in a business which it is desirable to continue, and which will be just low enough to discourage him from remaining in an undesirable business. To do otherwise would be to reward the company for staying in a socially less than economic business or to fail to reward it fairly for its contribution.

The preceding pages have discussed generally the question of the application of the cost of money. When consideration is given to the application of either the cost of money or a rate of return, some further observations can be made. The investor receives this return from the capital he has invested as a whole, not from each constituent part. In fact, every business carries on activities which require investment but which do not *in themselves* yield a direct return on investment. For example, office space and equipment for advertising and public relations staff is justified, not because these activities in themselves give a return on the capital, but because they increase the possibilities of earning a profit in other activities. In the peculiar circumstances of the export grain traffic, the investment required has similar characteristics. By the terms of the Railway Act, the railways are required to carry grain to export positions at a rate set by statute. As long as the railway as a whole returns a satisfactory yield upon the investment, investors will continue to make additional capital available as needed. Under these conditions the cost of money is indeterminate as far as the grain trade is concerned. In point of fact, the evidence presented by the railways would indicate that, according to this definition, the cost of money for the grain trade was negative in 1958, since they have testified that in their opinion they were required to carry

[1] Locklin, D. Philip: *Economics of Transportation,* Chicago, Richard D. Irwin Inc., 3rd edition, 1947, p. 135.

the grain at less than variable cost and have also indicated that, in fact, they did add capital by, for example, changing from steam to diesel locomotives.

In fact, the return on investment which is received from any movement is the residue which is left from the revenues which are received when all the expenses have been paid. It is impossible to determine what, in fact, the return on investment was for any particular segment of a business involving numerous products (for example, transport of many commodities between various pairs of points). To do so one would need to know the contribution of the particular segment to the constant costs of the enterprise. But, this can only be known if the return on investment is known since each of them is taken out of the difference between variable cost and revenue.[1]

For purposes of rate regulation this need not present an insuperable problem. The railroads' procedure can be followed. That is, one can assume a rate of return equal either (a) to what the firm received on its investment as a whole, or (b) what one judges it should have received. This rate can then be applied to the investment which is assignable to the commodity under study. A similar rate of return can be applied to that investment which is not assignable to any particular movement. The resulting amount can be included as a part of the constant costs. But in doing this it should be borne in mind that the resulting figures represent a guide to the proper rate, they do not constitute a rigid formula. Most important, once the rate has been fixed, except where each and every movement bears its fully-distributed cost, it is impossible to say what return is being earned on the investment by any specific segment of traffic.

The Railway Estimates of the Cost of Money

The definition of the cost of money presented to the Commission by the Canadian Pacific Railway witnesses was that:

> "In determining costs of producing a product or service full recognition must be given to the cost of capital or what is sometimes termed 'cost of money'. Such a cost is expressed as a percentage rate on investment and measures the compensation required for the use of capital."

The amounts included in this cost of money were estimated according to these criteria:

> "The cost of debt and preference stock capital is the current cost of servicing that capital which was outstanding on December 31, 1958.
>
> The cost of common or ordinary stock equity capital is what is required to protect the financial integrity of the enterprise and thus permit it to attract such capital on reasonable terms and conditions."

---

[1] Cf. the discussion of Chapter 2, p. 201-202.

In order to estimate the cost of equity capital[1] comparisons were made of the yields on market price of 18 railroads in the United States which for the year 1950:

(1) had a gross investment in plant of $300,000,000;

(2) had revenues amounting to $100,000,000 or more;

(3) paid dividends;

and for the Canadian Pacific Railway and 25 railroads for which Moody's publishes group data.

Comparisons were made of the earnings-price ratio, that is the percentage which annual earnings represented of the market price; the yield, that is the percentage which dividends represented of the market price; and the pay-out, that is the percentage which dividends represented of earnings available on stock.[2] Various comparisons were presented for the years 1950-1959. Further comparisons were presented for gas and electric utilities and for manufacturing corporations in the United States and Canada.

As a result of this study Canadian Pacific reached the conclusion that the cost of money for equity capital was between 9¼ and 9½ per cent for 1958.

This rate for equity capital and the current rates for debt and preference stock capital were then used to compute a composite cost of capital employed in rail enterprise as shown in Table I.

It will be noted in this table that the rate of 9¼-9½ per cent has been applied to an aggregate amount of capital of $847,107,330 which is the

[1] The argument, before the Commission, on the cost of equity capital was long and detailed. This section discusses at some length various arguments brought forward to support the procedure used by Canadian Pacific. Briefly the error, which I believe Canadian Pacific committed, can be outlined as follows. Canadian Pacific employed the following definitions:

$$\text{Yield} = \frac{\text{Total Dividends Paid}}{\text{Total Market Value of Common Stock}}$$

$$\text{Pay-out Ratio} = \frac{\text{Total Dividends Paid}}{\text{Total Earnings Available}}$$

An average current value of these ratios was then estimated. To estimate the amount of earnings required on investment the yield was multiplied by the reciprocal of the pay-out ratio. This, since

$$\frac{\text{Total Dividends Paid}}{\text{Total Market Value of Common Stock}} \times \frac{\text{Total Earnings Available}}{\text{Total Dividends Paid}} = \frac{\text{Total Earnings Available}}{\text{Total Market Value of Common Stock}}$$

allowed the Canadian Pacific to estimate required earnings on the basis of value of common stock. In fact, however, the Canadian Pacific multiplied these ratios by the value of common stock plus earned surplus. (I am ignoring the difference between the issued and the market values of the stock.) In effect, Canadian Pacific made a double allowance for retained earnings.

[2] The definitions employed in this chapter are those used by the railway witnesses.

amount of ordinary stock and retained earnings. The inclusion of retained earnings in this base was justified by the statement:

> "I make no distinction between the capital raised directly from stockholders through the sale of stock and that raised indirectly through investment of retained earnings, and none can logically be made, in my opinion. Every dollar invested in a diesel locomotive, for instance, is capital which must be compensated. Thus, if the money invested in a diesel locomotive is raised in part through issuance of debt securities, in part through the sale of ordinary stock, and in part through the investment of retained earnings, no distinction can reasonably be made between or among these sources such as to hold that part of the capital involves a cost or sacrifice and the other part is free. In my opinion, it makes absolutely no difference, in determining the cost of capital, whether the capital comes directly from stock sold to stockholders or whether it is derived indirectly from stockholders in the form of retained earnings: the important thing is that the capital is invested in the rail property which is used in the public service."

Undoubtedly, once the investment has been made no distinction can be made between the various sources of capital which are employed by the firm. There is no way of deciding for example that diesel locomotives were paid for by sums raised from one source and that box cars were paid for by sums raised from another. Even in the case of money raised through the issuance of trust certificates, although the immediate transaction includes the hypothecation of equipment which is bought in a literal sense with money loaned upon the trust certificate, other funds are thereby released for different forms of investment. Thus the distinction between the application of funds raised by means of trust certificates and funds raised otherwise is, as far as application is concerned, a formal distinction rather than a real distinction.

Although it is impossible to distinguish between the various sources of funds as far as their use in various applications is concerned, it is not impossible to distinguish between the costs of the various sources. In fact Table I shows that the cost rates applicable to Canadian Pacific, in view of the company, varied from 2.35 to over 9 per cent depending upon the type of security which was issued.

The method employed in Table I assumes that the cost of money for ordinary stock and for retained earnings is the same. Bearing in mind that this amount is defined as ". . . what is required to permit (the firm) to attract such capital on reasonable terms and conditions", we must ask whether in fact it has been necessary for the Canadian Pacific to pay a return on retained earnings of the same amount as that paid on ordinary stock. It is obvious that this is not so. By definition, retained earnings are not raised in the financial market. They result from the operations of the firm. Therefore no return has to be paid on them in order to obtain them. What is true, is

TABLE I—CANADIAN PACIFIC RAILWAY

COMPOSITE COST OF CAPITAL EMPLOYED IN RAIL ENTERPRISE AT DECEMBER 31, 1958

		Aggregate Amount	*Percent of Total*	*Cost* Rate*	*Weighted Cost Rate*	
1	Equipment Trust Certificates					1
2	U.S. Currency	$ 16,092,814	1.12	3.72%	.04%	2
3	Canadian Currency	39,743,414	2.76	4.10	.11	3
4	Leased Lines Securities—					4
5	Not owned					5
6	Sterling	$ 49,119,186	3.41	2.52	.09	6
7	U.S. Currency	175,300	.01	5.82	—	7
8	Other	11,314,122	.79	3.12	.02	8
9	Collateral Trust Bonds	$ 125,969,177	8.74	4.36	.38	9
10	Perpetual 4% Consolidated					10
11	Debenture Stock					11
12	Sterling	$ 184,635,859	12.82	2.35	.30	12
13	U.S. Currency	44,617,168	3.10	4.83	.15	13
14	Total Debt	$ 471,667,040	32.75	3.33	1.09	14
15	Preference Stock	$ 121,375,308	8.43	2.53	.21	15
16	Ordinary Stock and					16
17	Retained Earnings	$ 847,107,330	58.82	9.25–9.50	5.44–5.58	17
18	Total Capital	$1,440,149,678	100.00%			18
19	Composite Cost Rate				6.74–6.88%	19

*Reflects reductions in cost on account of exchange rates.

SOURCE: Exhibit 75, submitted by Canadian Pacific Railway to the Royal Commission on Transportation, December 17, 1959.

that if the company does not pay a satisfactory dividend on its ordinary stock, the owners of that stock will become dissatisfied and may refuse to permit the retention of earnings.

TABLE II—MANITOBA AND ALBERTA

RATE OF INTERNAL FINANCING; CANADIAN PACIFIC RAILWAY PERCENTAGES OF TOTAL CAPITAL REQUIREMENTS FINANCED BY DEPRECIATION CHARGES AND RETAINED NET EARNINGS

Date	*Total Capital Requirements*	*Depreciation Charges*	*Retained Earnings*	*Total Internal Financing*	*External Financing*
1884–1894	100	0	0	0	100.0
1895–1904	100	0.5	14.4	14.9	85.1
1905–1914	100	0.3	19.2	19.5	80.5
1915–1919	100	0.7	64.0	64.7	35.3
1920–1929	100	6.0	11.1	17.1	82.9
1930–1939	100	12.5	75.1	87.6	12.4
1940–1946	100	47.8	52.2	100.0	0
1947–1956	100	53.8	33.0	86.8	13.2
1957–1959	100	53.6	34.0	87.6	12.4

SOURCE: 1884–1956 derived from a study of the Source and Application of Funds prepared and filed with the Board of Transport Commissioners by Riddell, Stead, Graham & Hutchison, Chartered Accountants; 1957–59 derived from a similar study prepared by Peat, Marwick, Mitchell & Co., Chartered Accountants.

Quoted by witness M. J. Ulmer, transcript of evidence, *Hearings*, November 9, 1960, Vol. 115, p. 19071.

TABLE III

RATE OF INTERNAL FINANCING, CANADIAN PACIFIC RAILWAY PERCENTAGES OF NEW CAPITAL REQUIREMENTS FINANCED BY RETAINED NET EARNINGS AND EXTERNAL FINANCING

Date	*Retained Earnings*	*External Financing*
1884–1894	0	100.0
1895–1904	14.5	85.5
1905–1914	19.3	80.7
1915–1919	64.5	35.5
1920–1929	11.8	88.2
1930–1939	85.8	14.2
1940–1946	100.0	0
1947–1956	71.4	28.6
1957–1959	73.3	26.7

This point is of particular importance when a historical argument is presented. Table II shows the extent to which the Canadian Pacific Railway has been able to obtain its total capital requirements from internal financing. Since the meaning of "what is required to protect the financial integrity of the enterprise" is, presumably what is required to maintain the capital value of the enterprise, Table III shows an adaption of part of Table II, to estimate the rate of internal financing of new capital requirements. It will be seen that in terms of the definitions above, Canadian Pacific has been able to obtain an important portion of its needed capital without contracting to pay any additional cost.

None of the foregoing argument contradicts the claim that compensation must be paid the shareholders for every dollar raised from them whether "directly . . . . through the sale of stock" or "indirectly through investment of retained earnings". In fact they obtain the same return for either kind of investment. But for different purposes it may be more convenient to present this return as percentages of different bases. For example, according to the Annual Report for 1958 of the Canadian Pacific Railway Company, the dividends declared on ordinary stock of an issued value of $355,294,575 were $21,217,963. This amounts to a yield of 5.97 per cent. Table IV presents a comparison based on market price for the years 1950-1959. For purposes of evaluating the yield from the viewpoint of the present day investor, interested in comparing his likely profit from a purchase of

TABLE IV

YIELDS ON CANADIAN PACIFIC ORDINARY STOCK

Year	*Yield*
	%
1950	7.23
1951	6.21
1952	4.16
1953	5.45
1954	5.52
1955	4.71
1956	4.47
1957	6.09
1958	5.71
1959 (September)	5.56

SOURCE: Exhibit 75, Schedule 9, submitted by Canadian Pacific Railway to the Royal Commission on Transportation, December 17, 1959. (Testimony of Mr. C. W. Smith)

Canadian Pacific ordinary stock with that which might be obtained from purchase of another stock, the data of Table IV is appropriate. If one is interested in the cash return which an original investor would receive today on the cost of his original investment, the figure of 5.97 per cent is appropriate. If, however, one wishes to know the yield which investors in common stock obtain on the amounts which they have paid into the company treasury either directly through the purchase of ordinary stock upon original issue, or indirectly through retained earnings, then the appropriate calculation is to express the dividends of $21,217,963 as a percentage of the sum of the issued value of ordinary stock and of retained earnings, that is of $847,107,330. This calculation results in a yield of 2.1 per cent. Thus it can be seen that the method used by Canadian Pacific to obtain an estimate in current terms is equivalent to equating a yield which historically has been in the region of 6 per cent with one which has historically been in the region of 2 per cent. Had the Canadian Pacific, in developing its composite cost of capital, applied the rate of 9¼-9½ per cent to the base upon which it calculated the rate, that is the direct payments for ordinary shares, lines 16 to 19 of Table I would have appeared as follows:

	Aggregate Amount	*Per Cent of Total*	*Cost Rate*	*Weighted Cost Rate*
16 Ordinary Shares	$ 355,294,575	24.67	9.25–9.60%	2.28–3.24
17 Retained Earnings	491,812,755	34.15	0	0
18 Total Capital	$1,440,149,678	100.00%		
19 Composite Cost Rate				3.58–4.54%

It should be understood, of course, that the cost rate of zero indicated for retained earnings does not imply that in fact no return was earned or paid on this capital but rather that, as has been argued above, the return paid on retained earnings is included in the computation of yield on ordinary shares.

The proposal of the Canadian Pacific is not that the dividends paid on ordinary shares should be at the rate of 9¼-9½ per cent. Rather it was proposed that the dividends should be approximately 6 per cent and that the pay-out ratio should be between 60 and 65 per cent. If the method used by Canadian Pacific was not adopted in error, it contains at least one of three assumptions, none of which has been stated. These are:

(a) that the pay-out ratio will be changed to approximately 30 per cent;

(b) that the dividend rate will be increased beyond 6 per cent; or

(c) that the market price of Canadian Pacific ordinary stock will rise sharply.

This can be seen by examining what would in fact happen if the Canadian Pacific method were followed. The following three examples assume in each case that two of the assumptions listed above are not true.

Example 1:

Assumes that neither the dividend rate nor the market price increases.

(1) Earnings	=	847,107,330 × 9.25	= 78,357,428
(2) Dividends	=	355,294,575 × .06	= 21,317,674
(3) Retained Earnings	=	Line 1 — Line 2	= 57,039,754
(4) Pay-out	=	Line 2 ÷ Line 1	= 27.2%

Example 2:

Assumes that the pay-out ratio is unchanged and that the market price is unchanged.

(1) Earnings	=	847,107,330 × 9.25	= 78,357,428
(2) Dividends	=	78,357,428 × .6	= 47,014,457
(3) Market Value	=	$25.00 × 14,211,783	=355,294,575
(4) Dividend Rate	=	Line 2 ÷ Line 3	= 13.23%

Example 3:

Assumes that the pay-out ratio is unchanged and that the dividend rate is unchanged.

(1) Earnings	=	847,107,330 × 9.25	= 78,357,428
(2) Dividends	=	78,357,428 × .6	= 47,014,457
(3) Dividend Rate	=	6% of Market Price	
(4) Market Value	=	Line 2 × 100/6	=783,574,283
(5) Market Price	=	783,574,283 ÷ 14,211,783	= $55.14

If the Canadian Pacific scheme were followed, but the rates were computed upon the base of investment in ordinary stock (excluding retained earnings) dividends would amount to slightly over $21,000,000 and retained earnings to slightly over $14,000,000. This may be compared to the amounts included in the Board of Transport Commissioners' requirements formula for 1958, under the categories of dividends and surplus. (See Table V.) In the latter case dividends include dividends on preference stock of approximately $3,000,000. (See Table I.)

TABLE V—CANADIAN PACIFIC RAILWAY

REQUIRED EARNINGS ON BASIS OF REQUIREMENTS FORMULA OF THE BOARD OF TRANSPORT COMMISSIONERS FOR CANADA

	1958
Fixed Charges	15,581,000
Dividends	20,620,000
Surplus	15,235,000
Allowance account transfer of non-rail assets to rail	2,400,000
Total	53,836,000

SOURCE: Board of Transport Commissioners for Canada: Judgment and Order, File No. 48771, November 17, 1958, p. 31, Appendix, p.v., Exhibit 58-30.

Table VI restates the cost of money to the Canadian Pacific Railway after the adjustment outlined above and in form similar to the requirements formula of the Board of Transport Commissioners.

TABLE VI—CANADIAN PACIFIC RAILWAY

ADJUSTED COST OF CAPITAL

	1958
Fixed Charges	15,840,000
Dividends	24,388,469
Surplus	12,790,604
Allowance account transfer of non-rail assets to rail	2,400,000
Total	55,418,620

Based upon an investment of $1,440,149,678 this indicates a cost of money of 3.85 per cent, after income taxes. In contrast, the requirements formula indicates a cost of money of 3.74 per cent, after income taxes.

The presentation of Canadian National is shown as Table VII. Two adjustments have been made in these figures as presented by the CNR. The revised figures are presented as Table VIII. The first adjustment has been to remove the 4 per cent Preferred Stock from the pool of Shareholders' Equity to its own category. The rate charged on this stock has then been changed from 9¼ to 4 per cent. There appears to be no clear indication

TABLE VII—CANADIAN NATIONAL RAILWAYS

COMPOSITE COST OF CAPITAL EMPLOYED, AT DECEMBER 31, 1958

	Principal Outstanding		Debt-Equity Ratio	*Interest and Amortization*		
	December 31, 1958				*Annual Amount*	*Rate*
LONG TERM DEBT						
Bonds, Debentures and Equipment Obligations	$1,033,808,970			$35,777,824		
Less: Debt Incurred for Investment in TCA	11,056,977	1,022,751,993		409,006	35,368,818	3.458%
Government of Canada Loans and Debenture	484,791,699					
Less: Transferred to Equity	116,988,091					
	367,803,608			18,757,985		
Less: Loans in Respect of Investment in TCA	56,600,000	311,203,608		2,886,600	15,871,385	5.10 %
TOTAL LONG TERM DEBT		1,333,955,601	42.5		51,240,203	3.841%
SHAREHOLDERS' EQUITY						
6,000,000 Shares NPV Capital Stock—CNR	389,518,135					
Less: Capital Stock Issued for Investment in TCA	1,400,000	388,118,135				
882,320,571 Shares 4% Preferred Stock—CNR	882,320,571					
Less: Capital Stock Issued for Investment in TCA	19,043,023	863,277,548				
Capital Investment in Canadian Government Railways		432,549,139				
Capital Stock of Sub. Companies Owned by Public		4,504,203				
Transferred from Long Term Debt						
Debenture—Capital Revision Act 1952	100,000,000					
Can. Govt. Rlys.—Advances for Working Capital	16,988,091	116,988,091				
TOTAL SHAREHOLDERS' EQUITY		1,805,437,116	57.5		167,002,933	9.25 %
TOTAL LONG TERM DEBT AND SHAREHOLDERS' EQUITY		3,139,392,717	100.		218,243,136	6.95 %

Statement N.A.-1

SOURCE: Exhibit 76A, submitted by Canadian National Railways to the Royal Commission on Transportation, December 17, 1959.

TABLE VIII—CANADIAN NATIONAL RAILWAYS

REVISED COMPOSITE COST OF CAPITAL EMPLOYED AT DECEMBER 31, 1958

	Principal outstanding		Per cent of total	Interest and amortization		
	December 31, 1958			Annual amount		Rate
LONG TERM DEBT						
Bonds, Debentures and Equipment Obligations	$1,033,808,970			$35,777,824		
Less: Debt Incurred for Investment in TCA	11,056,977	1,022,751,993		409,006	35,368,818	3.458%
Government of Canada Loans and Debenture	484,791,699					
Less: Transferred to Equity	116,988,091					
	367,803,608			18,757,985		
Less: Loans in Respect of Investment in TCA	56,600,000	311,203,608		2,886,600	15,871,385	5.10 %
Total Long Term Debt		1,333,955,601	42.5		51,240,203	3.841
PREFERRED STOCK						
882,320,571 Shares 4% Preferred Stock—CNR	882,320,571					
Less: Capital Stock Issued for Investment in TCA	19,043,023	863,277,548	27.5		34,531,102	
ORDINARY STOCK						
6,000,000 Shares NPV Capital Stock—CNR	389,518,135					
Less: Capital Stock Issued for Investment in TCA	1,400,000	388,118,135				
Capital Investment in Canadian Government Railways		432,549,139				
Capital Stock of Sub. Companies Owned by Public		4,504,203				
Transferred from Long Term Debt						
Debenture—Capital Revision Act 1952	100,000,000					
Can. Govt. Rlys.—Advances for Working Capital	16,988,091	116,988,091				
Total Shareholders' Equity		942,159,568	30.0		87,497,600	6.00 %
TOTAL LONG TERM DEBT AND SHAREHOLDERS' EQUITY		3,139,392,717	100.0		173,268,905	5.52 %

TABLE IX—CANADIAN PACIFIC RAILWAY

INTEREST ON ("MARGINAL") INVESTMENT IN ROAD PROPERTY AND EQUIPMENT APPLICABLE TO STUDY TRAFFIC AT RECOMMENDED RATE

	Investment category	*Output unit*	*Interest per unit*	*Output units of study traffic*	*Applicable to study traffic*	
1	Road Property	Gross Ton-Miles	$0.16488	12,233,795	$2,017,108	
2		Yard and Train				
3		Switching Miles	0.47899	828,054	396,630	$2,413,738
4	Diesel Yard Locomotives	Yard Engine Miles	0.14693	600,527	88,235	
5	Diesel Road Locomotives	Train-Miles	0.17526	3,513,951	615,855	
6		Train Switching Miles	0.13509	227,527	30,737	
7	Steam Locomotives	Train-Miles	0.02446	3,513,951	85,951	
8		Yard Switching Miles	0.03451	600,527	20,724	
9		Train Switching Miles	0.10818	227,527	24,614	
10	Freight Train Cars	Car-Days	0.56997	4,189,930	2,388,134	
11	Work Equipment	Gross Ton-Miles	0.00448	12,233,795	54,807	
12	Shop and Power Plant Machinery	Train-Miles	0.01695	3,513,951	59,561	3,368,618
13						5,782,356

that after receipt of 4 per cent of this stock, the shareholder is entitled to participate further in company earnings. In the absence of such a clear indication it has been assumed that there will not be such participation. The second adjustment has been to remove from the portion claimed as return on the remaining equity, that part which is designed to allow retained earnings. Canadian National is not allowed to retain earnings, therefore it does not seem necessary to make provision for them. These adjustments result in a composite cost of capital of 5.52 per cent for the Canadian National.

This approach amounts to an attempt to place the Canadian National upon a basis similar to that of a corporation which is not owned by the Government. The fact is, however, that the Canadian National is owned by the Government. Whether the money invested in the CNR is raised by the railway directly or indirectly through the Government, the fact is that the money raised is guaranteed by the Dominion of Canada. The cost rate applicable is therefore the cost rate applicable to Dominion of Canada long-term bonds. As the first section of Table VII shows this rate has been of the order of 3.8 per cent.

I recommend that the Commission, in considering the appropriate rate for grain, utilize a rate of 3.74 per cent, after income taxes, in the case of the Canadian Pacific, and 3.8 per cent in the case of the Canadian National. This recommendation contains no judgement on the interest which either railway would have to pay were it to seek additional capital. Should the Canadian Pacific, for example, attempt to raise additional capital and should it be forced to pay seven per cent upon that additional capital, one would expect that the Board of Transport Commissioners would reassess the permissive level of earnings. This recommendation merely reflects the belief of the author that the rate of return used in considering an appropriate rate for grain should not differ from the rate used in considering railway operations generally, and the belief that to criticize the permissive level of earnings set by the Board would fall without the Terms of Reference of this Report.

Chapter 7

Substantially-Related Lines

Each service offered or line operated by a railway serves a partially separate market. The task of analysing the effect of a change of rates, or the abandonment of service on a line, on each of these thousands of markets would be herculean. Therefore, when rates are being considered, it is usual to assume that the present services and lines will be continued. Those costs of maintenance of track and road property which can be associated with miles of track are considered to be fixed costs.

In their presentations to the Commission, the railways departed from the practice of assuming that these road maintenance costs are fixed. Instead, they included, as part of their estimates of the variable cost of transporting grain, an amount to cover the cost of maintaining certain lines which they labelled "solely-related" to the grain trade. It was asserted that these facilities are in existence only to serve the grain trade, and that, therefore, for these lines, the grain trade should bear those costs of maintenance variable with size of plant, the taxes on this plant, depreciation and the cost of money.

Three tests were employed by the railways to identify the solely-related lines. The first test was an examination of the traffic carried to ensure that it was preponderantly grain; the second was an examination of the particular company's rail system to ensure that the remaining system would be viable if the particular lines in question were to be abandoned; the third was an economic test.

The economic test employed by the Canadian National was to find whether the net incremental return, that is the incremental revenues (for this purpose 50 per cent of the revenue was assumed necessary to meet the costs of transportation on the main line), less the incremental costs, were negative for non-grain traffic. Costs variable with output and with size of plant were both included in these incremental costs. If the net incremental return was negative, the line was said to be solely-related.

The Canadian Pacific, as their economic test, determined whether the incremental cost of the branch line non-grain traffic (both branch and main line non-grain costs), plus the maintenance expense which could be attributed directly to the existence of the miles of branch line track, was less than the total revenue from the branch non-grain traffic. The Canadian Pacific argued that: "Where non-grain revenues less incremental costs exceeded the size associated costs the line would have been economic to build if grain were not

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handled. Where the revenue fell short of these costs . . . the line would not have been economic if grain were not handled."[1] As a check the Canadian Pacific also employed the test used by Canadian National.

The economic tests applied by the railways suffer from a grave defect. If the revenues from the grain traffic are sufficiently low, and the burden of the railways' argument was that they are sufficiently low, one could show that most of those lines were solely-related to non-grain traffic by a simple reversal of terms. For example, the Canadian Pacific argument could be re-stated to read: "Where the grain revenues less incremental costs exceeded the size associated costs the line would have been economic to build if non-grain traffic were not handled. Where the revenue fell short of these costs the line would not have been economic if non-grain traffic were not handled." Thus, based on the same figures, and with the same form of argument, one could argue that certain lines were both solely-related to grain traffic and solely-related to non-grain traffic.

The first test which the railways applied, that the traffic over the line in question must be preponderantly grain traffic, does not give justification for the use of the term "solely-related". Other products were in fact carried over these lines.[2] General semanticists have pointed out for many years there is a constant danger that the characteristics implied by a label will be attributed to the thing or action labelled, whether or not these characteristics do, in fact, apply to the thing or action. In the present case, the use of the label "solely-related" implies that the facilities being examined are of use only to the grain trade. If this implication is accepted, it follows that the maintenance of these facilities is a charge which should be borne by the grain traffic. Since traffic other than grain is carried on these lines, they cannot be, with strict definition, labelled "solely-related". The term "substantially-related" suggested by R. L. Banks and Associates appears more suitable.

The extent to which the costs of maintaining these substantially-related lines should be borne by one particular class of traffic must be decided in accordance with considerations similar to those discussed in Chapter 5, "The Constant Costs of the Grain Traffic". The fact that a high proportion of the traffic carried on these lines is grain does not, in itself, mean that grain must carry the cost of maintaining the lines. But if the contribution of other traffic, to the cost of maintaining the line, cannot be raised, then (a) the contribution of grain must be raised, (b) the line must be abandoned or (c) the line must be subsidized.

[1] Transcript of evidence, *Hearings*, December 15, 1959, Vol. 18, p. 2559. Similar comments by the Canadian National can be found in Vol. 17, p. 2372.

[2] The Canadian Pacific said that the weighted average of grain to total traffic on the set of solely-related lines was 82.4 per cent. Transcript of evidence, *Hearings*, December 15, 1959, Vol. 18, p. 2563. The Canadian National said that in all cases the revenue ton-miles for grain were 70 per cent of those for all traffic. Transcript of evidence, *Hearings*, December 14, 1959, Vol. 17, p. 2379.

The last two of these possible solutions are especially important in view of the claims, heard by the Commission, that the existence of light-density lines is a greater problem to the railways than is the remuneration which is received from the transport of grain. Two exhibits, submitted by the railways at the request of the Commission, support the view that the existence of light-density lines is, indeed, a major problem of the railways. These exhibits (reproduced at the end of this chapter) indicate that, even if all the costs estimated by the railways were covered by revenues from the grain traffic, some of the substantially-related lines would remain unprofitable. At rate levels intermediate between those presently in force and those requested by the railways, still more lines were shown as unprofitable. These exhibits cast doubt on the proposition that all of the substantially-related mileage can be viewed as "used and useful" in any realistic sense. Until it has been shown that these lines are in fact necessary to the grain trade, it does not seem reasonable to include the costs of their maintenance among the variable costs of the grain traffic. Once it has been shown that particular rail lines do, in fact, remain in existence because of the grain trade, it seems clear that the grain traffic should bear the primary responsibility of making these lines economically viable. At such a time, the cost of maintaining these lines should be considered as a cost of transporting grain.

It is therefore recommended that the Commission make no provision for including the cost of maintaining substantially-related lines in the estimated cost of transporting grain. Rather, it is suggested that the problem of light-density lines be met as a problem of light density. The necessity of continuing each of the light-density lines should be examined. In doing this, where it is possible to do so (and the railways have demonstrated the possibility at least in the case of lines substantially devoted to grain), the method utilizing the entire revenue from the line in order to judge its profitability is much preferable to the more usual method of attributing one-half of the revenue to the line. The former method indicates clearly whether or not the line makes any contribution to the maintenance of the railway as a whole.

During some interim period, it may be desirable to aid the railways to continue unprofitable lines until a final adjustment has been made; either in the mileage operated or in the rates for the goods carried.

Since there is no way in which the Commission can now know the unprofitable lines of the entire Canadian railway system some criterion of estimation—such as the mileage below a set density—will have to be used as an aid. Similarly, some arbitrary figure for maintenance costs will have to be used in order to estimate the costs of light-density lines. The analysis of Chapter 4 indicates that the road property maintenance costs per mile will vary from division to division. Thus it is necessary to know the division in which the line is operating in order to estimate the costs. In lieu of this, it is

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recommended that the Commission use the linear estimates of the railways as its estimate of per mile cost in order to reach a reasonable conclusion on the cost of maintaining light-density lines.

Because of the approximations which must be made, it is suggested, that the Commission make any recommendations for assistance to the railways, in the area of light-density lines in terms of a maximum subsidy, with the proviso that the actual subsidy shall be the loss sustained by the railways on lines which they have proven to be uneconomic. For purposes of computing this maximum subsidy it is recommended that the cost of operating light-density lines be set at $1,500 per mile per year.

Exhibit No. 144

Request of Mr. Geo. Cumming, Vol. 69, p. 12346

CANADIAN PACIFIC RAILWAY

SOLELY RELATED BRANCH LINES WHICH WOULD REMAIN UNECONOMIC AT VARIOUS STATED AVERAGE REVENUES PER TON MILE FOR GRAIN AND GRAIN PRODUCTS

0.75¢ per Revenue Ton Mile			*0.90¢ per Revenue Ton Mile*			*1.00¢ per Revenue Ton Mile*		
Subdivision	*Date of Construction*	*Mileage*	*Subdivision*	*Date of Construction*	*Mileage*	*Subdivision*	*Date of Construction*	*Mileage*
Alida	1902–1912	53.9	Alida	1902–1912	53.9	—	—	—
Boissevain	1911–1913	35.5	—	—	—	—	—	—
Cassils	1928	23.2	Cassils	1928	23.2	Cassils	1928	23.2
Colony	1931	24.6	Colony	1931	24.6	—	—	—
Lorraine	1915	11.4	Lorraine	1915	11.4	—	—	—
McAuley	1904	16.8	McAuley	1904	16.8	McAuley	1904	16.8
Medstead	1931	36.0	Medstead	1931	36.0	Medstead	1931	36.0
Miniota	1888–1900	43.8	—	—	—	—	—	—
Rapid City	1886–1889	35.0*	Rapid City	1886–1889	35.0	—	—	—
Reston	1906–1908	122.4	Reston	1906–1908	122.4	—	—	—
Snowflake-Fallison	1900–1903, 1908–1909	41.6	Snowflake-Fallison	1900–1903, 1908–1909	41.6	Snowflake-Fallison	1900–1903, 1908–1909	41.6
Varcoe	1889–1906	55.5	Varcoe	1889–1906	55.5	Varcoe	1889–1906	55.5
Woolford	Raley-Woolford, 1905 Woolford-Wiskey Gap, 1929	20.4	Woolford	Raley-Woolford, 1905 Woolford-Wiskey Gap, 1929	20.4	—	—	—

*Forrest to Minnedosa only.

Exhibit No. 151

Request of Mr. Geo. Cumming, Vol. 75, p. 13196

CANADIAN NATIONAL RAILWAYS

SOLELY RELATED BRANCH LINES WHICH WOULD REMAIN UNECONOMIC AT VARIOUS STATED AVERAGE REVENUES PER TON MILE FOR GRAIN AND GRAIN PRODUCTS

	Revenue Per Ton Mile		
Subdivision	*0.75¢ Mileage*	*0.90¢ Mileage*	*1.00¢ Mileage*
Amiens	75.0	75.0	75.0
Bengough	71.5	—	—
Blewett	20.9	20.9	20.9
Carberry (Petrel Jct.–Carberry Jct.)	9.9	9.9	9.9
Conquest	59.3	59.3	59.3
Corning	22.3	—	—
Cutknife	43.8	43.8	43.8
Demay	25.0	25.0	25.0
Endiang	75.2	75.2	75.2
Goodwater	26.8	26.8	26.8
Haight	21.6	21.6	21.6
Harte (Pacific Jct.–East Tower)	46.6	46.6	46.6
Hartney	91.4	—	—
Hatherleigh	31.6	91.4	91.4
Kingman	23.4	23.4	23.4
Lewvan	116.8	—	—
Main Center	48.6	—	—
Meskanaw	91.4	91.4	91.4
Miami	62.1	—	—
Neepawa (Rossburn Jct.–Neepawa Jct.)	32.8	32.8	32.8
Pleasant Point (Brandon Jct.–West Tower)	51.7	51.7	51.7
Porter	48.2	48.2	48.2
Rapid City	74.4	74.4	74.4
Rhein	37.8	37.8	—
Robinhood	101.5	101.5	101.5
Spondin	17.7	17.7	17.7
Wakopa	79.9	79.9	79.9
Wawanesa	37.5	37.5	37.5
Total Mileage	1,444.7	1,032.0	994.2
Total No. Subdivisions	28	22	21

Costs and Statistics Branch, Montreal, August 31st, 1960.

Chapter 8

The Costs of Passenger-Train Service

The costs of passenger-train service presented by the railways were based upon the studies which are examined in detail in the previous chapters. Some of the problems of costing passenger-train service are less difficult than those of the grain trade since some classes of expenditures are recorded separately for passenger-train service. With this exception, the qualifications noted for many parts of the grain study apply to the estimates of the cost of passenger-train service.

Because of these qualifications, it is recommended that the Commission accept the cost presentations of the railways as a basis for a maximum subsidy, and that the actual subsidy be limited to the sum which the railways show to be their loss on this service, through the annual presentation of revised estimates.

Chapter 9

The Need for Future Analysis

This report has attempted to describe railway costing, as it exists in Canada today, using the cost of transporting grain to export positions as an extended example. Scattered throughout the report are references to areas of costing on which better evidence is needed. The point of view of the author, given at the conclusion of Chapter 3, is that the cost estimates given here provide a basis for decision, a better basis than has been available before. The Commission is faced with problems which demand decision. Insofar as cost is an element in those decisions, the cost estimates discussed here are, in the author's opinion, the best available at the moment.

To hold this point of view is not to suggest that there is no need for improvement. Improved cost estimates are needed by the railway managements in order that they may decide, with greater confidence, the limitations which their cost structure places upon their ability to compete with other modes of transport. They are needed in order to give better managerial control. It was pointed out in Chapter 3 that the precision with which management can attribute historical costs is one measure of its ability to control effectively the organization it controls. Imprecision in estimates of historical costs, whether caused by vagueness in knowledge or by the necessity to resort to arbitrary methods of apportionment of costs, is a measure of managements' lack of knowledge of the determinants of cost. Obviously, to the degree that the relation of costs to outputs is not known, the control of costs becomes impossible.

Improved knowledge of costs is important to the body which regulates the railroads or at least it will be so long as regulators insist that the railways cannot move traffic at non-compensatory rates. To those bodies which are responsible for determining the amount of investment which will be made in competing modes of transportation, a knowledge of the cost advantages and disadvantages of each mode of transportation will be a help in improving the quality of these decisions. As an example, it would be worthwhile to such an authority to know that if a projected highway transport operation is allowed, the new operation will be able to compete successfully with the railway for certain traffic and that the costs of transporting the traffic remaining with the railway will then rise sufficiently (on an average basis) that the total transportation bill will rise.

Because of the variety of situations which can arise, in which a knowledge of costs or of cost structures will be important to public authorities, a small cost section could well be formed by the Dominion Government. This section could be given as its duties, the examination of cost estimates submitted to Dominion regulatory bodies and departments of government. Initially, the cost section might confine its activities to railways, building upon the basis which has been constructed during the Commission's hearings. Expansion to air transportation could be envisaged, and, with the co-operation of provincial authorities, to motor transport.

Initially, this cost section might begin its operations by consulting with the railways on the construction of cost estimates submitted in support of various applications by the railways. For example, should it be decided that the railways will be reimbursed for losses suffered in providing services which they are required by law to provide, the cost section should examine the estimates of loss suffered. When the railways wish to initiate changes in costing procedure, prior consultation with the cost section would do much to increase the public acceptance of improved costing techniques.

It would be unfortunate if such a cost section should leave the initiative for improvements in costing techniques entirely in the hands of the railways. As we have seen, some ways of attempting improvement are suggested by comparison of the results of using one railway's methods with another's data. A cost section in the Dominion Government may well be able to initiate such studies more successfully than could either of the railways. There are also cases, such as the method of attributing car days to particular traffic. Where basic differences in method such as this exist, an obvious function of the cost section would be to attempt to bring about agreement on the superiority of one method, and failing this, to recommend to the regulatory authority one method to be acceptable in official proceedings.

One of the purposes of the present report has been to provide a point of departure for such a body.

COST ESTIMATES

PRESENTED BY CANADIAN PACIFIC RAILWAY

Exhibit No. 63
(Revised)

CANADIAN PACIFIC RAILWAY

VARIABLE PORTION OF ROAD MAINTENANCE EXPENSE APPLICABLE TO THE STUDY TRAFFIC

	Account	*Group of Accounts*	*Independent Variable*	*Unadjusted Coefficient or Unit Cost*	*Adjust-ment Factor*	*Adjusted Coefficient or Unit Cost*	*Suptce*	*Total Coefficient or Unit Cost*	*Output Unit of Study Traffic*	*Applicable to Study Traffic*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	
1	201	Road Maintenance Superin-	Road Mtce Expenses	$0.03288	1.59587	$0.05247	—	—	—	—	1
2	274	tendence and Overhead	Excluding Suptce								2
3	276										3
4	277										4
5	202	Track Maintenance and De-	Thousands of Gross	$0.16475	1.01430	$0.16711	$0.00864	$0.17575	12,233,795	$2,150,089	5
6	208	preciation	Ton-Miles-Frt.								6
7	212										7
8	214		Yd and Train Swg.	$0.39053	1.01430	$0.39611	$0.02049	$0.41660	1,046,493	435,969	8
9	216		Miles								9
10	218										10
11	229										11
12	266										12
13	269										13
14	271										14
15	273										15
16	281										16
17	227	Station and Office Bldgs	Carloads	$1.33237	1.06861	$1.42378	$0.06991	$1.49369	175,203	261,699	17
18	266	Maintenance and Depreciation									18
19	231	Water and Fuel Stations	$ of Fuel Expense[1]	$0.01070	1.00285	$0.01073	$0.00056	$0.01129	2,662,837	30,063	19
20	266	Maintenance and Depreciation	$ of Water Expense[1]	$0.45140	1.00285	$0.45269	$0.02368	$0.47637	72,565	34,568	20

21	235	Shops and Enginehouses	$ of Direct Equip. Mtce	$0.05230	1.31299	$0.06867	$0.00274	$0.07141	7,072,797	505,068	21
22	266	Maintenance and Depreciation									22
23	249	Signals Maintenance and De-	Train-Miles	$0.04772	1.06483	$0.05081	$0.00250	$0.05331	3,490,182	186,062	23
24	266	preciation									24
25	253	Power Plants Maintenance and	$ of Station Employees	$0.01546	1.23230	$0.01905	$0.00081	$0.01986	885,043	17,577	25
26	266	Depreciation									26
27	275	Insurance and Joint Facilities	$ of Road Maintenance	$0.01060	1.00000	$0.01060	$0.00056	$0.01116	3,621,095	40,411	27
28	278										28
29	279										29
30										$3,661,506	30

[1]Account 231 was analysed by regression which showed that this account varied with water and fuel expense. The expense was in turn charged to output units of the study traffic on the basis of fuel and water expense of the study traffic.

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Exhibit No. 64
(Revised)

CANADIAN PACIFIC RAILWAY

VARIABLE PORTION OF EQUIPMENT MAINTENANCE EXPENSE APPLICABLE TO THE STUDY TRAFFIC

	Account	*Group of Accounts*	*Independent Variable*	*Unadjusted Coefficient or Unit Cost*	*Adjustment Factor*	*Adjusted Coefficient or Unit Cost*	*Output Unit of Study Traffic*	*Applicable to Study Traffic*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
1	301	Equipment Mtce Suptce and Over-	$ of Direct Equip. Mtce	$0.04990	$2.00526	$0.10006	$7,072,797	$707,704	1
2	302	head	Excl. Depreciation						2
3	305								3
4	306								4
5	329								5
6	332								6
7	333								7
8	334								8
9	335								9
10	336								10
11	337								11
12	308-311	Road Locomotive Repairs	Train Miles	$0.39718	—	$0.39718	4,465,450	1,773,587	12
13			Train Swg. Miles	$0.34653	—	$0.34653	244,029	84,563	13
14		Yard Locomotive Repairs	Yard Swg. Miles	$0.20762	—	$0.20762	802,464	166,608	14
15								2,024,758	15
16	331	Road Locomotive Depreciation	Train Miles	$0.16496	—	$0.16496	4,465,450	736,621	16
17			Train Swg. Miles	$0.26799	—	$0.26799	244,029	65,397	17
18		Yard Locomotive Depreciation	Yard Loco-Miles	$0.14384	—	$0.14384	802,464	115,426	18
19	314	Freight Train Car Repairs	Car-Miles	$0.01712	—	$0.01712	213,831,793	3,660,800	19
20			Car Days	$0.25363	—	$0.25363	5,274,358	1,337,735	20
21								4,998,535	21

22	331	Freight Train Car Depreciation	Car-Miles	$0.00427	—	$0.00427	213,831,793	913,062	22
23			Car Days	$0.22957	—	$0.22957	5,274,358	1,210,834	23
24								2,123,896	24
25	326	Work Equipment Repairs	$ of Road Mtce	$0.01352	—	$0.01352	$3,661,506	49,504	25
26	331	Work Equipment Depreciation	$ of Road Mtce	$0.00437	—	$0.00437	$3,661,506	16,001	26
									27
27								$10,837,842	28
28									

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Exhibit No. 65
(Revised)

CANADIAN PACIFIC RAILWAY

VARIABLE PORTION OF TRANSPORTATION EXPENSES APPLICABLE TO THE STUDY TRAFFIC

	Account	*Group of Accounts*	*Independent Variable*	*Unadjusted Coefficient or Unit Cost*	*Adjust-ment Factor*	*Adjusted Coefficient or Unit Cost*	*Suptce*	*Total Coefficient or Unit Cost*	*Output Units of Study Traffic*	*Applicable to Study Traffic*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	
1	371	Transportation Superintendence	$ of Transportation Exp.	$0.02442	1.79756	$0.04390	—	—			1
2	374	and Overhead									2
3	410										3
4	411										4
5	415										5
6	416										6
7	420										7
8	372	Dispatching and Station	Carload	$5.61490	1.01101	$5.67672	$0.24649	$5.92321	175,203	$1,037,764	8
9	373	Employees and Expenses									9
10	376										10
11	377	Yardmasters and Clerks	Yard Switching Mile	$0.46992	1.09439	$0.51428	$0.02063	$0.53491	802,464	429,246	11
12	378	Yard Expenses		$2.37435	1.00498	$2.38617	$0.10423	$2.49040	802,464	1,998,456	12
13	379										13
14	380										14
15	382										15
16	385										16
17	389										17
18	386, 388	Yard Other Expenses	Yard Switching Mile	$0.14389	1.01193	$0.14561	$0.00632	$0.15193	802,464	121,918	18
19	392	Train Enginemen, Train Loco.-	Direct	—					—	6,378,621	19
20	394	Fuel and Power, Trainmen									20
21	401	Train Switching	Direct	—					—	279,950	21

22	398	Train Enginehouse Expenses and	Loco.-Miles	$0.14400[1]	1.02378	$0.14742	$0.00632	$0.15374	4,709,724	724,073	22
23	400	Train Loco. Other Supplies									23
24	397	Train Locomotive Water	Direct per Loco.-Miles	$0.01331	0.99913	$0.01330	$0.00058	$0.01388	4,709,724	65,371	24
25	402	Train Other Expenses	Car-Miles	$0.00222	0.94909	$0.00211	$0.00010	$0.00221	213,831,793	472,568	25
26			Grain Doors (Direct)							716,395	26
27			Train Miles	$0.17772	0.94909	$0.16867	$0.00780	$0.17647	4,465,450	788,018	27
28	404	Signals Operation	Train Miles	$0.01146	1.06483	$0.01220	$0.00050	$0.01270	3,490,182	44,325	28
29	390-391	Joint Facilities and Insurance	$ of Transportation	$0.01206	1.00000	$0.01206	$0.00053	$0.01259	13,371,910	168,352	29
30	412,413,414										30
31	418	Loss and Damage—Freight	Direct						—	315,205	31
32										$13,540,262	32

[1]Regression analysis indicated separate coefficients for steam and diesel locomotive-miles. A weighted coefficient was developed from that analysis based on the weighted locomotive-miles of steam and diesel on the Prairie and Pacific Region in 1958.

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Exhibit No. 66
(Revised)

CANADIAN PACIFIC RAILWAY

COST OF MONEY FOR INVESTMENT IN ROAD PROPERTY AND EQUIPMENT APPLICABLE TO STUDY TRAFFIC

	Name of Investment Category	Independent Variable or Output Unit	Unit Variable Cost	Output Units of Study Traffic	Applicable to Study Traffic		
	(1)	(2)	(3)	(4)	(5)	(6)	
1	Road Property	Gross Ton-Miles	$0.28926	12,233,795	$ 3,538,748		1
2		Yard and Train					2
3		Switching Miles	$0.84033	1,046,493	879,399	$ 4,418,147	3
4	Diesel Yard Locos	Yard Engine Miles	$0.25778	802,464	206,859		4
5	Diesel Road Locos	Train-Miles	$0.30748	4,465,450	1,373,037		5
6		Train Swg. Miles	$0.23700	244,029	57,835		6
7	Steam Locos	Train-Miles	$0.04291	4,465,450	191,612		7
8		Yard Swg. Miles	$0.06055	802,464	48,589		8
9		Train Swg. Miles	$0.18979	244,029	46,314		9
10	Freight Train Cars	Car Days	$0.99994	5,274,358	5,274,042		10
11	Work Equipment	Gross Ton-Miles	$0.00786	12,233,795	96,158		11
12	Shop and Power Plant Mach'y	Train-Miles	$0.02974	4,465,450	132,802	$ 7,427,248	12
13						$11,845,395	13

408 (Revised)

Exhibit No. 67
(Revised)

CANADIAN PACIFIC RAILWAY
DEVELOPMENT OF COST FOR LINES SOLELY RELATED TO THE STUDY TRAFFIC

	Account Number	Group of Accounts	Coefficient (per Mile of Track)	Adjustment Factor	Adjusted Coefficient per Mile of Track	
	(1)	(2)	(3)	(4)	(5)	
	A. *Road Maintenance and Depreciation*					
1	201, etc.	Road Maintenance Superintendence and	$ 43.92223	1.64255	$ 72.14446	1
2		Overhead				2
3	202, etc.	Track Maintenance and Depreciation	1136.81110	1.04397	1186.79668	3
4	221-266	Fences, Snowsheds and Signs, Maintenance				4
5		and Depreciation	$ 58.83700	.98748	58.10036	5
6					$1317.04150	6
7		*ADD* Superintendence (at $0.05247 per $ of direct Road Maintenance)			62.73566	7
8		Total Road Maintenance per Mile of Track			$1379.77716	8
	B. *Investment in Road Property*					
9	Gross Property Investment Associated with					9
10	Miles of Track (Statement 404)	$15,130.387				10
11	*Less* Accrued Depreciation @ 36.07%	5,457.531				11
12	Net Investment	$ 9,672.856				12
13	Investment Cost				$1004.04245	13
14				Total	$2383.81961	14
15	Miles of Track Solely Related to Study Traffic			3114.9		15
16	Total Cost for Lines Solely Related to Study Traffic					16
17	Road Maintenance Portion			$4,297,868		17
18	Road Property Investment Portion			3,127,492		18
19			Total	$7,425,360		19
20	*Less* Credit Net Contribution Non-Grain Traffic					20
21	Road Maintenance Portion		$677,207			21
22	Road Property Investment Portion		492,793	$1,170,000		22
23					$6,255,360	23

409 (*Revised*)

Exhibit No. 68

(Revised)

CANADIAN PACIFIC RAILWAY

VARIABLE COST OF TRAFFIC AND GENERAL, COMMUNICATIONS—RAIL, RENTS AND TAXES (OTHER THAN INCOME TAXES) APPLICABLE TO THE STUDY TRAFFIC

A. *Percentage Relationship that Traffic and General, Communications—Rail, Rents and Taxes (other than Income Taxes) is to Total Freight Operating Expense—Year 1958*

Traffic and General	12.423%
Communications—Rail	1.965
Rents and Taxes	2.819
Total	17.207%

B. *Base Relationship Variable Cost Study Traffic*

Roadway Maintenance—Variable	$ 3,661,506
Roadway Maintenance—Solely Related Facilities	4,297,868
Equipment Maintenance	10,837,842
Transportation	13,540,262
	$32,337,478

C. *Applicable to Study Traffic*

Traffic and General	12.423%	$4,017,285
Communications—Rail	1.965	635,431
Rents and Taxes	2.819	911,594
Total	17.207%	$5,564,310

410 (Revised)

Exhibit No. 69
(Revised)

CANADIAN PACIFIC RAILWAY

DEVELOPMENT OF CONSTANT COSTS

A. *System Railway Expenses*		
System Railway Expenses—1958	$430,919,006	
Deduct:		
Total Freight Variable Expenses (including Traffic General and Taxes)	$230,807,578	
Passenger Variable Expenses (including Traffic General and Taxes)	86,303,682	
Income Tax	19,200,000	
Accts. 237, 241 and 265 (including Overhead and Traffic General Taxes)	635,980	
Size Related Costs—Constant	37,887,169	374,834,409
Balance		$ 56,084,597
Percentage Chargeable Study Traffic		15.013%
Amount Applicable Study Traffic (excluding Cost of Money)		8,419,981
B. *Cost of Money*		
Total Road Property Investment—1958		$1,265,184,445
Deduct:		
Commercial Communications	$ 57,303,370	
Wharves	16,400,206	
Grain Elevators	3,033,101	
Other Structures	5,980,070	
Size Related Investment	354,470,168	
Variable Investment	461,216,114	898,403,029
Balance (Gross Investment)		$366,781,416
Net Investment @ 63.93%		234,483,359
Cost of Money @ 10.38%		24,339,373
Plus Work Equipment	$ 167,756	
Shop and Power Plant machinery	203,868	371,624
		$ 24,710,997
Percentage Chargeable Study Traffic		15.013%
Amount Applicable Study Traffic		3,709,862
C. *Total Constant Costs* Applicable to Study Traffic		$ 12,129,843

411 (Revised)

Exhibit No. 70
(Revised)

CANADIAN PACIFIC RAILWAY

DEVELOPMENT OF CONSTANT COST PORTION OF SIZE RELATED COSTS

	Account Number	Group of Accounts	Cost per Mile of Track	Adjustment Factor to reflect System Exps.	Adjusted Cost per Mile of Track	
	(1)	(2)	(3)	(4)	(5)	
1	201, etc.	Road Maintenance, Superintendence and Overhead	$ 43.92223	1.64255	$ 72.14446	1
2	202, etc.	Track Maintenance and Depreciation	1136.81110	1.04397	1186.79668	2
3	221–266	Fences, Snowsheds and Signs Maintenance and Depreciation	58.83700	.98748	58.10036	3
4		*Add* Superintendence (at $0.05247 per $ of Direct Road Maintenance)			62.73566	4
5					$ 1379.77716	5
6		Traffic, General, Joint Facility Rents, Communications—Rail and Taxes @ 17.207%			237.41826	6
7					$ 1617.19542	7
8		Investment Cost in Road Property (Statement 409)			1004.04245	8
9					$ 2621.23787	9
10		Miles of Track Maintained System after deducting miles of track of solely related facilities			20,312.8	10
11		Total Costs Associated with size of plant			$ 53,244,681	11
		Applicable to Study Traffic				
		Percent that variable expense applicable to study traffic after deducting costs of solely related facilities bears to total variable expenses freight services				
12		Percent			15.013%	12
13		Amount			$ 7,993,624	13

412 (Revised)

Appendix B

COST ESTIMATES

PRESENTED BY CANADIAN NATIONAL RAILWAYS

Exhibit 57 ZZ

(Revised)

CANADIAN NATIONAL RAILWAYS

VARIABLE COST OF MOVING GRAIN AND GRAIN PRODUCTS AT STATUTORY AND RELATED RATES

Road Maintenance	*Units variable with study traffic*	*Unit variable cost*	*Variable costs less depreciation*	*Depre-ciation ratio*	*Depreciation*	*Total variable costs*
	$	$	$		$	$
Superintendence and miscellaneous						
201, 274, 275, 276, 277						
Direct road maintenance expense	5,086,003	0.11554				587,637
Track and road maintenance						
202, 208, 212, 214, 216, 218,						
229, 269, 270, 271, 273, 281						
Miles of roadway	2,955.3	893.37	2,640,176	.41548	1,096,940	3,737,116
Gross ton-miles freight trains (000)	10,491,665	.15041	1,578,051	.41548	655,649	2,233,700
Yard locomotive-miles	556,290	.78064	434,262	.41548	180,427	614,689
Fences, snowsheds and signs—221						
Miles of fence	5330.8	41,167	219,458	.40473	88,821	308,279
Water and fuel stations—231						
Total diesel locomotive-miles	5,383,268	.0067222	36,187	.76379	27,639	63,826
Shops and enginehouses—235						
Direct equipment maintenance and enginehouse expenses	4,295,307	.04141	177,869	.27881	49,592	277,461
TOTAL ROAD MAINTENANCE VARIABLE COST						7,772,708

NR 3-9 Revised

CANADIAN NATIONAL RAILWAYS

VARIABLE COST OF MOVING GRAIN AND GRAIN PRODUCTS AT STATUTORY AND RELATED RATES

Equipment Maintenance	*Units variable with study traffic*	*Unit variable cost*	*Variable costs less depreciation*	*Depreciation ratio*	*Depreciation*	*Total variable costs*
	$	$	$		$	$
Superintendence and miscellaneous						
301, 306, 329, 332, 333, 334, 335						
Direct equipment maintenance expenses	6,135,124	.068629				421,047
Shop and power plant machinery—302						
Locomotive, freight cars and work equipment expenses	5,878,650	.043628	256,474	.19466	49,925	306,399
Diesel locomotives—311 A						
Road unit miles	7,933,928	.31794	2,522,513		876,494	3,399,007
Yard unit miles	556,290	.23676	131,707		76,584	208,291
Freight train cars—314						
Car days	3,547,084	.22842	810,225			
Car-miles	192,188,135	.011255	2,163,077			
Total			2,973,302		1,264,607	4,237,909
Work equipment—326						
Related road maintenance accounts 201, 202, 208, 212, 214, 216, 218, 229, 269, 270, 271, 272, 273, 274, 275, 276, 277, 281	5,240,126	.047924	251,128	.26469	66,471	317,599
TOTAL EQUIPMENT MAINTENANCE VARIABLE COST						8,890,252

NR 3-9 Revised

CANADIAN NATIONAL RAILWAYS

VARIABLE COST OF MOVING GRAIN AND GRAIN PRODUCTS AT STATUTORY AND RELATED RATES

Transportation	*Units variable with study traffic*	*Unit variable cost*	*Variable costs less depreciation*	*Depre-ciation ratio*	*Depreciation*	*Total variable costs*
		$	$		$	$
Superintendence and miscellaneous—371, 374, 410, 411, 414, 415, 416, 420						
Total train-miles	4,805,923	.13927				669,321
Yard locomotive-miles	556,290	.45875				255,198
Train control—249, 372, 404						
Total train-miles	4,805,923	.084036	403,871	.13546	54,708	458,579
Total carloads	141,134	.94938	133,990	.13546	18,150	152,140
Station employees and expenses—373, 376						
Carloads C.L.	141,134	4.3612				615,514
Yardmasters and yard clerks—377						
Yard locomotive-miles	556,290	.55244				307,317
Yard trainmen and enginemen—378, 380						1,029,989
Yard switchmen—379						19,504
Yard locomotive fuel and power—382						
Yard locomotive-miles	556,290	.1111				61,804

NR 3-9 Revised

CANADIAN NATIONAL RAILWAYS

VARIABLE COST OF MOVING GRAIN AND GRAIN PRODUCTS AT STATUTORY AND RELATED RATES

Transportation (continued)	*Units variable with study traffic*	*Unit variable cost*	*Variable costs less depreciation*	*Depre-ciation ratio*	*Depreciation*	*Total variable costs*
		$	$		$	$
Yard locomotive other supplies and enginehouse expenses—386, 388						
Yard locomotive-miles	556,290	.13996				77,858
Yard other expenses—389						
Yard locomotive-miles	556,290	.017906				9,961
Train enginemen and trainmen—392, 401						4,447,502
Train locomotive fuel and power—394						
Gallons of diesel fuel	12,142,947	.135				1,639,298
Train locomotive supplies and enginehouse expenses—398, 400						
Train locomotive-miles	4,826,978	.051696				249,535
Train other expenses—402						
Grain doors						847,846
Car lubrication—car-miles (000)	195,754	2.3456				459,161
Train supplies—train-miles	4,805,923	.18002				865,162
Loss and damage—freight						131,610
TOTAL TRANSPORTATION VARIABLE COST						12,297,299

NR 3-9 Revised

CANADIAN NATIONAL RAILWAYS

VARIABLE COST OF MOVING GRAIN AND GRAIN PRODUCTS AT STATUTORY AND RELATED RATES

Traffic, General and Other Expenses	*Units variable with study traffic*	*Unit variable cost*	*Variable costs less depreciation*	*Depreciation ratio*	*Depreciation*	*Total variable costs*
	$	$	$		$	$
Communications—Rail—247, 407						
Road maintenance, equipment maintenance and transportation expenses except depreciation and communications	24,454,252	.013642	333,605	.16391	54,681	388,286
Traffic expenses—351, 352, 353, 354, 355, 356, 357, 358, 359						
All expenses except traffic expense and depreciation	25,594,358	.026018				665,914
General expenses—451, 452, 453, 454, 455, 458, 460						
Road maintenance, equipment maintenance and transportation expenses except depreciation and communications	24,454,252	.032930				806,501
Pensions—457						
Labor expenses variable with study traffic	16,964,134	.06				1,017,848
Taxes—468						
Unemployment insurance—all expenses except pensions and depreciation	26,260,272	.004719				123,922
Property tax						262,883
Joint facilities and operation						35,155
Cost of money						
Net investment variable with study traffic	122,447,367	.1096				13,420,231
TOTAL TRAFFIC, GENERAL AND OTHER EXPENSES VARIABLE COST						16,720,740
TOTAL VARIABLE COST						45,680,999

NR 3-9 Revised

Exhibit 57 AAA

(Revised)

CANADIAN NATIONAL RAILWAYS

CROWSNEST GRAIN TRAFFIC STUDY

CONSTANT COSTS AND COSTS VARIABLE WITH TOTAL FREIGHT TRAFFIC, YEAR 1958

	Costs Variable With Freight Traffic	*Constant Costs*
	$	$
Road maintenance	39,000,000	77,900,000
Equipment maintenance	89,200,000	11,900,000
Traffic	3,900,000	3,700,000
Transportation	154,500,000	26,500,000
General	17,900,000	28,800,000
Communications—rail	3,300,000	2,500,000
Miscellaneous, rentals, taxes, and cost of money	113,200,000	160,400,000
	$421,000,000	311,700,000

NR 3-10 Revised

Exhibit 57 BBB

(Revised)

CANADIAN NATIONAL RAILWAYS

SHARE OF CONSTANT COSTS APPORTIONED TO GRAIN AND GRAIN PRODUCTS MOVING AT STATUTORY AND RELATED RATES

Cost variable with total freight traffic........................		$421,000,000
Variable cost of study traffic..	$ 45,700,000	
Less Solely related size variable costs.................................	$ 9,000,000	
Cost variable with study traffic output.......................		$ 36,700,000
$\frac{\text{Costs variable with study traffic}}{\text{Costs variable with total freight traffic}} =$		$\frac{36,700,000}{421,000,000} = 8.72\%$
Study traffic's share of total constant costs $311,700,000 × 8.72%		$ 27,200,000
Less Solely related size variable costs.................................		$ 9,000,000
Study traffic's net share of constant costs.................		$ 18,200,000

NR 3-11 Revised

Exhibit 57 XX

(Revised)

CANADIAN NATIONAL RAILWAYS

CROWSNEST GRAIN TRAFFIC STUDY

ANNUAL DEPRECIATION OF ROLLING STOCK VARIABLE WITH GRAIN AND GRAIN PRODUCTS MOVING AT STATUTORY AND RELATED RATES

BOX CARS		
Number of cars	9,976	
Average cost	$ 4,448	
Gross investment	$44,372,192	
Annual depreciation @	2.85%	$1,264,607
LOCOMOTIVES		
Road		
Number of units	91	
Average cost	$ 192,636	
Gross investment	$17,529,876	
Annual depreciation @	5.0%	$ 876,494
Yard		
Number of units	16	
Average cost	$ 119,663	
Gross investment	$ 1,914,608	
Annual depreciation @	4.0%	$ 76,584
WORK EQUIPMENT		
Gross investment	$ 1,899,171	
Annual depreciation @	3.5%	$ 66,471
Total annual depreciation variable with study traffic		$2,284,156

NR 3-7 Revised

Exhibit 57 YY

(Revised)

CANADIAN NATIONAL RAILWAYS

CROWSNEST GRAIN TRAFFIC STUDY

INVESTMENT VARIABLE WITH GRAIN AND GRAIN PRODUCTS MOVING AT STATUTORY AND RELATED RATES

FREIGHT CARS		
Gross investment	$ 44,372,192	
Less depreciation	10,793,092	
Net investment		$ 33,579,100
DIESEL LOCOMOTIVES		
Gross investment	$ 19,444,484	
Less depreciation	2,160,282	
Net investment		$ 17,284,202
ROAD PROPERTY		
Gross unit investment		
$ 4.35896 × 10,491,665 Gross ton-miles (000)	$ 45,732,748	
$12.6634 × 701,113 Switching miles	8,878,474	
$15,130.39 × 3439.9 Miles of track	52,047,029	
Gross investment	$106,658,251	
Less depreciation	38,471,631	
Net investment		$ 68,186,620
WORK EQUIPMENT		
Gross investment	$ 1,899,171	
Less depreciation	362,172	
Net investment		$ 1,536,999
SHOP AND POWER PLANT MACHINERY		
Gross investment	$ 1,973,320	
Less depreciation	112,874	
Net investment		$ 1,860,446
TOTAL NET INVESTMENT VARIABLE WITH STUDY TRAFFIC		$122,447,367

NR 3-8 Revised

INDICES OF GRADIENT AND CURVATURE PRESENTED BY W. B. SAUNDERS & CO.

DIVISION INDEXES OF GRADE AND CURVATURE

Division	Total Weighted by Mileage	Total Weighted by Freight NTM	Weighted by Mileage Subtotal for:	
			Main Subs.	Branch Subs.
DAR	301	295	......	301
Brownville	357	316	313	508
Woodstock	468	359	330	512
QCR	371	356	......	371
Farnham	325	279	315	344
Montreal Terminals	100	100	100	......
Laurentian	345	225	253	518
Smith's Falls	283	194	220	390
Trenton	291	195	244	401
Toronto Terminals	100	100	100	......
London	261	217	210	314
Bruce	309	212	194	357
Sudbury	292	239	252	412
Schreiber	295	296	294	300
Ft. William Terminals	100	100	100	......
Kenora	186	185	185	192
Winnipeg Terminals	100	100	100	100
Portage	193	185	181	196
Brandon	236	226	251	224
Regina	195	185	182	201
Moose Jaw	227	178	172	233
Saskatoon	196	174	171	212
Medicine Hat	211	192	199	217
Lethbridge	251	249	260	247
Calgary	285	276	284	288
Edmonton	220	162	221	220
Revelstoke	292	366	367	212
Vancouver	239	234	237	271
Kootenay	428	312	352	654
Kettle Valley	361	333	389	283
E and N	421	308	......	421

NOTE: Indexes are reciprocals of tonnage ratings for standard diesel units, related to the tonnage rating over straight, level track at 100.

Appendix D

A NOTE ON THE RELATIONSHIP BETWEEN VARIATIONS IN PROFIT AND VARIABLE COST

It was argued, before the Commission, that the revenues received from the grain trade must, in reality cover variable costs because, "in years when there was a large grain crop, the Canadian Pacific Railway net revenues reflected a definite upward trend and . . . in years when there was a poorer grain crop there was a noticeable decline in the Canadian Pacific Railway's net revenues".[1]

The basis of this argument was that, for the years 1947 to 1958, the average yearly net revenues of the Canadian Pacific were $80,021,000 for the four years in which more than 300,000 cars of grain were loaded in Western Canada, while the net revenues of the railway averaged only $60,060,810 for the eight years in which less than 300,000 cars of grain were loaded in Western Canada. So that, "in other words, on the average, when western grain car loadings were over 300,000 cars a year the average 'net' was 33.23 per cent better than when such loadings were under 300,000 cars".

This argument neglects the possibility that net revenues were higher in years of greater car-loadings of grain because the Canadian economy was more active in those same years. It is possible that the greater net revenues of the Canadian Pacific were obtained from other types of traffic than shipments of western grain. It may be possible that the upsurge in the remainder of the economy was related to increased activity in the grain trade. However, as long as the possibility remains that the increased net revenues obtained by the railway were generated by other sectors of the economy independently of the grain trade, the contentions quoted in the paragraph above cannot be accepted without question.

A second and more important question can be raised to the argument of the first paragraph. The estimates of variable cost, presented by the Canadian Pacific, support the view that the net revenues of that railway will be higher in years of larger shipments of grain. That railway presented, as its revenues from shipments of western grain, some $35 million for the year 1958. Its estimate for the cost of transporting these shipments was some $33 million after deduction of its apportionment of fixed costs, the cost of maintaining "solely-related" lines, and the allowance for what may, variously, be termed cost of money, interest or normal profit. Of the three items deducted,

[1] The extended argument can be found in the transcript of Summations and Arguments, Vol. 1, p. 249-52.

only a portion of the normal profit can be expected to vary with traffic volume in a given year. Included in the variable costs were items of depreciation which are charged on a straight-line basis. These, too, will not vary with traffic volume in a given year to any appreciable extent. However, if one recalls the discussion of Chapter 2, it is possible to conceive of these costs being variable with a sufficient change in traffic volume, and given sufficient time to make the necessary adjustments.

If a segment of traffic returns revenues sufficient to cover those costs which vary in a given year, that segment will appear to add to the profits of the railway in good years. This effect can occur because the increased revenues, which accrue in years when the specific traffic is heavy, are sufficient to reduce the loss which is incurred on expenditures which cannot be varied in the course of a single year; even though these expenditures would be eliminated over a period of two or more years, if the particular traffic were removed from the railway.[1]

An example of this type of expenditure, which will vary over a period of years but is unlikely to change significantly in a single year, is the expenditure required for the ownership of box cars. R. L. Banks and Associates argued that the reaction of the Canadian Pacific to increased traffic is to increase the utilization of box cars, and that, similarly, Canadian Pacific decreases the utilization of box cars in response to decreases in traffic volume. This contention was supported by the presentation of two graphs which are reproduced at the end of this Appendix. Banks argued that the closeness, with which the points of his Figure I, "Intensity of Use Compared with Traffic Volume", fitted the trend line, suggested that from 1924 through 1958 the reaction of Canadian Pacific to changed traffic volume, as measured by loaded freight car-miles, was to change the utilization of cars, as measured by car-miles per car owned. On the other hand, he argued that the poorness, with which the points of his Figure II, "Calendar Car-Days Compared with Traffic Volume", fitted the trend line, indicated that there was no significant adjustment of freight car fleet to changes in traffic volume.

An examination of Banks' Figure II shows that there was a considerable reduction in the number of available car-days between the years 1929 and 1940 inclusive. During this period, traffic declined from 1929 to 1933 and then increased until 1940. Between 1929 and 1933, the decrease in traffic, as measured by loaded freight car-miles, was approximately one-third. Figure II suggests that the adjustment, required to complete the changes in numbers of cars owned in response to this loss of traffic, was not completed until 1940. In 1941 the railway was able to carry a sharply increased amount of traffic with few more cars available. Following that

[1] Cf. the discussion in Chapter 2, p. 202-205.

period the general trend in car ownership seems to have approximated the trend in traffic. Thus, in the two periods, 1927 to 1933 and 1941 to 1958, the general trends exhibited in Figure II are those which one would expect if car ownership is adjusted on the basis of traffic volume. The contrary trend exhibited for the years 1933 to 1940 can be explained by the long time necessary to adjust to the large decrease in traffic of the depression years. The contrary trend of the years 1924 to 1926 or '27 remains unexplained but the movement does not appear sufficiently large to bring the general pattern into serious question.

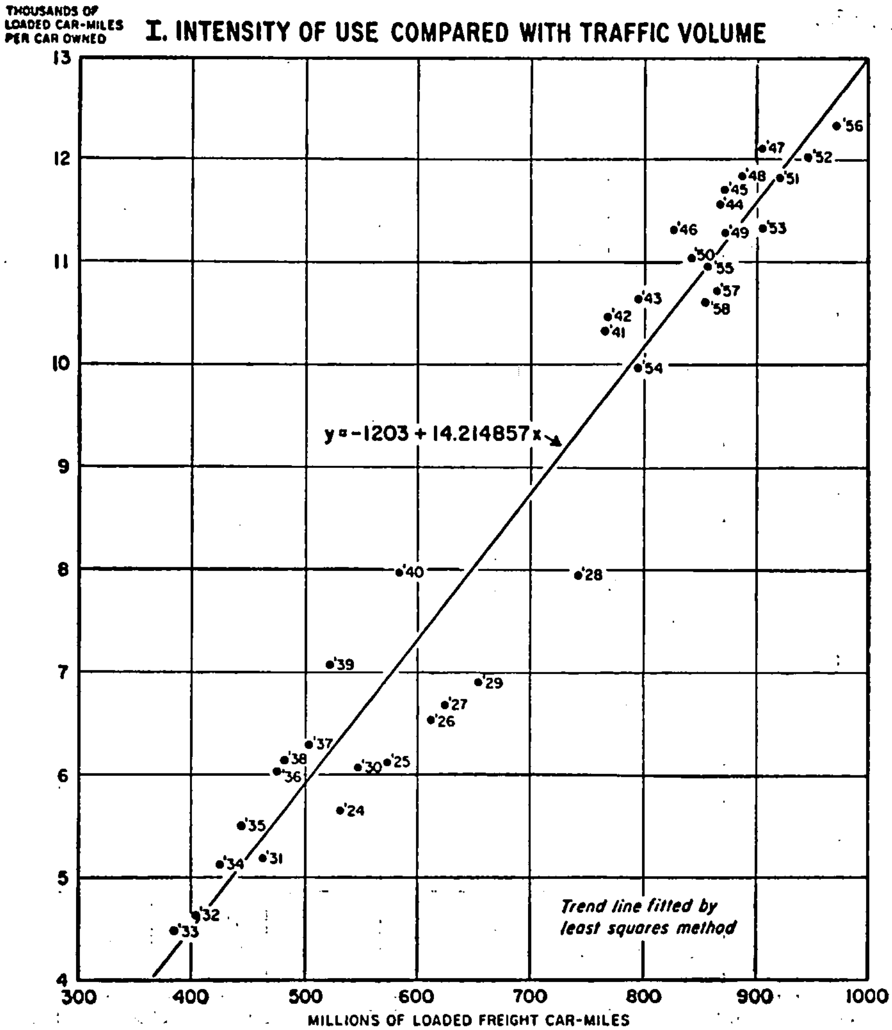
Reverting to Figure I, it will be seen that from 1924 to 1931 the points fall below the general trend line, from 1932 to 1950 they fall above the trend line, and that from 1951 to 1958 the points again fall below (with the exception of 1955 which appears to fall upon the line). If there is not at least one factor systematically affecting the relationship exhibited by Figure I, the points for consecutive years would be expected to fall above and below the trend line at random. The chances of the pattern shown by Figure I, arising by chance are similar to the chances, when tossing a coin, of obtaining eight consecutive heads followed by nineteen consecutive tails followed, in turn, by seven consecutive heads. (The year 1955 is omitted in this analogy.) The discussion of Figure II given above appears to shed some light upon this unusual result. It must be assumed, in the absence of further evidence, that the Banks' argument does not prove that the ownership of cars will not be varied in response to changes of traffic volume. However, it also seems clear that the immediate result of a change in traffic volume will be a change in the utilization of the car fleet. In these circumstances, an increase in traffic will yield increased revenues which may appear to yield a profit while, in fact, merely reducing the loss caused by the necessity to own sufficient cars to carry the peak traffic.

CHART I
Manitoba-Alberta
Memorandum No. 2
Exhibit No. ______

CANADIAN PACIFIC RAILWAY

(including subsidiary companies in Canada)
Freight Car Trends, 1924 through 1958

I. INTENSITY OF USE COMPARED WITH TRAFFIC VOLUME



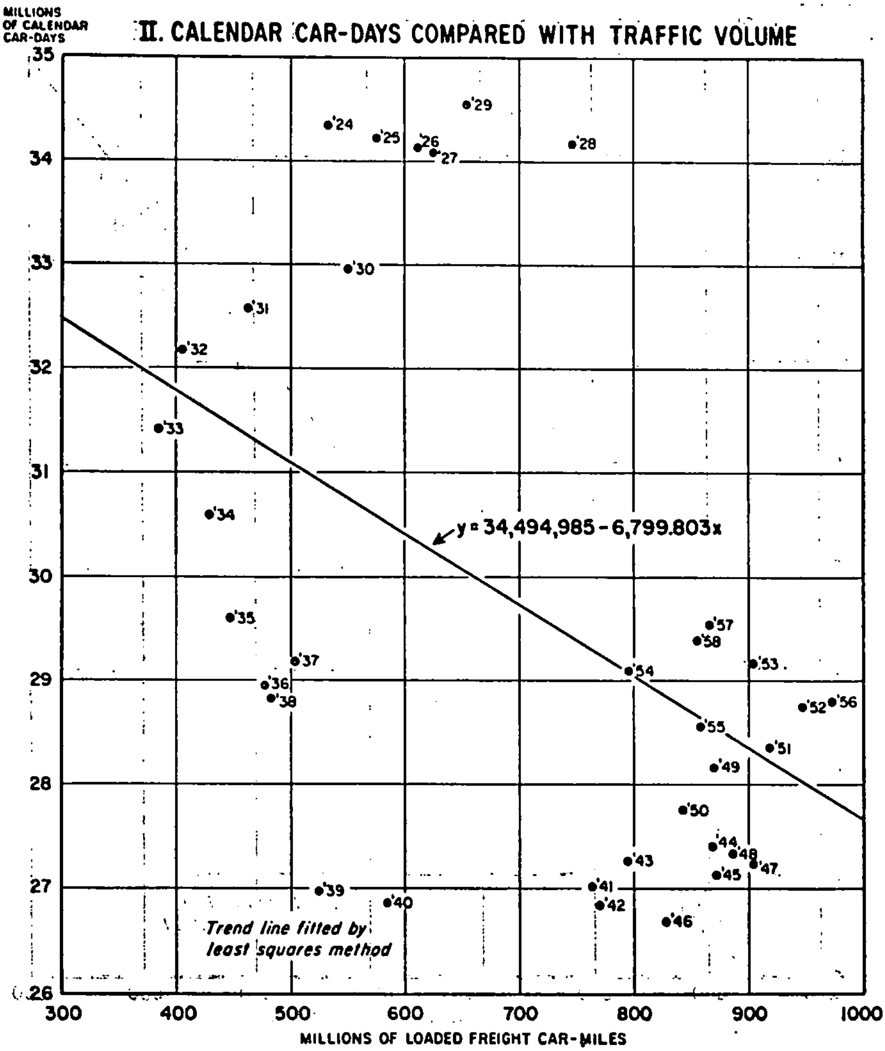
Source: Dominion Bureau of Statistics

CHART II
Manitoba-Alberta
Memorandum No. 2
Exhibit No. ______

CANADIAN PACIFIC RAILWAY

(including subsidiary companies in Canada)
Freight Car Trends, 1924 through 1958

II. CALENDAR CAR-DAYS COMPARED WITH TRAFFIC VOLUME



Source: Dominion Bureau of Statistics

RELATION OF PRESENT ESTIMATES TO EARLIER RECOMMENDATIONS

Prior to the publication of Volume I of the Report of the Commission, preliminary estimates of the cost of moving grain to export positions were given to the Commission. In memoranda and discussions, amounts were suggested for the marginal cost, a reasonable range of contribution to fixed costs, and the cost of maintaining substantially-related lines. Of these amounts, only the estimate of variable cost has been significantly changed, in this report, from the earlier estimate presented to the Commission.

The preliminary estimate of the variable cost of transporting grain to export positions, including an allowance for interest or normal profit on the investment variable with the grain trade, was approximately $37.6 million for the Canadian Pacific Railway. In the present report, this amount has been estimated at approximately $34.8 million. The difference is due to modifications in the estimates of the variable cost, excluding the allowance for interest.

Since the Commission has recommended that the estimates of variable cost be recalculated each year, the numerical results of this report are chiefly, if not entirely, of historical interest. Therefore, it is suggested that the Commission make no change in the recommendations which it made in Volume I of its Report, insofar as those recommendations are concerned with remuneration for the transportation of grain to export positions. The fact that, in making its recommendations, the Commission foresaw the possibility that the revenues for the transportation of the grain traffic might exceed the variable cost in certain years, is a further reason that no revision of these recommendations need be made as a result of the changed estimates presented in this report.