CTA Costing Model Review
Phase 1
Empirical Methodology

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Table of Content

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Executive Summary

Agency staff solicited CN's input in the review of the Agency's costing methodology. This document outlines and suggests CN's alternative analytical approaches for Agency staff's consideration.

Ever since the 1959 MacPherson Royal Commission on Transportation, the corner stone of railway costing has been to separate railway costs into two broad categories: first, variable costs which represent expenses resulting from changes in the volume of traffic, after allowing a reasonable period of time for adjustment; and second, fixed or constant costs which represent expenses that would not change with the volume of traffic. Estimating a railway movement costs becomes then an exercise in estimating first their variable costs, and then the necessary contribution over variable costs in order to cover the movement's share of fixed costs.

Central to the definition of variable costs are the notions of "reasonable period of time" and what rational management would do for "adjustment". These hypothetical notions require some subjective judgment guided by railway industry experience and knowledge. Thus variable costs are not a rigid mathematical or accounting definition, and they cannot be observed or measured. They can only be inferred using judgment as to what rational railway management would do to adjust in the face of a change in traffic volume, not observing what past management may have done to adjust, if any, since the latter can be influenced by a myriad of other factors and circumstances not related to traffic volume.

In 1959, with the relatively new availability of electronic data processing equipment, the Commission saw regression analysis as a promising technique but warned that "*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.*" Unfortunately, after decades of collecting data and trying different regression techniques that promise was not fulfilled. A wonderful idea in theory, turned into an intractable problem in practice.

CN firmly believes that the Agency's use of regression analysis to determining railway costs is fundamentally flawed and cannot yield adequate results. Agency's staff own 2010 review of the regression results that have been used so far concluded that they were either statistically invalid or not reliable. CN also firmly believes that the new regression results adopted by the Agency in 2015 are just as flawed as the old results they replaced. Several examples are discussed in the report to illustrate the nonsensical and illogical nature of the results in the face of railway operation.

Fundamentally, regression analysis cannot yield adequate results in determining the variable portion of railways costs for the following reasons:

1. It has no notion of the "reasonable period" to adjust, which can be different for different cost items and circumstances;
2. It has no notion of which adjustments were made in order to estimate their costs;
3. It does not take into account the myriad of factors that influence railway costs such as congestion and capacity in yards and on mainlines, weather, productivity, technology, regulations, etc., and therefore erroneously ascribes all cost variations to changes in volume;
4. It does not have sufficiently large data series to cover long life cycle of railway assets lasting 25, 40 or even 50 years;
5. Even if it did manage to have such long data series, too many other factors would have changed over such a long period – in technology, operations, regulations, etc. – to render data un-comparable over the years.

CN proposes a simpler costing model where the level of variability is estimated based on informed judgment and railway expertise. CN welcomes the opportunity to have an open discussion of this proposal with the Agency, CP and other stakeholders. CN believes that it should be easier to defend common sense, reason, logic and railway knowledge than to defend increasingly complex statistical methods that few can comprehend and that CN believes to be fundamentally flawed. CN finds that an open and transparent process of determining variable costs is vastly superior to an opaque process where many arbitrary choices are made for technical reasons without any industry input or discussion.

CN proposes to keep the costing model simple. Experience has shown that recent history is the best predictor of current costs. Using data extending back over longer periods of 10 to 15 years is unnecessary and misleading because data can be tainted by too many factors. For most cost elements, the use of one year of the latest data is sufficient, and exceptionally for a few cost elements, a moving average of the last three years can be used to estimate average unit costs. Recent costs reflect all recent conditions in operations, technology, regulation, and general economic conditions under which the railway operates. There is no need for 200+ costs relationships some of which have a negligible effect on an estimate, giving a false impression of accuracy. CN proposes to reduce and aggregate cost elements and workload drivers as much as possible.

CN firmly believes, given its extensive expertise in railway operation and costing, that the proposed common sense approach produces a vastly more credible and accurate result than the false precision purported by a flawed regression approach that has been clearly demonstrated to produce absurd results for several cost categories.

The CN proposed simpler model is certainly easier to update, understand and use. Most importantly, it leads to more useful and accurate descriptions of the railway business behaviors and decision making.

This more accurate insight about railway economics is as crucial in regulatory oversight as it is in business oversight of the railway operations.

1 Introduction

1.1 Agency staff solicited CN's input in the review of the Agency's costing methodology.

1.2 This document outlines and suggests CN's alternative analytical approaches for Agency staff's consideration.

1.3 CN believes, based on its experience in estimating costs to run its business, that the Agency's methods can be greatly simplified while at the same time providing more reliable and meaningful results.

2 Railway Costing and Variable Costs

2.1 Transportation by railways is an industrial activity with unique characteristics:

2.1.1 It requires huge up-front capital investments, some of which are necessary irrespective of the volume of traffic to be carried, for example for land, track and roadway.

2.1.2 Investments that do vary with the volume of traffic, for example for locomotives and freight cars, are also capital intensive and the equipment has a very long life.

2.1.3 There is a huge amount of shared resources over a long period of time, for example rail and signals, which cannot be easily apportioned or allocated to individual movements of traffic.

2.1.4 Resources cannot be rapidly acquired nor sold, resulting in most costs appearing to be fixed in the short to medium term.

2.2 Traditionally, railway costing is concerned with the separation of costs into two broad categories:

2.2.1 Variable costs: Railway Costing Regulations (SOR/80-310) define variable costs as "expenses resulting from changes in the volume of traffic, after allowing a reasonable period of time for adjustment …"

2.2.2 Fixed or constant costs: as a corollary of the definition of variable costs, fixed or constant costs are those expenses that would not change with the volume of traffic.

2.3 The purpose of such a separation is to allow estimating costs for specific movements of freight by first determining their variable costs and then adding a contribution over variable costs to cover their portion of fixed costs.

2.4 Central to the definition of variable costs is the notion of "reasonable period of time for adjustment". Variable costs are not a rigid mathematical or accounting definition.

2.5 A “reasonable period” can be different for different cost items and/or circumstances, and observers. There is no absolutely “right” or “wrong” answer.

2.6 There is a need for discussion to determine what is “reasonable”.

2.7 The “reasonable period” cannot be observed or measured; it requires some subjective judgment guided by railway industry experience and knowledge.

2.8 Determining variable costs requires therefore judgment as to what rational management would do over some time to adjust in the face of a change in traffic volume due to one set of conditions, not observing what past management may have done to adjust, if any, since the latter can be influenced by a myriad of other factors totally unrelated to the set of conditions under consideration.

2.9 In the very short term, say one week to a couple of months, railway costs are largely fixed. In such a short period of time, railways cannot acquire or sell, for example, locomotives, cars, land or track to accommodate even huge changes in traffic volumes.

2.10 On the other hand, in the very long term, say 5 to 10 years, railway costs are largely variable. Lines can be abandoned or bought, headquarter functions can contract or expand, etc. to accommodate changes in traffic volumes.

2.11 Therefore, determining variable costs requires also some judgment as to the time horizon over which railway management can or will adjust operations to changes in traffic volumes.

2.12 Different cost categories will require different time horizons for adjusting.

2.13 For management to adjust operations, change in traffic volume must be perceived as being the new norm, not a temporary fluctuation. Many of the observable variations in costs are due to normal business cycle fluctuations, and therefore cannot serve as the basis for measuring how management would adjust operations, adjustments that are the foundation of the variable cost definition in the regulations.

2.14 CN believes that a sensible approach to determining variable costs, in line with the regulations definition, is to consider what rational management would do to adjust operations in the face of changes in traffic volume, believing that the change under consideration would last indefinitely.

2.15 George E.P. Box, one of the greatest statistical minds of the 20th century – and who developed the Box-Cox transformations used by the Agency in its latest determination of the variable portions of railway costs – is famous for writing “Essentially, all models are wrong, but some are useful.”

2.16 A good test of any costing model is to ask whether it is useful. Are the results reasonable and expected? Would knowledgeable industry experts agree with these results? Does it drive the right conclusion and the correct decision making?

2.17 Unfortunately, as expounded further below, many of the Agency's adopted costing model results fail these simple tests. It is time to explore a different approach that would yield more useful results.

3 Railway Costing and Regressions

3.1 The 1959 MacPherson Royal Commission on Transportation envisioned the application of regression analysis to railway costing as a possible solution to the problem of discovering "*which variations in one quantity can be related simultaneously to variations in a number of relevant other quantities.*"

3.2 The idea was to measure two things:

3.2.1 How much of an expense was fixed vs. variable with the volume of traffic, as measured by a number of different quantities such as Gross Ton Miles (GTM) or Train Miles (TM) or Car Miles (CM), etc.

3.2.2 How to apportion the variable part among the different cost drivers (GTM, TM, CM, etc.).

3.3 The MacPherson Commission report warned (p 55-56): "*However, there remains a significant amount of expense incurred in the operation of the railway as a whole for which there exists no tool known to the statistician or the accountant which will uniquely apportion the items between various operations performed by the railway. In these apportionments, judgement must be used by the analyst.*"

3.4 In the supporting study in Vol. III of the Commission report, "A Note on Multiple Regression Analysis and A Note on Tests of Significance", Wm . C. Hood added: "*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.*"

3.5 The Commission recommendation was not to blindly use the results of regression analysis, but to use judgment and discernment in their application.

3.6 In 1959, with the relatively new availability of electronic data processing equipment, regression analysis was held as a promising technique.

3.7 Unfortunately, after decades of collecting data and trying different regression techniques that promise was not fulfilled. A wonderful idea in theory, turned into an intractable problem in practice.

3.8 The success of regression analysis depends on two critical factors:

3.8.1 Having all the correctly relevant independent and dependent variables that drive the observed change in expenses, in sufficiently large data series.

3.8.2 Ceteris paribus – Everything else remaining the same for the period under observation, except for the variables in the regression analysis.

3.9 In railway operations none of the conditions above can be met, and therefore regression analysis as first envisioned in 1959 is doomed to fail.

3.9.1 There are too many variables that influence costs and that are absent from the regressions.

3.9.2 There are no adequate data sets that cover asset lives of 25, 40 or 50 years.

3.9.3 Too many conditions are changing at the same time as traffic volumes are changing, resulting in regression analysis being unable to fulfill its objective of measuring the variation of costs with respect to traffic volume alone, not measuring the variation of costs with the variation of all other factors and erroneously ascribing it to volume.

4 Failure to Have All the Correctly Relevant Variables in Regressions

4.1 Railway operating costs are highly influenced by operating factors such as congestion and capacity in yards and on mainlines, and yet there isn't even an operating statistic that measures these factors.

4.2 Railway costs are also influenced by a myriad of other factors such as weather, productivity, technology, lags between need and use of equipment, regulations, etc., and yet these factors are not measured and cannot be easily incorporated in a regression analysis.

4.3 In any regression analysis that does not have all the relevant variables, the variation in expenses could be wrongly attributed to the variables considered in the analysis, when in fact they could be due to another variable absent from the analysis.

4.4 For example, suppose a regression were to analyze fuel consumption as a function of only GTM as a measure of traffic volume, which is not an unreasonable assumption. Further suppose that GTM was increasing by 2% per year, while improving technology and productivity was reducing fuel consumption per GTM by an equivalent amount such that total fuel consumption remained constant over the years. Regression analysis, seeing that GTM is increasing while fuel expenses remain constant, would conclude that fuel expenses are a fixed cost, a totally unacceptable result for anyone with any knowledge of railway operation. The problem here is that technology and productivity are not variables considered in the regression, even though they do have an influence on the fuel consumption outcome, leading to an erroneous conclusion.

4.5 Another example is the investment in locomotives. Procurement cycles often take two to three years, from engineering specifications, to bidding, negotiations, ordering, building and final delivery of locomotives. An increase in traffic volumes will not see its influence on locomotive numbers until some years later. Similarly, a decrease in traffic will not be felt on locomotive numbers until a few years later, to prudently make sure that the decrease is long term in nature, given the delays in re-acquiring locomotives. Sometimes, orders are placed when traffic is increasing, only to take delivery when traffic has decreased due to unforeseen economic conditions. Regression analysis, looking only at locomotives and traffic volumes, would conclude that investment in locomotives is less variable with volume than warranted. The problem here is that the lag in purchasing locomotives is not part of the regression analysis and cannot be easily incorporated. The lag is dependent on the competition for locomotives in the greater North American market. The lag can increase or decrease depending on the demand by other railways. An uncertain lag, which depends on unpredictable market conditions, is not a good candidate to introduce in a regression analysis to produce coherent results over the entire locomotive life cycle.

4.6 CN does not perform regression analysis to determine the variability of locomotive ownership. CN knows from railway operating experience that the sole purpose of locomotives is to move freight. Thus, with a reasonable period of time to adjust for changing traffic volume, all other factors being equal, CN considers that locomotive costs are 100% variable with volume. CN can think of no reason to acquire, keep or sell locomotives other than to match the need of changing traffic volumes, given a reasonable period of time to adjust and all other factors being equal.

4.7 Investments in longer sidings allow for running longer trains, which means that increases in traffic volumes can be accommodated with the same number of locomotives. Again, looking at locomotive investment as a function of only traffic volume would conclude that investment in locomotives is less variable with volume than warranted. The problem here is the absence from analysis of a variable representing siding length by corridor.

4.8 Investments in safety like wayside detectors (hot box, wheel impact, etc.), more frequent inspection of infrastructure with better technology, and better employee training, are all factors that lead to a reduction in accidents and loss & damage expenses if everything else remained the same. But with increases in traffic volumes, and increases in the costs of individual accidents, loss & damage expenses may appear to remain constant with traffic volume. Regression analysis that doesn't take into account advances in safety technology, changes in safety training and culture, and the transported commodity value will wrongly conclude that loss & damage expenses are less variable with traffic volume than warranted.

4.9 Numerous factors influence costs but can't be easily measured nor represented in a regression analysis. Their absence leads to erroneous conclusions by regression analysis. The Agency's costing model is not useful for either drawing the right conclusion or driving the proper decision making.

5 *Ceteris Paribus* and Regressions

5.1 Railway assets are very long lived, lasting 25, 40 or even 50 years.

5.2 During this long period of time, many technology factors and operating practices are changing, rendering comparison of data over 10 or 15 years almost meaningless.

5.3 Fifteen data points representing fifteen years of data, other than being disparate over the years, are an insufficient number of data points for meaningful statistical analysis.

5.4 New locomotives are being introduced as older ones are being fitted with new electronics, and locomotive engineers are trained in new train handling techniques, all driving down fuel use, yet there is no variable to reflect new locomotives, retrofitted technology nor new operating practices.

5.5 New grinding technology and different metallurgy greatly extend rail life reducing track costs.

5.6 Better train scheduling and smarter yard classification software reduce yard costs.

5.7 Sever winter conditions and new crude oil safety regulations increase costs.

5.8 Operating conditions are ever changing in railway operations which leads regressions to yield incoherent results.

5.9 There has never been a period long enough where everything else remained the same to observe only the influence on costs of a few independent variables.

6 Agency Regression Results

6.1 The results of the Agency regression analysis bear proof to the practical difficulties and shortfalls of regression analysis.

6.2 An Agency staff review of the original linear regression analyses ("*Updating of the Currently Fixed Variabilities for the Class I Railways – Phase I: Methodology Review*", June 2010) found that 17 of the regressions reviewed were invalid, and 9 were not reliable.

6.3 There was not a single regression in the report with acceptable statistical results.

6.4 The failure of regression analysis is entirely expected and could easily have been predicted as explained before by:

6.4.1 The absence of many important but unrepresented driving factors.

6.4.2 Numerous changes in technology and operations over the years.

6.4.3 The dearth of data with a limited number of data points for each regression.

6.5 Instead of changing to a new approach, Agency staff embarked on ever more sophisticated regression techniques that don't address the practical and real shortcomings above.

6.6 Non-linear regression techniques do not compensate for the failure to account for all relevant variables, nor for the principle of *ceteris paribus*. They still lead to absurd results, and a costing model that is not useful in driving the correct conclusion.

6.7 More importantly, there were numerous results that were clearly nonsensical and illogical in the face of even general understanding of railway operation.

6.8 The definition of variable costs requires taking into account "a reasonable period of time for adjustment". Rational management will adjust the number of locomotives to traffic volume. CN finds absurd the Agency's regression result of locomotive investment being only 39% variable with traffic volume. Given a reasonable time to adjust, why would rational management keep 61% of the locomotives that are no longer needed?

6.9 Another example is Freight Loss & Damage expenses that have been determined by the Agency to be only 26% variable with traffic volume. These expenses occur when the railway damages the freight it is transporting either thru its operations, or by accidents including derailments. The expenses are influenced by many factors in addition to traffic volume, such as the frequency and severity of accidents, the value of the freight itself, and therefore are very volatile. In the absence of including these other variables in the regression, it is entirely plausible that the Agency may observe that the variability with traffic volume to be low. But this is not the variability of costs with respect to volume alone while other factors are held constant. Certainly the cost related to freight damage must be highly variable with the amount of freight, all other factors being equal, a fact that cannot be observed by a regression that cannot take into account these other factors.

6.10 It is time to change to a new more common sense approach.

7 CN Variability Proposal

7.1 CN proposes that all variabilities be estimated based on informed judgment and railway expertise.

7.2 CN proposes 5 variabilities categories with most costs falling in the first two: 100% variable, 0% variable, and partially variable with 25%, 50% and 75% variable.

7.3 CN does not believe that any more precision is either necessary or required.

7.4 Ultimately, it matters less whether the distribution of fixed/variable costs is 80/20, 70/30 or 60/40 since the total is unchanged, than it is to know and trust that the results are reasonable, make sense, and are useful in driving the correct conclusions, decisions and behaviors.

7.5 Having a 3-digit precision in a useful model that accurately describes railway decisions, behaviors and operations, is far superior to having 6-digit precision in a less useful model that inaccurately describes railway operations or, worse, would drive the wrong conclusions and decisions.

7.6 CN welcomes the opportunity to have an open discussion of this proposal with the Agency, CP and other stakeholders.

7.7 CN believes that it should be easier to defend common sense, reason, logic and railway knowledge than to defend increasingly complex statistical methods that few can comprehend and that CN believes to be fundamentally flawed.

7.8 CN finds that an open and transparent process of determining variabilities is vastly superior to an opaque process where many arbitrary choices are made for technical reasons without any industry input or discussion.

7.9 In terms of the accuracy of estimating the costs for individual railway movements, CN firmly believes, given its extensive expertise in railway operation and costing, that the proposed common sense approach produces a vastly more credible and accurate result than the false precision purported by a flawed regression approach that has been clearly demonstrated to produce absurd results for several cost categories.

8 CN Proposal vs. the Status Quo

8.1 CN's proposal is no more arbitrary than the current staff methodology that hides many of its arbitrary choices behind hopelessly opaque techniques.

8.2 A transparent process where all decisions are discussed and documented is preferable to arbitrary parameters choices buried deep in analytical techniques.

8.3 CN believes that regulations are not the place for academic econometric research.

8.4 Both railways and shippers should be able to grasp regulations with moderate level of expertise.

8.5 Incomprehensible regulations lose public trust and respect with the appearance of capricious and dogmatic fiat.

8.6 If the Agency insists on using the new methodology, it should at least be subjected to public consultations and proper academic econometric peer-review where all stakeholders get the chance to express their views.

9 Keep the Costing Model Simple

9.1 Recent history is the best predictor of costs.

9.2 For most cost elements, the use of one year of the latest data is sufficient.

9.3 Exceptionally for a few cost elements, to avoid undue influence of non-recurring events, a moving average of the last three years can be used to estimate average unit costs.

9.4 Using data extending back over longer periods, say 10 to 15 years, is unnecessary and can be misleading because of too many other factors changing over this long period, rendering years un-comparable.

9.5 There is no need for 200+ costs relationships some of which have a negligible effect on an estimate, giving a false impression of accuracy.

9.6 Reduce and aggregate cost elements and workload drivers as much as possible. For example, railways charge each other by the Horsepower Hour (HPH) for the use of locomotives, i.e. HPH is the workload driving locomotive costs, and there is no need to track locomotive power costs by different sizes of locomotives. The railway customer does not care whether the railway uses two 2,000 HP locomotives or only one 4,000 HP locomotive, and would certainly object if their traffic was allocated higher costs because the railway used the former configuration rather than the latter. The only important fact is that 4,000 HP are needed for the train, and therefore it should be allocated the average costs of 4,000 HP, irrespective of how the power was supplied.

9.7 A simpler costing model will allow its update on a more timely basis.

9.8 A simpler model using less variables and workloads is more conducive to studying cost relationships, and is preferable to a more complex model that offers a false sense of precision.

9.9 The Uniform Classification of Accounts (UCA) is an accounting system, not a costing system, so it has to be used discerningly.

9.10 Costing a railway movement should start by focusing on the activities related to the movement, not on replicating the entire UCA structure for the movement.

9.11 Movement activities costs are estimated using the UCAs relevant to the activities.

9.12 UCAs not directly related or allocated to movement activities are deemed part of the fixed costs.

10 CN Costing Model

10.1 CN estimates movement variable costs using six categories, and welcomes the opportunity to discuss in more details how this model can be implemented

Cost Category	Cost Component	Drivers
1.Train Costs	Crew Travel & Accommodations	Train Mile
	Crew Wages	Train Mile
	Locomotive Maintenance	Horsepower Hour
	Locomotive Ownership	Horsepower Hour
	Siding Ownership	Train Mile
	Signals Ownership	Train Mile
	Signals Maintenance	Train Mile
	End of Train Units	Train Mile
	Dispatch	Train Mile
2.Fuel Costs	Train Fuel	GTM
	Yard Fuel	YSM
	Fuel Tax	Fuel Gallons
3.Car Costs	Car Maintenance	Car Mile
	Car Inspection	Car Mile
	Car Ownership	Car Day
	Car Hire	Car Mile & Car Day
4.Track Costs	Track Ownership	GTM
	Track Maintenance	GTM
5.Yard Costs	Yard Classification	Carload
	Yard Delivery	Carload
6.Other Costs	Sales	Carload
	Billing	Carload
	Freight Loss & Damage	Carmile by commodity
	Car Damage & Claims	Carmile by car type
	Derailment & Accidents Cleanup	Carmile
	Intermodal Terminals	Intermodal Unit

11 Conclusion

11.1 The Canada Transportation Act 157(2):

> The Agency may also consider
>
> *a) the principles of costing adopted by the Royal Commission on Transportation … and*
>
> *b) later developments in railway costing methods and techniques and current conditions of railway operations.*

11.2 Current conditions of railway operations are certainly vastly different than in 1959, and so is our understanding of railway economics after privatization and deregulation.

11.3 It is time to move beyond the regression techniques first suggested more than 50 years ago, as they have proven to be very difficult to apply meaningfully in practice over the last 25+ years.

11.4 It is time to explore new, simpler railway costing methods and techniques as allowed under 157(2)(b).

11.5 The CN proposed simpler model is certainly easier to update, understand and use. Most importantly, it leads to more useful and accurate descriptions of the railway business behaviors and decision making.

11.6 This more accurate insight about railway economics is as crucial in regulatory oversight as it is in business oversight of the railway operations.