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Modelling the Effect of Passenger/Freight Interference on Railway Costs

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I. INTRODUCTION

The purpose of this paper is to investigate the potential application of railway capacity and cost models to the estimation of incremental costs incurred by interaction between passenger and freight trains. In addition to the use of existing models, this study also develops computer models to aid in computations of the interference cost. These models are designed to examine the route specific impact on the cost of freight service of different options for rail passenger service, including the removal of passenger trains and the incremental expansion of passenger train service.

Both the cost and the capacity implications of running freight and passenger trains on the same track have been subjects of much interest in various railway studies. However, they are usually dealt with separately, with costing studies examining passenger service costing methodologies and railway capacity models trying to determine the impact of passenger trains on the average train trip time and required improvement in existing plant. The present study attempts to combine the methodologies that have been developed in these two fields to examine delay-induced increases in costs of freight services at different levels of passenger traffic.

Although passenger/freight interference currently exists in railway operations, the traditional railway costing methodology does not specifically deal with capacity issues nor interference costs. Rather, these costs are hidden costs included in annual actual expenditures, and they are accounted for in the calculation of systems average unit costs.

The concept of interference cost associated with passenger trains is one of current importance. Since VIA acquired the railway passenger operations in Canada, freight and passenger services have become two separate services offered by different firms. While the traditional method of railway costing in Canada is considered as satisfactory in costing freight and passenger services on a system basis, it lacks flexibility in dealing with the problem of allocation of costs for individual passenger services, e.g. the corridor, regional and remote passenger services. This is particularly true in the allocation of indirect cost because the cost is prorated to each service based on output units and system average unit costs.

As the cost effect of passenger/freight interference is dependent on the railway line capacity, its significance could vary from one rail segment to the other. Thus, the interference cost analysis could provide useful information supplemental to the traditional costing method.

In this paper, freight train delays are calculated with the railway capacity model developed by the Canadian Institute of Guided Ground Transport (CIGGT). Two different approaches are used in the estimation of interference costs. One follows the concept of railway costing as normally applied in Canada where unit costs of delay affected railway service units are calculated and applied. The other adopts largely the method of the World Bank's Rail model in the interference cost analysis.

II. INTERFERENCE ANALYSIS

A. Railway Line Capacity Analysis

The CIGGT's LINE Model is used to investigate the impact of passenger trains on the capacity of the railway line to provide freight train services. LINE is an analytical model that calculates the expected transit time for each train type at given traffic levels on a specific line segment.[2] The expected transit time is estimated from the free running time plus the interference delays. The length of interference delay is influenced by the frequency of meets and overtakes, which is, in turn, affected by a number of factors in railway systems and operations. The following is a list of factors that affect interference delay; correspondingly, a list of input requirements to the model is also provided.

Factors Affecting Train Delays	Inputs to the LINE Model
1. Traffic level and mix	—Trains per day by train classes in each direction.
2. Track configuration	—Single or double trackage, mileages.
3. Train speed	—Free running speed for each type of train in each direction.
4. Signal System	—e.g. Automated Train Control (ATC), Centralized Train Control (CTC). Number of intermediate signals, etc.
5. Train priority	—Train priority matrix indicating the relative priority between a pair of trains.
6. Switch time	—Switch delays for each priority class.
7. Safe stopping distance	—Minimum headway between trains.
8. Changes in traffic level	—The class of trains for which traffic can be increased for capacity measurements.

At the start of the analysis, it is necessary to define line capacity. Depending on the constraints set by the analyst, capacity can be defined in various ways. For the purposes of this study, the capacity is considered reached if any of the following conditions hold:

1. Average total delay reached 50% of free running time.
2. Average total delay for any class of train reached 60% of that class' free running time.
3. Any train or class of trains had a transit time that exceeded 10 hours.[3]

A case study is established based on railway operations on the CN tracks between Kamloops and Hydro in British Columbia. This rail segment is 227 miles in length. The signal system is CTC. This route is chosen partly because traffic density on this rail segment is relatively high and partly because detailed data are available in a recent study of joint-track usage of this area.[4]

In order to measure delays due to interference between passenger and freight trains, the daily frequencies of freight trains are held constant while the number of passenger trains per day is varied.

The base case assumes 17.2 freight and 2 passenger trains per day. The freight traffic level represents the railway's 1984 operations; the daily run of passenger trains on this CN route did not start until the middle of 1985. Thus, the traffic level in the base case is hypothetical, but not unlike the actual operation in the middle of 1980's. The alternative cases include the removal of passenger trains and the incremental increase in the number of passenger trains, two at a time (one in each direction) until the capacity is reached.

The results of the rail line capacity analysis is summarized in Table 1. The table contains two parts. The first part shows transit times and speeds of freight trains when there is no passenger train. It is noted that even without passenger trains, there could be interference delays due to interaction between different freight trains. This is shown in the last two columns. In this paper, the freight train interference delay is held constant.

The second part of the table shows train transmit times when passenger trains are added. The first column shows the number of passenger trains per day in each alternative case. Based on the CIGGT model, the capacity as above defined will be reached at the level of 12 passenger trains (including both directions) in addition to the daily freight trains. The columns numbered 1 to 10 represents the five classes of trains in each direction as listed in the first part of the table.

B. Analysis of Train Delays

Interference delays are reflected in the changes in transit times of freight trains at different passenger service levels. The interference delays represent the first order delay resulting from more frequent meets and overtakes. A second order delay may also be generated due to increased track maintenance times at higher traffic levels. Work program slow orders may in turn affect first order delays. However, in this study, only the interference delay is estimated.

To obtain yearly delay due to passenger/freight interference, changes in average freight train trip times are multiplied by the total number of freight trains per day and by 365 days for a given traffic level as compared to the base case.

Delays in train hours can be directly converted to car-days and locomotive hours based on the average number of cars and locomotives per train respectively. Train equipment and traffic of the route studied are estimated based on CN 1984 operating statistics. In Table 2, the interference delays measured in train hours, locomotive hours and car days are presented.

TABLE 1

Effect of Passenger Trains on Freight Train Transit Times
Kamloops–Hydro Based On CIGGT Capacity Model

I. FREIGHT TRAIN TIME AND SPEED - WITHOUT PASSENGER TRAINS

Train Code	Dir.	Type of Trains	Trains* per day	Free Running Time: Time (hr)	Free Running Time: Speed (ml/hr)	With Interference: Time (hr)	With Interference: Speed (ml/hr)
1	EB	Slow Freight	3.4	7.28	31.2	8.92	25.5
2	EB	Solid/Unit	3.7	7.10	32.0	8.38	27.1
3	EB	Fast Freight	1.4	7.03	32.3	7.88	28.8
4	EB	Local	.2	6.85	33.2	8.43	26.9
5	EB	Passenger	.0	6.13	37.0	6.42	35.4
6	WB	Passenger	.0	6.03	37.7	6.25	36.4
7	WB	Local	.2	6.87	33.1	8.32	27.3
8	WB	Fast Freight	1.8	7.03	32.3	7.63	29.8
9	WB	Solid/Unit	3.8	7.38	30.8	8.70	26.1
10	WB	Slow Freight	3.1	7.55	30.1	8.95	25.4

II. TRANSIT TIME IN HOURS - WITH PASSENGER TRAINS

Passenger Trains/Day	Train Code 1	2	3	4	5	6	7	8	9	10
Free Time	7.28	7.10	7.03	6.85	6.13	6.03	6.87	7.03	7.38	7.55
2	9.28	8.69	8.13	8.77	6.52	6.30	8.67	7.83	9.07	9.34
4	9.67	9.05	8.38	9.14	6.62	6.36	9.01	8.01	9.44	9.69
6	10.11	9.40	8.60	9.51	6.71	6.44	9.38	8.24	9.84	10.16
8	10.59	9.83	8.93	9.91	6.83	6.54	9.82	8.42	10.31	10.61
10	11.13	10.25	9.26	10.37	6.89	6.66	10.26	8.67	10.78	11.15
12	11.67	10.71	9.56	10.91	7.02	6.76	10.80	8.90	11.33	11.69

* See Footnote 7.

TABLE 2
Measures of Interference Delay Impact of Passenger Trains on Freight Operators

KAMLOOPS - HYDRO

	Annual Increase in		Increase in Car Days by Train Type				
Psg. Trn Per Day	Freight Trn Hrs	Loco Hrs	SL Frt	Unit	Fast Frt	Local	Total
0	-2 103	-4 838	-3 727	-3 848	-844	-44	-8 464
2							
4	2 146	4 935	3 666	4 117	820	43	8 646
6	4 537	10 435	8 114	8 409	1 688	89	18 301
8	7 193	16 544	12 725	13 524	2 621	143	29 014
10	10 078	23 180	18 060	18 640	3 735	201	40 636
12	13 072	30 065	23 396	24 342	4 717	269	52 725

III. THE COST OF INTERFERENCE DELAY

Two approaches are used in the cost estimation. One is based largely on the traditional railway unit cost method; the other estimates the interference cost based on delay effect on equipment cycle time and productivity.

A. The Railway Unit Cost Approach

This approach involves three steps: firstly, the cost items affected by the train delay are determined; secondly, a set of unit costs related to train delay measurements is developed; and finally, interference costs are calculated by multiplying the quantities of delay time units by the appropriate unit costs.

Cost Items Affected by Train Delay. In Table 3, major cost items associated with delay time units are identified. This table is constructed based on the unit cost system adopted by Canadian railways. Train interferences and delays are considered to have a direct impact on costs associated with the following five groups: train control and communication, crew wage, freight car, locomotive and fuel.

Traditionally, crew wages are computed on a train-run (or distance) rather than on an hourly basis. However, in the long run, unions negotiate for income levels would probably press for an increase in mileage rates should hours per train-run rise. Ultimately, it is hourly income that matters. Therefore, in this analysis, hourly crew wages are applied to train delay and included in the determination of the total interference cost.

In the traditional railway unit cost development, most operations and maintenance expenditures are related to output units, by either direct analysis or regression analysis. In addition, many of the indirect expenses including administration, supervisory and overhead expenses are related to other sets of expenses. For example, a part of the maintenance of shops and engine houses is explained by freight car maintenance expenses which is, in turn, related to

TABLE 3
Cost Items Affected By Train Delay

Train Delay	Cost Directly Affected	Cost Indirectly Affected	Service Units* Associated with Cost
Train Hours	- Signals, Communication and Train Control, Maintenance, and Ownership	- Overhead	Train hour (CP), Train mile (CN)
	- Crew Wages		Train hour
Car Days	- Freight Car Maintenance and Ownership	- Shop Machine and Equipment Maintenance and Ownership - Overhead	Car days
Locomotive Hours	- Locomotive Maintenance and Ownership	- Shop Machine and Equipment - Overhead	Diesel Unit Miles
	- Fuel	- Fuel Station Maintenance and Ownership	Gallons

* The service or output units are for Directly Affected Cost Items; the unit costs of indirect cost items are normally associated with the expenditure of direct costs.

car days and car miles. This process is known as "cost pyramiding." Thus, one work unit may be directly and indirectly linked to a number of expense accounts in the railway system.[5]

Unit Cost Development. In estimating interference costs, some distance or other physical units have to be converted to time-related units. These include the conversion from train miles to train hours, from diesel unit miles to locomotive hours and relating gallons of fuel consumption to delay in locomotive hours.

An average speed of 12 miles per hour is used to convert distance to hours. This speed is derived based on an analysis of the train acceleration profile produced by the AAR's Train Energy Model. The speed represents the average train speed during the first 10 minutes after the starting of a train, on level track.

Accordingly, the unit costs of train miles and diesel unit miles calculated from costing models are adjusted to unit costs of train and locomotive hours respectively.

The fuel consumption per locomotive hour of delay is also determined based on the Energy Report of the AAR model which calculates fuel consumption of a locomotive unit at a given notch position or speed. As train delay in each meet or overtake involves train slow down, speed up and wait time, fuel consumption in interference delay is calculated assuming 25% acceleration time and 75% train idle time. The results show that fuel consumption per locomotive hour of delay is approximately 58% of fuel consumption (in gallons per hour) at normal speed. The unit cost of fuel per locomotive hour is adjusted accordingly for interference cost estimation.

Results of the Unit Cost Model. Results of the unit cost model are summarized in Table 4. The table shows the total interference cost and breakdowns by the five cost groups. The case with 0 passenger trains can be interpreted from two points of view. On the other hand, it represents the interference cost that can be saved by removing the passenger trains. On the other hand, it represents the hidden cost borne by the freight service because of the existence of the passenger train runs.

B. The Productivity Approach

Train delay results in longer car and locomotive trip times. Thus, it increases the rolling stock cycle (turnaround) time and reduces the annual mileages that can be generated per car and per locomotive. In other words, to carry the same traffic level of ton-miles, more rolling stock is required. The relationships, between average train speed and equipment cycle time, and between cycle times and rolling stock requirement, can be calculated with the World Bank's RAIL Model.

The RAIL model was designed in the late 1970's to investigate alternative investment policies for developing nations. The RAIL is a large scale and multi-function model by construction. It permits the user to define parameters of eight basic ELEMENT types in a railway system. The types of elements are Project, Locomotive, Wagon, Route, Service, Traffic by service/route, Line and Yard. Furthermore, RAIL provides a range of analysis types which represent varying levels of complexity.

The model calculates the locomotive and car turnaround times using the following two formulae.

LTURN = (TIME + WKDEL + LOCDEL)/24
CTURN = (TIME + WKDEL + DELSHN + NSHUNT)/24 + CDEL

TABLE 4
The Unit Cost Approach Estimated Interference Costs

KAMLOOPS - HYDRO

Yearly Estimates in 1983 Costs
Dollars

Passenger Trains/Day	Signal & Comm.	Loco	Freight Cars	Fuel	Crew Wages	Total
0	-67266	-159652	-50824	-253760	-102669	-634170
2						
4	68620	162865	51874	258867	104736	646962
6	145092	344367	109899	547357	221457	1368171
8	230027	545955	174183	867773	351094	2169031
10	322298	764956	244029	1215867	491930	3039081
12	418022	992150	316598	1576982	638035	3941787

Where LTURN = locomotive turnaround time in days
TIME = average road time over route
WKDEL = average working delay
LOCDEL = locomotive terminal delay per trip
CTURN = car turnaround time in days
DELSHN = average delay per shunt
NSHUNT = number of shunts en route
CDEL = car delays at rail terminals per trip in days

In the above formulae, train interference delay is included in the average road time (TIME). In order to measure the effect of train itneraction on locomotive and car turnaround times, the other delay components are held constant. Specifically, based on CN freight operating data and train schedules, average work program delay and locomotive and car terminal delay are estimated. These delay components are assumed unchanged in the interference analysis.

For the first formula, an average locomotive terminal delay of 40 hours and a work delay of 8 hours are assumed. Thus the total delay for these two components is assumed 2 days.

In the second formula, terminal delay is the most important component affecting car turnaround time. The terminal delay includes car loading and unloading. For the purpose of this study, a terminal delay of 4 days per trip is assumed. Car shunting delay is also a major factor that affects car cycle time; however, it is not affected by train congestion on the main line. A total of 1 day in car shunt and working delay per trip is assumed.

The requirements for rolling stock are calculated using:

LSERV (I) = (NTR/DAYS) * NLOC * TURN
LSTOCK (I) = (LSERV(I) * 100) /LAVAIL
CSERV (I) = (NTR/DAYS) * NTCAR * CTURN
CSTOCK (I) = (CSERV(I) * 100) /CAVAIL

where LSERV (I) = Number of locomotives required in service of Case I
LSTOCK (I) = number of locomotives required in stock
CSERV (I) = number of cars required in service
CSTOCK (I) = number of cars required in stock
NTR = number of train runs a year
NLOC = number of locomotives per train
LAVAIL = percent of time locomotive available for service
DAYS = number of days per year service operates
NTCAR = number of cars per train
CAVAIL = percent of time car available for service

Inputs to the World Bank Model are presented in Table 5. To demonstrate the methodology, the base

TABLE 5

Operating Statistics—Inputs

KAMLOOPS-HYDRO

		PASSENGER TRAINS PER DAY			
DESCRIPTION	INPUTS*	2	0	4	6
System Trackage	ML	227	227	227	227
Length of Haul	ML	227	227	227	227
Annual Traffic	TONS (000)	26591	26591	26591	26591
Average Car Load	TONS	78	78	78	78
Loaded Cars/Train	CARS	54	54	54	54
Empty/Loaded Ratio		0.784	0.784	0.784	0.784
Average Speed	ML/HR	25.65	26.58	24.70	23.74
Average Road Time	HRS	8.85	8.54	9.19	9.56
Locomotives/Train	LOCOS	2.31	2.31	2.31	2.31
Loco. Availability**	%	95	95	95	95
Locomotive Weight	TONS	180	180	180	180
Empty Car Weight	TONS	28	28	28	28
Car Availability**	%	90	90	90	90
	INTERMEDIATE OUTPUTS				
Car Cycle Time	DAYS	9.58	9.55	9.60	9.63
Loco. Cycle Time	DAYS	2.37	2.36	2.38	2.40

* Estimated based on CN 1984 operating data.

** The availability figures in the table apply to existing equipment only. For new equipment, a 100% availability is assumed.

case and three alternative cases are analyzed. The latter include the case with passenger trains removed, and the cases with 4 and 6 passenger trains per day respectively. it is noted that among the inputs, only two variables, average speed and average transit time, are different in each case.

The Rail Operations Report shown in Table 6 includes annual freight traffic statistics and rolling stock requirement estimated by the model.

Cost Estimation from the Productivity Approach Under this approach interference cost is analyzed from the point of view of costs incurred due to reduced productivity. Train delay increases the number of rolling stock units required in service, the cost implication is investigated here.

The World Bank Model has bult-in mathematical equations to calculate revenues and costs based on route specfici cost and traffic data. In this analysis, the World Bank Model method is used wherever possible. In addition, a method of calculating the incremental costs in train control and rail operation administration is proposed.

Four major cost groups are identified for the interference analysis; they are rail operation costs, maintenance costs, depreciation and capital charges. Data on cost components are presented in Table 7.

1. Rail Operation Costs

In the World Bank's LINE model, line haul costs are the variable cost of operating a train and include crew wages, fuel and oil. The crew labour cost is assumed to be distance rather than time related. Oil cost is estimated as a percentage of the fuel cost. The equation used to calculate fuel cost per train is of interest in estimating interference delay cost; it is specified as:

FUEL C (I) = FCON * FCOST * HORSEP * NLOC * ((.15 + .85 * AVSPD (I)/MXSPD) * FRTIME + .15 * (WAIT (I)/60-FRTIME + .25 * LOCDEL))

A detailed description of this equation and its variables can be found in reference.[6] Essentially, this equation specifies fuel cost per train as a function of the free running time (FRTIME), train speeds (AVSPD and MXSPD), road time (WAIT) which

TABLE 6

Freight Operation Report

KAMPLOOPS–HYDRO

DESCRIPTION	PASSENGER TRAINS PER DAY			
	2 (Base Case)	0	4	6
Number of Trains	6313	6313	6313	6313
Locomotive Miles (000)	3310	3310	3310	3310
Train Miles (000)	1433	1433	1433	1433
Net Ton Miles (000)	6036157	6036157	6036157	6036157
Gross Ton Miles (000)	10497651	10497651	10497651	10497651
Car Miles (000)	138058	138058	138058	138058
Equipment Required in Service				
Locomotives	94.6	94.1	95.2	95.8
Freight Cars	8945.7	8924.2	8969.3	8995.0
Equipment Required in Stock				
Locomotives	99.6	99.1	100.2	100.8
Freight Cars	9939.7	9918.2	9963.3	9989.0
Increase in Rolling Stock Requirement				
Locomotives		-0.52	0.57	1.18
Freight Cars		-21.52	23.61	49.29
Annual Miles per Locomotive	34978	35170	34770	34576
Annual Miles per Car	15433	15470	15392	15348
GTM/Locomotive	6296106	6330626	6258674	6218443
GTM/Car	1106873	1109542	1103959	1100807
Train Hours	55871	53914	58018	60354

TABLE 7

Cost Data

COST COMPONENTS	VAR OR FX	UNIT	COSTS $*
Crew	V	Trn-HR	48.81
Fuel	V	Trn-HR	208
Other Rail Operation	V	GTM	0.0015
Maintenance			
Locomotive	V	Loco-ML	1.3534
	F	Annual/Loco	79838
Freight Car	V	Car-ML	0.0750
	F	Annual/Car	807
Way and Structure	V	Trn-ML	10.2834
	F	Annual/ML	4123
Depreciation			
Locomotive	V	Loco-ML	0.7153
Freight Car	V	Car-ML	0.0219
Way and Structure	V	GTM	0.0007
Capital Charges**			
Loco	V	Locomotive	10%
Wagon	V	Car	10%
Way and Structure	V	ML	10%

* Derived based on CN system data from the 1983 Railway Financial and Traffic Statistics. Statistics Canada Report 52-215.

** The opportunity cost of capital is assumed at ten percent.

includes delays, and other variables related to locomotive characteristics. With some mathematical operations, the equation can be reduced to show that the fuel cost per unit of delay time can be calculated as 15% of the cost for free running time. This ratio is a low estimate compared with the factor of 58% developed in the unit cost approach. The fact that this formula gives lower estimates of fuel consumption in delay time than a previously used formula is considered unimportant, because the main purpose of this study is to investigate alternative methods for the estimation of interference costs.

In this paper, a set of formulae is developed to estimate the possible changes in the other rail operation cost, i.e. administration and train control. These formulae are described below.

First, it is assumed that total annual gross ton miles are not affected by interference delay, only the requirement for new rolling stock. Thus:

(1) $GTM = GTM_{oj} + GTM_{nj}$

where GTM is annual gross ton miles, GTM_{oj} represent the GTM carried by existing equipment (including cars and locomotives) and GTM_{nj} represents the GTM carried by added equipment at a given traffic level j. In the base case:

$GTM = GTM_{oj}$ and $GTM_{nj} = 0$.

the unit cost per gross ton-mile for a given traffic level is adjusted as:

$RCGTMj = RCGTM_o * (GTM/GTM_{oj})$

where $RCGTM_j$ and $RCGTM_o$ represent rail operation costs per GTM at traffic level j and the base case o respectively. The interference cost is calculated as:

$IRC = (RCGTM_j - RCGTM_o) * GTM = RCGTM_j * GTM_{nj}$

where IRC represents the incremental railway operating cost.

2. Maintenance Costs

In the World Bank Model, maintenance costs for rolling stock are specified as a combination of fixed annual cost per unit plus per mile travelled. The delay induced rolling stock maintenance costs are calculated based on number of new locomotives and cars required in each alternative case.

3. Depreciation Costs

In this analysis, depreciation is calculated on rolling stock usage and replacement value. Thus, the delay induced increases in equipment depreciation are calculated as a function of new rolling stock requirement, annual mileage per equipment, replacement cost and equipment life in distance.

4. Capital Charges

Capital charges are defined as the opportunity cost of the undepreciated capital invested in rolling stock.

The annual capital charge is the average book value (equal to half the replacement value) times the required rate of return. The interference costs are calculated based on new equipment requirement in each alternative case.

Results of the Productivity Approach. Under this approach, train delay times are built into equipment cycle times and the incremental costs associated with the resulted new equipment requirement are calculated. The results of interference costs based on the simulated operation on CM Kamloops segments are presented in Table 8.

It is noted that for two reasons, the general expense group e.g. overhead and other expenses is not included in the productivity approach: First, it is debatable whether this cost group should be included in the incremental cost analysis, and second, it would require further analysis to develop functional relationship between the overheads and the interference delay. Consequently, the total interference costs presented in Table 9 are lower than those estimated under the unit cost approach where system overheads are allocated to output units.

However, the lower cost estimates are also attributable to the different mathematical equations adopted in the two approaches. In particular, fuel costs estimated in the previous section are about three times higher than those presented here; this is due to the use of different fuel consumption formulae rather than the unit cost of fuel, i.e. cost per gallon. Furthermore, the crew cost is included in the unit cost approach based on a long term perspective, while in the World Bank Model, crew wage is assumed not changed in short-run marginal cost calculations.

IV. CONCLUSIONS

The preliminary modelling effort made in this study indicates the feasibility of estimating the interference cost for individual train services. However, further development effort would be necessary to make use of the methodology as alternative costing approach. The following is an evaluation of the two cost models illustrated here.

Firstly, the advantage of the unit cost approach is that the "pyramiding" unit cost method provides a link between train delays and the cost items directly and indirectly affected by the delays. The major difficulty of this approach is that most of the unit costs currently adopted by the railways were developed based on system total costs. These unit costs may lead to an overestimate of incremental or marginal cost. Thus, to develop more precise interference costs it would be necessary to review and reconstruct the unit costs in the railway costing system.

Secondly, the World Bank Model is found very useful in analyzing the effect of interference delay on rolling stock requirement and costs. Furthermore, the Model's ability to analyze the marginal cost on a route or service basis is particularly useful for the route-specific interference analysis. However, more

TABLE 8

The Productivity Approach Estimated Interference Costs

KAMLOOPS–HYDRO

Yearly Estimates in 1983 Costs

	Remove Passenger Trains	Add Two Passenger Trains	Add Four Passenger Trains
RAIL OPERATING COST			
Fuel	-61061	66970	139849
Other	-40517	44646	93476
MAINTENANCE			
Locomotive	-41203	45190	94367
Freight Car	-17369	19049	39780
DEPRECIATION			
Locomotive	-12983	14078	29209
Freight Car	-7307	7974	16604
CAPITAL CHARGES			
Locomotive	-25804	28301	59099
Freight Car	-32284	35408	73940
TOTAL	-238528	261616	546324

case studies are required to draw conclusions on its cost estimates.

Overall, the interference cost approach may provide useful information supplementary to the traditional railway costing method. It is an aspect of importance to a railway for its internal investment evaluation and traffic development purposes. Moreover, it may be of potential use in service contract negotiations between passenger and freight railways. However, it remains to emphasize that this is a research project which concentrates on methodologies. Further studies are required to deal with their practical applications in railway costing systems.

ENDNOTES

*Transport Canada.

1. The views expressed in this paper are those of the author and do not reflect the views of the Transport Canada.
2. English, G.W. and G. Schwier (1986) "User Analyst Guide CIGGT Linemodel V. 2.1." Canadian Institute of Guided Ground Transport, Queen's University, Kingston.
3. The ten hours limit on train-run is based on crew shift specified in industry labour agreements. See Spector, A.N. "An assessment of railway line capacity models available to the CTC," Canadian Transport Commission, 1986.
4. Delcan, Deleun Chather, Canada Ltd., "Joint Track Usage Study, Kamloops—Mission, B.C." Report No. 32-1727, November, 1985.
5. Hariton, G., "Railway Costing—A Review," Research Branch, Canadian Transport Commission, 1984, WP 60-84-04.
6. Taborga, P.M., "Railway Analysis Interactive Language, Rail User's Manual" The Work Bank, March, 1986.
7. Table 1, the trains per day are inputs to the Model. They are annual averages derived from train schedules. For local trains, the average number of daily trips was weighted by the proportion of the line that was traversed. The passenger train inputs were .001.