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Citation of this paper:

Poon, Larry C. L.. "An Economic Evaluation of Urban Railway Relocation." Research Program. Impact of the Public Sector on Local Economies Discussion Papers, 011. London, ON: Department of Economics, University of Western Ontario (1976).

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# AN ECONOMIC EVALUATION OF URBAN RAILWAY RELOCATION

C. Larry Poon*

## RESEARCH PROGRAM: IMPACT OF THE PUBLIC SECTOR ON LOCAL ECONOMIES

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## I. INTRODUCTION

Many urban areas are debating whether to relocate the railways which pass through their centres. The cost of each of these relocation projects runs into millions of dollars. Furthermore, their impact on urban development is usually expected to be profound. Yet, almost no economic analysis of the effects of these projects is available to guide public policy makers in evaluating relocation proposals. The purpose of this study is to develop such a framework for appraisal of urban railway relocation projects. A case study of railway relocation in London, Canada, is included.

With regard to railway location and service, four alternatives are possible:

(1) maintain the status quo (STATUS QUO);
(2) relocate part or all of the railways in one of the following ways:
  (a) consolidate through services onto a smaller number of rail lines within the urban area and maintain local service (CONSOLIDATION);
  (b) relocate through services from the urban areas outside the city, but maintain local service to industries in the urban area (PARTIAL RELOCATION);
  (c) relocate through service and discontinue local service to industries (COMPLETE RELOCATION);
(3) leave the location of the railways and their services unchanged

but do something to reduce the railways' external effects, e.g., adopt measures to reduce railway pollution, apply safety devices to reduce accident rates, and build grade separations at road-rail level crossings to reduce congestion (GRADE SEPARATION); and

(4) discontinue all rail service (DISCONTINUATION).

In this study we evaluate alternatives (1) - (3) but not alternative (4). The analytical technique we use to evaluate the alternative policies is cost-benefit analysis. We compare the social benefits with the social costs for alternatives (1) - (3) above.

## II. FRAMEWORK OF ANALYSIS

In order to isolate the benefits and costs of railway relocation, it is useful to consider such projects separately, rather than in conjunction with other transportation or urban development projects, and to look at polar cases. The two polar cases are (a) maintaining the status quo -- alternative (1) above -- and (b) relocating all railway activities outside the urban area -- alternative (2c) above. The benefits and costs of railway relocation will be discussed in terms of these two extremes. They can be modified easily to accommodate intermediate cases.

A summary of benefits and costs of railway relocation and grade separation is given in Table 1. These are aggregate consumption benefits and costs. We do not include income distributional effects in the list, but we do consider these in a separate chapter in the thesis. We shall briefly go over the list of benefits and costs.

## TABLE 1

### Benefits and Costs of Railway Relocation and Grade Separation*

| Policy Alternative | Benefits | Costs |
|---|---|---|
| Relocation (alternatives 2.a-c) | 1. Savings in travel time and vehicle operating expenses.†<br>2. Net benefit of generated travel.<br>3. Reduction in accident rates.†<br>4. Land released for redevelopment.<br>5. Improvement of areas abutting railway facilities.† | 1. Capital costs.<br>2. Railway operating costs.<br>3. Transportation and relocation costs of railway users.<br>4. Transportation and relocation costs of non-users.<br>5. Delay in traffic while construction is in progress. |
| Grade Separation (alternative 3) | 1. Savings in travel time and vehicle operating expenses.†<br>2. Net benefit of generated travel.<br>3. Reduction in accident rates.†<br>4. Reduction in air pollution at level crossings.† | 1. Capital costs.<br>2. Railway operating costs.<br>3. Delay in traffic while construction is in progress. |

*It is assumed that there is no change in frequency of through railway service.

†All these should be on a net basis, i.e., improvements at old railway site less adverse effects at new railway site.

## A. Benefits of Railway Relocation

### 1. Savings in road travel time and vehicle operating expenses

The presence of railway crossings causes delays to motorists for a number of reasons. For example, each time a train passes a level crossing, street traffic slows down and stops. Also, because railroad crossings are rough and represent a potential hazard, many motorists slow down at grade crossings even when there is no train or train warning. In addition, some people may start their trips early every day in order to allow for a margin of safety in case they get caught by a train. Other people may take longer routes in order to avoid the possibility of being delayed at level crossings. Railway relocation eliminates or reduces all these sources of delay and hence saves motorists' time and vehicle operating expenses.

### 2. Net benefits of generated travel

To the extent that railway relocation reduces costs of travel for other traffic, more trips may be taken. The net benefit of the generated travel is a benefit of railway relocation.

### 3. Reduction in accident rates

Railway installations on high embankments and road-rail level crossings present a safety hazard to pedestrians and vehicles. Elimination of road-rail crossings as a result of railway relocation would reduce accident rates.

### 4. Land released for redevelopment

Another consequence of railway relocation is that some urban railway land is released for redevelopment. It could be used for residential, commercial or industrial purposes, or it could be used for public facilities such as parks and highways.

### 5. Improvement of areas abutting railway facilities

Railways and their dependent industries impose external diseconomies on surrounding neighbourhoods in the form of noise, vibration, air, and "visual" pollution. Hence, removal of the railways will improve adjacent areas.

## B. Costs of Railway Relocation

### 1. Capital costs

Capital costs of relocation include costs of (a) acquiring properties for new railway facilities; (b) construction of new railway facilities; and (c) removal of old tracks and installations. To obtain net capital costs, salvage value of existing facilities should be deducted.

### 2. Railway operating costs

The main items of railway operating costs are: (a) crew wages; (b) maintenance and depreciation of locomotives, cars, tracks, yards and other structures; and (c) fuel. These may change as a result of relocation.

### 3. Transportation and relocation costs for railway users

Transportation costs for firms and households who use the railway service will increase if relocation moves the railway away from them. Relocation costs would be incurred by industries or households who relocate as a result of discontinuation of rail service.

### 4. Transportation and relocation costs for non-users

Employees of railway companies and industries which relocate may have to travel a longer distance to work and thus incur additional commuting costs or move and thus incur relocation costs.

### 5. Delay in traffic while construction is in progress

Vehicle traffic will be delayed while construction is in progress at both the old and new locations. In addition, construction adds to air, noise and visual pollution.

## C. Benefits and Costs of Grade Separation

Some of the benefits of relocation can be achieved (to a different degree) by building more grade separations at level crossings. However, it is unlikely that grade separations can release land for redevelopment or improve areas abutting railway facilities to any significant extent.

# III. MEASUREMENT OF BENEFITS AND COSTS

In this section we formulate methods for estimating the social benefits and costs identified. The discussion of the benefits and costs follows the same order as in Section II.

## A. Benefits of Railway Relocation

### 1. Savings in road travel time and vehicle operating expenses

a. Savings to motor vehicles which are slowed or stopped by trains.

As the train approaches the crossing, a warning light begins to flash and, for some crossings, a gate is closed. After the train passes, the light stops flashing and the gate is reopened. Suppose that as a result of the passing of a train road vehicles cannot cross the tracks for a period of C hours. When this period ends, the first vehicle in the line immediately begins to accelerate, but the second vehicle cannot begin to accelerate until it has enough headway to do so, or until A hours after the crossing reopens. The third vehicle cannot begin to accelerate until 2A hours after the crossing reopens, etc.

Suppose that the one-way flow of traffic on the road is F vehicles per hour. In this case, on average the first vehicle will arrive at the crossing 1/2F hours after the crossing closes. It will be delayed a total of

$$C - 1/2F$$

hours. The second vehicle will arrive 1/F hours after the first and will start up again A hours after the first. It will thus be delayed a total of

$$C - 1/2F - (1/F - A)$$

hours. It follows that the nth car to be stopped by the train will be delayed

$$C - 1/2F - (n-1)(1/F - A)$$

hours.

Finally, the total number of vehicles that will be stopped by the train is approximately the integer closest to:

$$Q = FC/(1 - AF).$$

This figure is arrived at as follows: When the crossing reopens at the end of C hours, FC vehicles will have been stopped at the gate. Since it takes A hours for each of these vehicles to move far enough from its position of rest for the vehicle behind it to begin moving, it will be FCA hours after the crossing opens before the last of the FC vehicles has moved far enough to permit the vehicle behind the FCth vehicle to move. During this period of FCA hours, FC(AF) vehicles behind the FCth vehicle will be forced to stop. This continues, and the total number of vehicles that will be forced to stop is

$$FC + FC(AF) + FC(AF)^2 + FC(AF)^3 + \ldots$$

This series converges to FC/(1 - AF).

Thus, we arrive at the following formula for the vehicle hours lost during deceleration and while at rest for vehicles which are forced to come to a stop.

$$Q(C - 1/2F) - \sum_{n=1}^{Q} (n-1)(1/F - A)$$

Still considering only one train, but considering both directions of traffic flow and the case of any number of lanes in each direction, let $G_{ji}$ be the traffic flow per hour in direction i on lane j. Then the formula for the vehicle hours lost during deceleration and while at rest for vehicles which are forced to come to a stop is:

$$\sum_{i=1}^{2} \sum_{j=1}^{m_i} \left[ Q_{ji}\left(C - \frac{1}{2G_{ji}}\right) - \sum_{n=1}^{Q_{ji}} (n-1)\left(\frac{1}{G_{ji}} - A\right) \right]$$

where $Q_{ji} = G_{ji}\, C/(1 - A\, G_{ji})$, $m_i$ = number of lanes in direction i.

We must also develop a formula for the amount of time vehicles lose while they accelerate back to their normal speed. Suppose that it takes a vehicle T hours to accelerate from rest to its normal speed of S miles per hour. Assuming a constant rate of acceleration, during a period of T hours the vehicle will travel at an average speed of S/2 instead of S and hence lose a distance of TS/2, compared to the distance it would have travelled at its normal speed. It will take the vehicle a period of T/2 hours at its normal speed to make up this lost distance, and hence the vehicle loses T/2 hours of time. Since each vehicle that comes to a stop loses T/2 hours, the total time lost by the FC/(1 - AF) vehicles which are stopped in one lane in one direction by a train is:

$$FCT/2(1 - AF)$$

hours. This can easily be generalized to the case of any number of lanes in two directions.

Our next step is to aggregate over all trains and all crossings. Let

$G_{jitkd}$ = traffic flow per hour in direction i on lane j at crossing k as train t passes during day d.

$C_{tkd}$ = hours crossing k is closed as train t passes during day d.

Then the total vehicle hours saved during day d without undergoing the deceleration and stopping processes will be:

$$H_{1d} = \sum_k \sum_t \sum_i \sum_j \left[ Q_{jitkd} \left(C_{tkd} - \frac{1}{2G_{jitkd}}\right) - \sum_{n=1}^{Q_{jitkd}} (n-1)\left(\frac{1}{G_{jitkd}} - A\right) \right]$$

where $Q_{jitkd} = G_{jitkd}\, C/(1 - AG_{jitkd})$

This formula can be simplified to the following:

$$H_{1d} = \sum_k \sum_t \sum_i \sum_j \frac{G_{jitkd}\, C_{tkd}}{1 - AG_{jitkd}} \left( \frac{C_{tkd} - A}{2} \right)$$

The total vehicle hours saved in one year from both sources will be

$$H_1 + H_2 = \sum_{d=1}^{365} (H_{1d} + H_{2d})$$

So far we have been concerned with savings in vehicle hours at railway crossings. Now let us turn to the annual savings in vehicle operating expenses such as gas and oil consumption, tire-wear, maintenance, etc. Extra vehicle operating expenses will be incurred if there are level crossings because vehicles undergo stop-go cycles and idle while waiting for trains. Let $G_1$ be the idling vehicle operating cost. Then

$$G_1 = g_1^p h_1^p + g_1^c h_1^c + g_1^t h_1^t$$

where $h_1^p$, $h_1^c$, $h_1^t$ refer to the hours of idling time of passenger, commercial, and public transit vehicles respectively at level crossings, and $g_1^p$, $g_1^c$, $g_1^t$ are the corresponding vehicle operating expenses per hour of idling.

The savings in vehicle operating expenses per annum for not undergoing the stop-go cycle at level crossings can be estimated as follows:

$$G_2 = g_2^p K_2^p + g_2^c K_2^c + g_2^t K_2^t$$

where $K_2^p$, $K_2^c$, $K_2^t$ refer respectively to the number of passenger, commercial, and public transit vehicles stopped at all level crossings during the year, and $g_2^p$, $g_2^c$, $g_2^t$ are the extra operating costs per vehicle incurred in undergoing the stop-go cycle for the three individual modes of transport.

b. Savings to motor vehicles which slow down at level crossings.

Let $ADT_{kd}$ be the number of vehicles (excluding those stopped by trains) passing level crossing k on day d. Let $e_{kd}$ be the loss in time (in hours) per vehicle while passing level crossing k on day d. The yearly savings in vehicle-hours as a result of the removal of K level crossings will be

$$H_3 = \sum_{d=1}^{365} \sum_{k=1}^{K} e_{kd} \, ADT_{kd}$$

Annual savings in vehicle operating expenses resulting from the removal of the K level crossings will be equal to

$$G_3 = \sum_{d=1}^{365} \sum_{k=1}^{K} r_{kd} \, ADT_{kd}$$

where $r_{kd}$ is the per vehicle increase in operating expenses during the slow down and speed up process at level crossing k on day d.

c. Other sources of savings.

Savings in travel time and vehicle operating expenses to motorists who depart early or use longer routes can be estimated in a similar manner if we have the data. However, such data usually do not exist and hence savings arising from these sources may have to be ignored in practice.

d. Value of man-hours saved.

It is necessary to put a dollar value on the man-hours saved. The problem of valuation of travel time has given rise to a substantial body of literature.

e. Time horizon.

Since savings in travel time and vehicle operating expenses are recurrent benefits, it is necessary to calculate their present discounted value over the time horizon of the project.

### 2. Net benefit of generated travel

To estimate the net benefit of generated travel we would have to know, among other things, the elasticity of the hourly demand curves for vehicle miles of travel in the urban area. Since it would be extremely difficult to obtain the data necessary to estimate the elasticity of demand, the additional net benefit of generated trips has been ignored in practice.

### 3. Reduction in accident rates

In order to estimate this item of benefit, we must estimate how many accidents will be avoided and put a dollar value on the reduction in accidents. To our knowledge no study has been done with respect to the valuation of railway crossing accidents per se though quite a number of studies have been done to value highway accidents. The formula which we use in this study to get the present discounted value of the reduction in road-rail crossing accidents is the following:

$$\sum_{t=1}^{N} \frac{\sum_{i=1}^{3} C_i \; A_{i1} \; (1 + g_i)^{t-1}}{(1+r)^{t-1}}$$

where $A_{i1}$ = number of type i road-rail accidents in year 1;

$C_i$ = cost per type i road-rail accident;

$g_i$ = annual growth rate of type i road-rail accident;

$r$ = discount rate;

$N$ = project life in years.

The following three types of road-rail crossing accidents are distinguished: fatal, non-fatal injury, and property damage only.

### 4. Land released for redevelopment

The benefit from release of land is often taken to be the market price of the land released. However, for various reasons, market prices may not correctly measure the social benefit from the release of land. Unfortunately, this is probably the only practical measure that is available under most circumstances.

### 5. Improvement of areas abutting railway facilities

If railways impose external diseconomies on the residential neighbourhoods through which they pass, the removal of the railways may confer benefits (such as reduced noise, air, and visual pollution) on present and future residents and passersby in these areas. The value of the benefits is the amount that these people would be willing to pay for removal of the railway.

Under certain circumstances an indirect measure of the benefits due to removal of spillovers may be derived from data on property values. In general, because the marginal willingness to pay for removal of railway externalities will exceed the average willingness to pay, use of property values will lead to an estimate of this category of benefits which is biased upwards.

To find out whether railway externalities are capitalized in property values, we estimate the following function:

$$P = f(x_1,\ldots,x_n)$$

where P is the price of a residential property and $x_1,\ldots,x_n$ are locational, housing characteristics, environmental, and other variables which affect housing prices. One of the independent variables, say $x_i$, will be distance from the railway. Our main hypothesis will be that because of railway externalities:

$$\frac{\partial P}{\partial x_i} > 0 \quad \text{and perhaps} \quad \frac{\partial^2 P}{\partial X_i^2} < 0$$

In Appendix A, we show one of the estimated equations. Our main hypothesis is confirmed by the empirical evidence.

To estimate the aggregate social benefits from the removal of railway externalities we employ the following function.

$$\int_{x_i = 0}^{\infty} f(x_i)\, g(x_i)\, dx_i$$

where $f(x_i)$ relates discount in dollars per property to distance from railway ($x_i$) and $g(x_i)$ shows the number of properties at each distance ($x_i$) from the relevant railway tracks. If $f(x_i)$ becomes zero for $x_i$ greater than D, then the integration can be carried out from zero to D.

In practice we work with discrete rather than continuous functions. The actual function which we use is the following:

$$SB = \Sigma\, d(x_i)\, n(x_i)$$

where

SB = dollar value of social benefits from the removal of railway externalities as measured by the discount in property values;

$d(x_i)$ = average discount in dollars in property value between $100x_i$ and $100(x_i - 1)$ feet from the railway;

$n(x_i)$ = number of properties between $100x_i$ and $100(x_i - 1)$ feet from the railway.

## B. Costs of Railway Relocation

Estimation of these costs falls mainly within the realm of civil engineering. However, as economists, we should make sure that all the correct opportunity costs are included and that none are double counted.

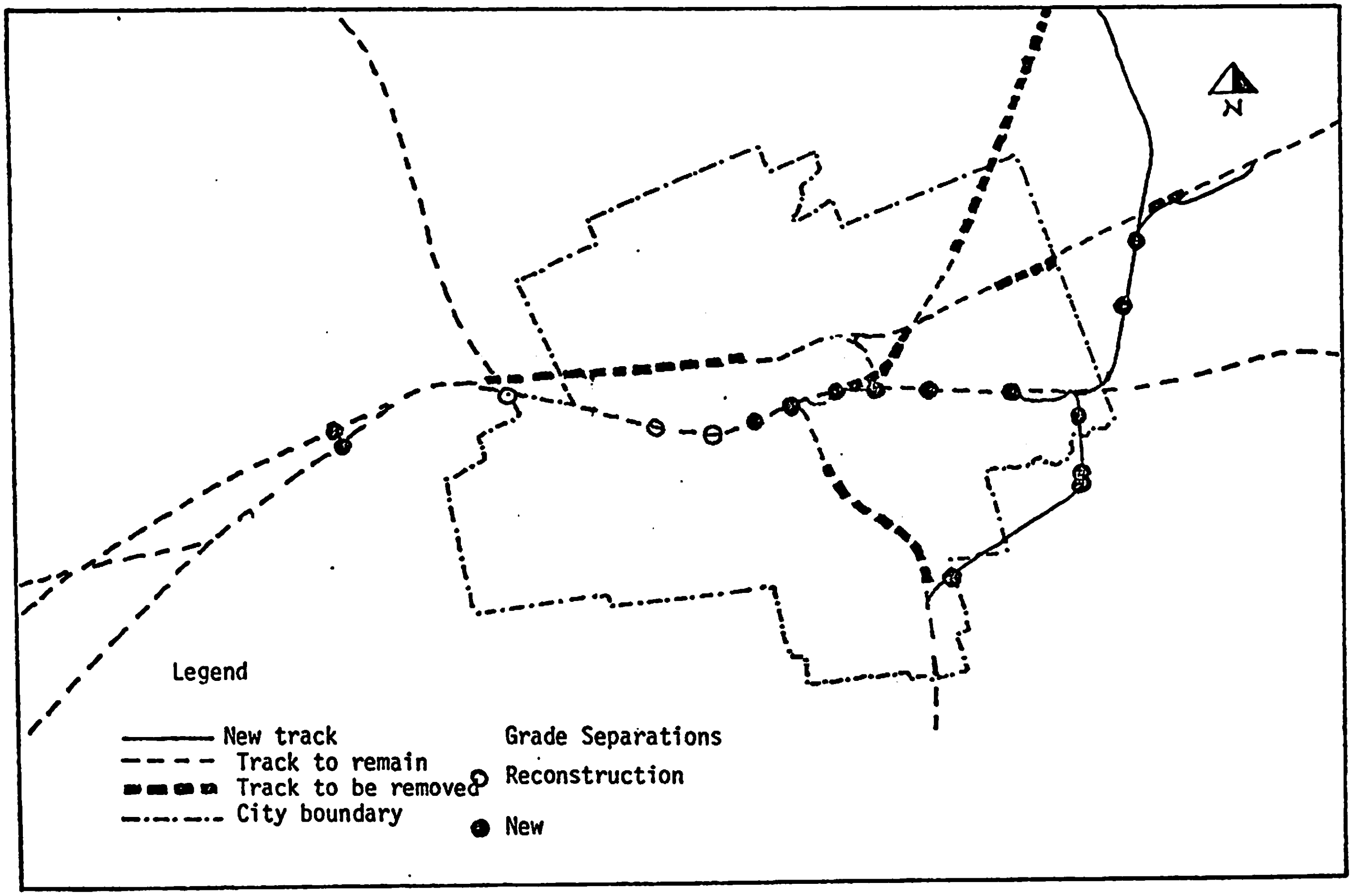
## IV. EMPIRICAL RESULTS: RAILWAY RELOCATION IN LONDON, CANADA

In the recent London Urban Transportation Study (LUTS) by DeLeuw Cather, some consideration was given to railway relocation schemes. After preliminary investigation, two schemes were retained for further study, the CNR scheme (Figure 1) and the Southern scheme (Figure 2). LUTS recommended the CNR scheme. These two schemes resemble alternatives (2.a) CONSOLIDATION, and (2.b) PARTIAL RELOCATION, respectively in Section I. The main thrust of the CNR scheme is to consolidate CPR traffic on CNR's Toronto-Woodstock-London-Windsor or Sarnia route. The Southern scheme directs through rail traffic to a new line outside the city but maintains local service to industries. For comparison purposes, we propose another altnerative, the Complete Removal scheme (Figure 3), which resembles alternative (2.c) TOTAL RELOCATION. This scheme is similar to the Southern scheme except that it discontinues local service to all industries except a few which are located at the outskirts of the city.

1972 was chosen as the base or "present" year and all the estimated benefits and costs are in terms of 1972 dollars. Due to the lack of data, we are unable to estimate some of the benefits and costs. Also, in some

FIGURE 1

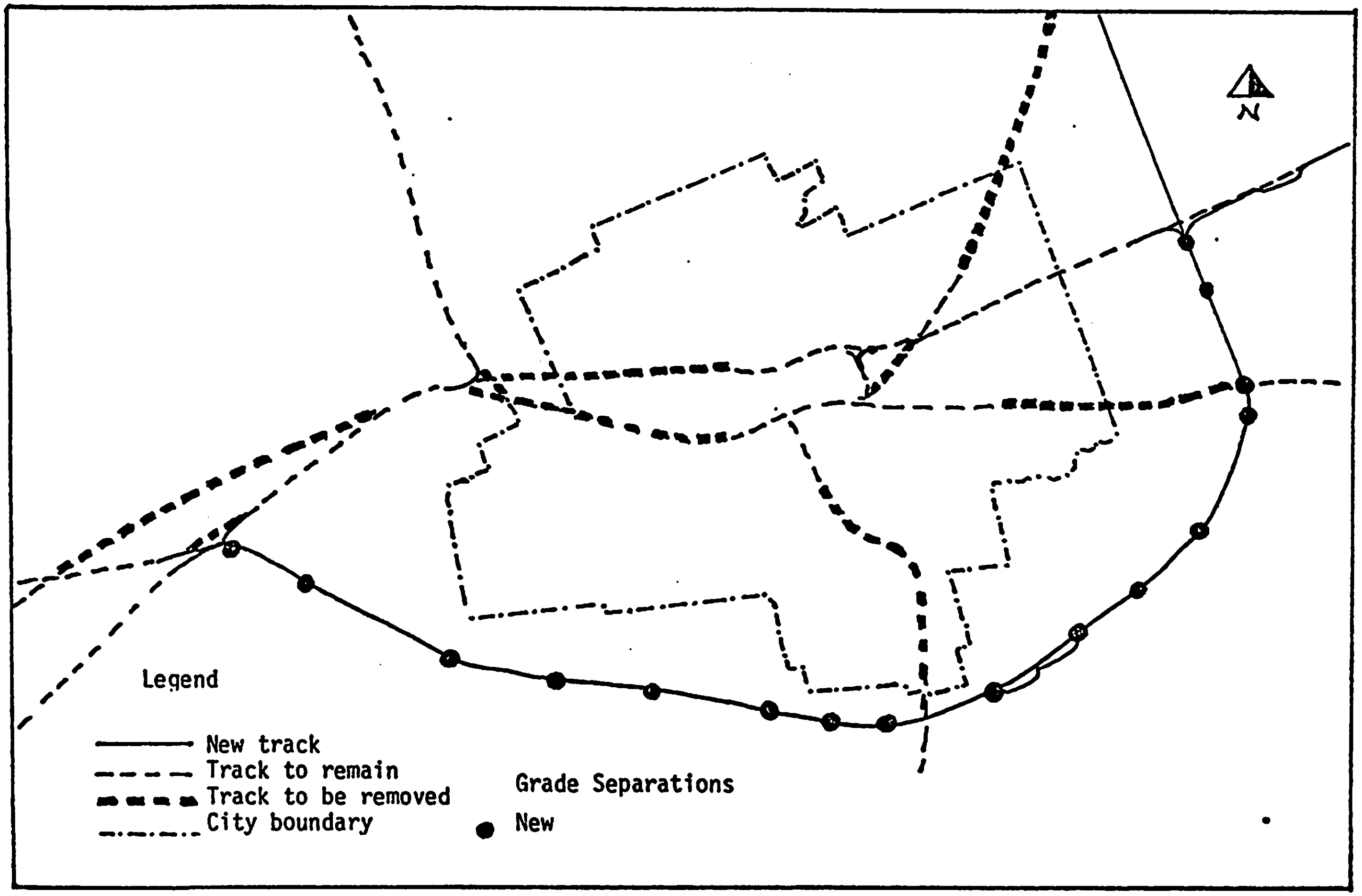
Railway Relocation: The CNR Scheme



Source: DeLeuw Cather (34).

FIGURE 2

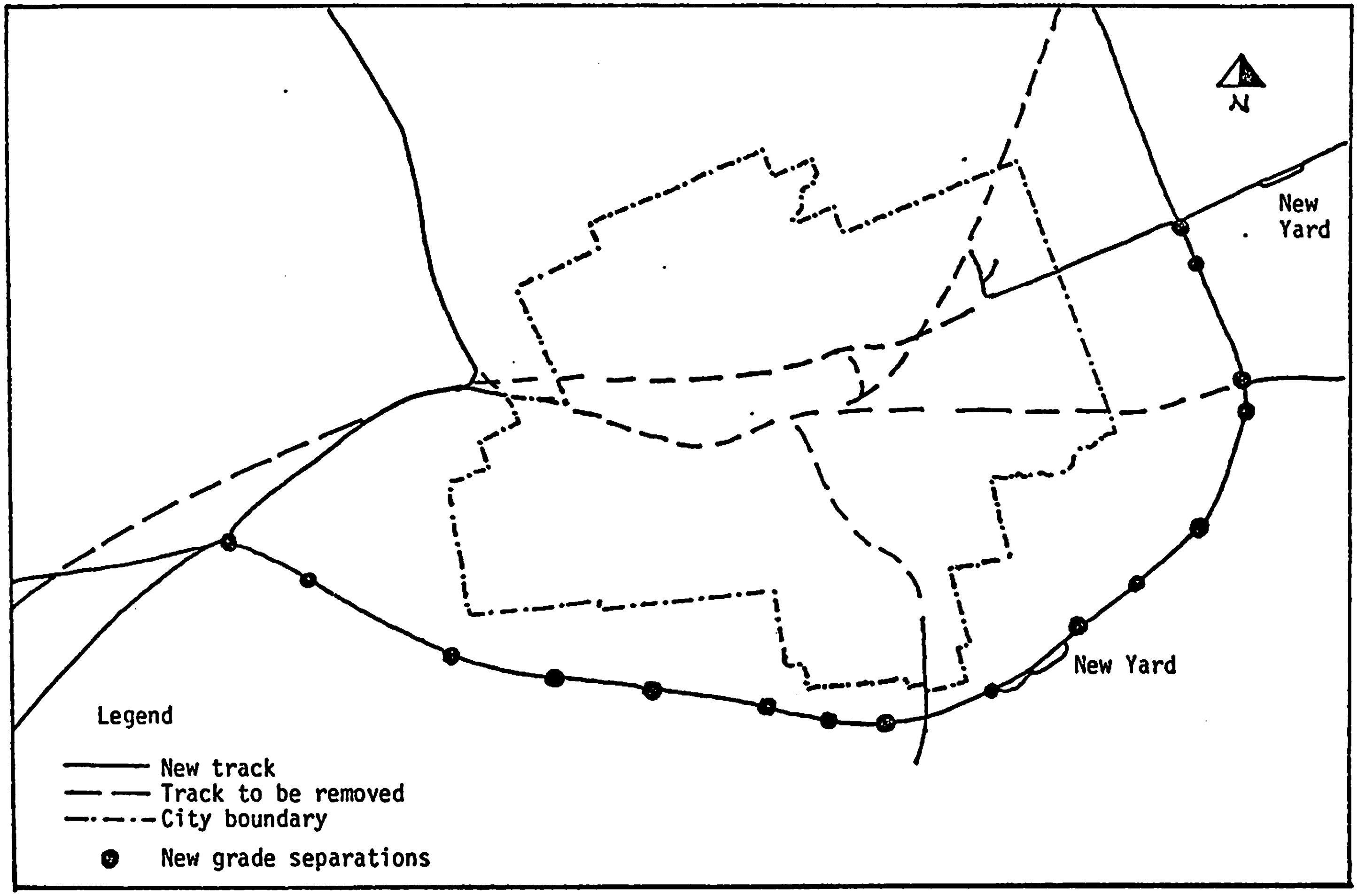
Railway Relocation: The Southern Scheme



Source: DeLeuw Cather (34).

FIGURE 3

<u>Railway Relocation: The Complete Removal Scheme</u>



Source: DeLeuw Cather (34).

cases, a good point estimate of a parameter is not available and we resort to sensitivity analysis in an attempt to establish interval estimates for benefits and costs. Consequently, numerous sets of benefits and costs can be derived, using different combinations of parameter values.

Table 2 gives a summary of the values of key parameters used in this study. These parameter values are arranged in three sets: "low," "middle," and "high." The "middle" values are the ones we consider to be the mostly likely. The set of "low" parameter values is unfavourable to the projects in the sense that it combines low estimates of benefits with a high estimate of capital costs. The set of "high" parameter values is favourable to the projects in the sense that it combines high estimates of benefits with a low estimate of capital costs.

In Table 3 we show the estimated benefits and costs of the three relocation shcemes and the grade separation alternative, based on the three sets of parameter values given in Table 2. It can be seen that under both the "low" and "middle" sets of parameters, none of the projects is justified on the basis of aggregate net benefits. With the set of "high" parameter values, all three relocation schemes show positive returns. The net benefit is largest in the case of the CNR scheme. The grade separation alternative, however, remains a marginal project even under this set of favourable assumptions.

These results are most sensitive to the discount rate and unit capital costs used. If a ten per cent discount rate[1] is used along with the other "low" or "middle" parameter values, no proposed project appears to be worthwhile. If the same discount rate were used with the "high" values of other parameters, then the benefits and costs of the three relocation schemes would be as follows ($ million):

## TABLE 2

### Range of Parameter Values Assumed

| Parameters | Values | | |
|---|---|---|---|
| | "Low" | "Middle" | "High" |
| (1) Dollar value of travel time (per man hour) | | | |
| (a) Passenger and transit users | .70 | 1.25 | 1.80 |
| (b) Commercial vehicle users | 5.00 | 5.00 | 5.00 |
| (2) Cost ($) per railway crossing accident | | | |
| (a) Fatal | 10,800 | 55,000 | 262,500 |
| (b) Non-fatal | 820 | 3,000 | 11,800 |
| (c) PDO | 200 | 350 | 600 |
| (3) Project life (years) | | | |
| (a) Railway relocation | 30 | 50 | 100 |
| (b) Grade separation | 30 | 50 | 50 |
| (4) Discount rate, % per annum | 10 | 7 | 4 |
| (5) Trend in rail traffic, % per annum | 0 | 0 | 0 |
| (6) Trend in motor traffic, % per annum | 1 | 2 | 3 |
| (7) Trend in railway accidents, % per annum | 0 | 1 | 2 |
| (8) Trend in value of travel time, % per annum[a] | 0 | 0 | 0 |
| (9) Unit costs of capital | High | Middle | Low |

Notes: (a) Estimates based on the assumption that the value of travel time grows at the same rate as the real wage rate are shown in Appendix B.

## TABLE 3a

### Benefits and Costs of Railway Relocation and Grade Separation in London, Canada (in million dollars, 1972)

("Low" Estimates)

| Benefits and Costs | Relocation | | | Grade Separation[a] |
|---|---|---|---|---|
| | CNR | Southern | Complete | |
| $B_1$ Savings in road travel time and vehicle operating expenses | 2.18 | 2.05 | 3.43 | 2.30 |
| $B_2$ Net benefit of generated travel | + | + | + | + |
| $B_3$ Reduction in accident rates | .18 | .20 | .23 | .16 |
| $B_4$ Land released for redevelopment | 5.50 | 5.80 | 5.80 | 0 |
| $B_5$ Improvement of areas abutting railway facilities | 2.08 | 2.89 | 4.47 | 0 |
| B. Total Benefits | 9.94+ | 10.94+ | 13.93+ | 2.46+ |
| $C_1$ Capital costs | 43.39 | 64.88 | >64.88 | 18.80 |
| $C_2$ Railway operating costs | -1.22 | .38 | .38 | 1.42 |
| $C_3$ Transportation and relocation costs of railway users[b] | 0 | .64 | .64 | 0 |
| $C_4$ Transportation and relocation costs of non-users | 0 | 0 | + | 0 |
| $C_5$ Delay in traffic while construction is in progress | + | + | + | + |
| C. Total Costs | 42.17+ | 65.90+ | >65.90+ | 20.22+ |

Notes: (a) Consists of 14 new and 10 reconstructed grade separations.
(b) Passengers only.

## TABLE 3b

### Benefits and Costs of Railway Relocation and Grade Separation in London, Canada
(in million dollars, 1972)

("Middle" Estimates)

| | Benefits and Costs | Relocation | | | Grade Separation[a] |
|---|---|---|---|---|---|
| | | CNR | Southern | Complete | |
| $B_1$ | Savings in road travel time and vehicle operating expenses | 4.72 | 4.48 | 7.24 | 4.79 |
| $B_2$ | Net benefit of generated travel | + | + | + | + |
| $B_3$ | Reduction in accident rates | 1.46 | 1.56 | 1.82 | 1.28 |
| $B_4$ | Land released for redevelopment | 6.72 | 8.03 | 8.70 | 0 |
| $B_5$ | Improvement of areas abutting railway facilities | 2.20 | 3.07 | 4.65 | 0 |
| B. | Total Benefits | 15.10+ | 17.14+ | 22.41+ | 6.07+ |
| $C_1$ | Capital costs | 25.54 | 36.79 | >36.79 | 18.80 |
| $C_2$ | Railway operating costs | -1.31 | 3.54 | 3.54 | 3.08 |
| $C_3$ | Transportation and relocation costs of railway users[b] | 0 | 1.17 | 1.17 | 0 |
| $C_4$ | Transportation and relocation costs of non-users | 0 | 0 | + | 0 |
| $C_5$ | Delay in traffic while construction is in progress | + | + | + | + |
| C. | Total Costs | 24.23+ | 41.50+ | >41.50+ | 21.88+ |

Notes: (a) Consists of 14 new and 10 reconstructed grade separations.
(b) Passengers only.

## TABLE 3c

### Benefits and Costs of Railway Relocation and Grade Separation in London, Canada
(in million dollars, 1972)

("High" Estimates)

| Benefits and Costs | Relocation | | | Grade Separation[a] |
|---|---|---|---|---|
| | CNR | Southern | Complete | |
| $B_1$ Savings in road travel time and vehicle operating expenses | 18.84 | 18.08 | 28.42 | 11.55 |
| $B_2$ Net benefit of generated travel | + | + | + | + |
| $B_3$ Reduction in accident rates | 18.75 | 19.35 | 22.54 | 11.43 |
| $B_4$ Land released for redevelopment | 7.93 | 10.26 | 11.73 | 0 |
| $B_5$ Improvement of areas abutting railway facilities | 2.38 | 3.34 | 4.92 | 0 |
| B. Total Benefits | 47.90+ | 51.03+ | 67.61+ | 22.98+ |
| $C_1$ Capital costs | 15.23 | 21.10 | 21.10 | 18.80 |
| $C_2$ Railway operating costs | -1.47 | 11.64 | 11.64 | 4.80 |
| $C_3$ Transportation and relocation costs of railway users[b] | 0 | 2.49 | 2.49 | 0 |
| $C_4$ Transportation and relocation costs of non-users | 0 | 0 | + | 0 |
| $C_5$ Delay in traffic while construction is in progress | + | + | + | + |
| C. Total Costs | 13.76+ | 35.23+ | >35.23+ | 23.60+ |

Notes: (a) Consists of 14 new and 10 reconstructed grade separations.
(b) Passengers only.

| | CNR | Southern | Complete |
|---|---|---|---|
| Total Benefits | 19.11+ | 21.83+ | 27.63+ |
| Total Costs | 17.06+ | 31.96+ | > 31.96+ |

The CNR scheme is only marginally worthwhile while the others are not justified.

If we use a ten per cent discount rate but otherwise combine the "high" estimates of benefits with the "middle" estimates of costs, the results are:

| | CNR | Southern | Complete |
|---|---|---|---|
| Total Benefits | 19.11+ | 21.83+ | 27.63+ |
| Total Costs | 25.57+ | 42.38+ | > 42.38+ |

Hence none of the projects is justified with a ten per cent discount rate and the most plausible capital cost estimates.

We may now draw some general conclusions:

(1) Based on what we regard as the most plausible assumptions and a discount rate of 7 per cent, none of the proposed railway relocation schemes is justified economically on the basis of aggregate net benefits. Also, the proposed grade separations, both new and reconstructed, if evaluated as a group, yield a negative return. However, two individual reconstructions give positive returns. This conclusion basically contradicts the LUTS recommendation in favour of the CNR scheme.

(2) If the social discount rate for Canada is approximately ten per cent as estimated by Jenkins (10), then the results would be even more unfavourable to the projects. With a discount rate of ten per cent, only

the CNR scheme would give a positive return if assumptions favourable to the projects were made with respect to other parameter values. All the other projects would be unjustified.

(3) It should be noted that we have considered only two alternatives to the status quo -- relocation and grade separation -- in the present study. There are other options which we have not evaluated, for example: prohibit train movements in the urban area during the rush hours, or schedule trains and publish schedules so that people could avoid trains.

(4) We have not considered the issue of optimal timing of railway relocation in this study. We have found that the present discounted value of benefits is less than the present discounted value of costs under the most plausible set of parameter values. However, if relocation were carried out at a later date, for example, in year 2000, then different conclusions might be reached.

(5) It should be kept in mind that the conclusions reached here are subject to the qualification that they are based on aggregate willingness to pay.

## APPENDIX A. Estimated Residential Sale Price Equation

Dependent variable is sale price of individual properties adjusted to 1972 dollars.

| Independent Variable | Estimated Coefficient | t-value |
|---|---|---|
| Age of house (years) | -500.94 | -3.64 |
| Age of house squared | 5.77 | 2.67 |
| Garage space | 643.66 | 1.97 |
| Number of bathrooms | 1538.87 | 3.24 |
| Lot size (sq. ft.) | .39 | 4.06 |
| Number of rooms | 827.12 | 5.08 |
| Siding material | 1318.42 | 2.43 |
| Number of stories | 1266.82 | 2.24 |
| Basement | 1957.43 | 2.14 |
| Heating | 456.22 | 1.01 |
| Fireplace | 735.12 | 1.26 |
| Recreation room | -120.75 | -.15 |
| Corner lot | 2041.77 | 2.99 |
| Distance from arterial road | -499.39 | -.69 |
| Duplex, Triplex | 1135.98 | 1.86 |
| Distance from railway (in hundred foot intervals) | 588.72 | 2.65 |
| Distance from railway squared | -35.43 | -1.68 |
| Mortgage variable | .00 | .06 |

| Independent Variable | Estimated Coefficient | t-value |
|---|---|---|
| Area dummies | | |
| A2 | 598.64 | 1.14 |
| A3 | -616.33 | -.75 |
| A4 | 4116.08 | 2.24 |
| Constant | 10030.47 | |
| Number of observations | 285 | |
| $R^2$ | .85 | |

# FOOTNOTES

[*] Ministry of Transportation and Communications, Ontario. This is a summary of my thesis entitled "Urban Railway Relocation: An Economic Evaluation," Department of Economics, University of Western Ontario, September 1976. I am especially grateful to my committee chairman, Professor Mark Frankena for detailed guidance and continuous encouragement through the entire study. I wish to thank Professors Erik Haites and Gordon Davies for valuable suggestions. I am solely responsible, however, for any errors that remain.

[1] According to Jenkins (10), the social opportunity cost of public funds was approximately ten per cent per year for Canada.

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