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All errors that remain in this study are solely the responsibility of the author.

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AN ECONOMIC EVALUATION OF
URBAN RAILWAY RELOCATION

Contents

Chapter I

INTRODUCTION

Many urban areas are debating whether to relocate the interurban
railways which pass through their centres. The cost of each of these reloca-
tion 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 a framework for appraisal of urban railway reloca-
tion 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:[1]

    (a) consolidate through services onto a smaller number of rail

        lines within the urban area and maintain local service

        (CONSOLIDATION);

    (b) remove through services from the urban area and relocate them

        outside the city, but maintain local service to industries

        in the urban area (PARTIAL RELOCATION);

    (c) relocate through services and discontinue local service to

        industries (COMPLETE RELOCATION);

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[1]The following three types of relocation are illustrative rather
than exhaustive.

(3)   leave the location of the railways and their services unchanged

but reduce the railways' external effects, e.g., adopt measures

to reduce railway pollution, apply safety devices to reduce

accident rates, and built grade separations at road-rail level

crossings to reduce delays to road traffic (GRADE SEPARATION); and

(4)   discontinue all rail services (DISCONTINUATION).

In this study we evaluate alternatives (1) to (3) but not alternative
(4). The analytical technique we use is cost-benefit analysis. We compare
the social benefits with the social costs for alternatives (1) to (3) above.
We consider both efficiency of resource allocation and distributional
effects.[2]

Chapter II gives an account of the nature of the benefits and costs
of the alternatives. Chapter III examines the benefits and costs in more
detail and discusses estimation procedures. Chapter IV presents estimates
of benefits and costs of the alternatives in London, Canada.

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[2]This report deals with the efficiency aspect only. For discussion
of distributional effects, see Poon [1976], Chapter V.

Chapter II

SOCIAL BENEFITS AND COSTS OF URBAN
RAILWAY RELOCATION

In this chapter we present the basic framework used in evaluating railway relocation proposals. We list and briefly discuss the social benefits and costs associated with railway relocation and grade separation.

A. Benefits and Costs of Railway Relocation

In order to isolate the benefits and costs of railway relocation, it is useful to consider polar cases. The two polar cases are (a) maintaining the status quo -- alternative (1) in Chapter I above -- and (b) relocating all railway activities outside the urban area -- alternative (2.c) in Chapter I. The benefits and costs of railway relocation will be discussed in terms of these two extremes. They can be easily modified to accommodate intermediate cases.

A.1 Benefits of Railway Relocation Compared with Status Quo

It is possible to identify five categories of aggregate consumption benefits from relocation of railways out of urban areas,[3] namely:

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

2. Net benefits of generated travel;

3. Reduction in accident rates;

4. Land released for redevelopment; and

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[3]In a general equilibrium model of the economy, one might identify other, less direct benefits. As in all cost-benefit analyses, we assume that such indirect effects are small enough that we are justified in ignoring them.

5. Improvement of areas abutting railway facilities.

These are discussed in turn below.

1.1 Savings in road travel time and vehicle operating expenses

Savings in road travel time and vehicle operating expenses for street traffic may occur under different circumstances.

(a) STOPPED AND DELAYED. Relocation estimates existing road-rail level crossings and hence the delays imposed by railways on street traffic. Each time a train passes a road-rail level crossing, street traffic slows down and stops. People lose time and vehicles use fuel while they wait at crossings. Thus, removal of a railway would reduce both travel time and vehicle operating expenses.

(b) MECHANICAL DAMAGE. Level crossings are rough and may, at normal speeds, cause mechanical damage. To reduce the potential damage many motorists slow down at level crossings even when there is no train or train warning. The elimination of the grade crossing would save the motorist the cost of slowing down and accelerating the vehicle, the cost of any mechanical damage, and the value of the motorist's time consumed in this delay.

(c) DEPART EARLY. Before relocation some individuals, especially those going to work, may start their trips early, in order to allow a margin of safety in case they get caught by a train. In this case, the time saving resulting from relocation is not only the occasional time spent waiting for trains to pass but the daily safety margin, as well.

(d) DEVIOUS ROUTES. Before railway relocation some vehicles may take longer routes in order to avoid the possibility of being delayed at level crossings. The elimination of the level crossings would allow them to take

shorter routes and hence would reduce both travel time and vehicle operating expenses. After relocation motorists may be able to use routes that previously did not have either a level crossing or a grade separation.

(e) CHANGE IN ORIGIN/DESTINATION. As a result of railway relocation, there may be changes of trip origins and destinations (i.e., changes in the location of economic or social activities) from other areas in the city to areas in which traffic was previously subject to delays imposed by railways.

The above potential savings in travel time and vehicle operating expenses accrue to motorists who travel in the areas from which railways are removed. However, motorists in areas where the new railway is to be located tend to incur additional transportation costs, and these increased costs should be deducted to get net savings in travel time and vehicle operating expenses. Also, there may be some net changes in congestion on urban streets as a result of the various adjustments discussed above, and the amount saved should be calculated net of any such increase. Some local industries may transport more inputs and products by truck as a result of discontinuation of local railway service to industries.[4] Consequently congestion and hence travel time and vehicle operating expenses may increase on some streets, and these increases should be deducted.

1.2 Net benefit of genrated travel

To the extent that railway relocation reduces costs of vehicle travel more trips may be taken. The net benefit of the generated travel is a benefit of railway relocation. Should the generated travel result in

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[4]On the other hand, truck traffic in the urban area may be reduced if many firms relocate.

congestion on some streets, the net benefit of generated travel should be calculated net of the additional congestion costs.[5]

1.3 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 will reduce accident rates.[6] This should be calculated on a net basis, i.e., net of increased accidents at new grade crossings.

1.4 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. The use of the released land for non-railway purposes may be beneficial. Land may have to be converted from other uses in order to relocate the railway. The costs of using the land in the new location must be deducted from the benefits derived from the released land to obtain the net benefit of relocation.

1.5 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

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[5] If the use of roads is not priced at marginal social cost, the increase in trips might involve a net social cost.

[6] Maintenance and policing costs may also be reduced.

"visual" pollution. Hence, removal of the railways may improve adjacent areas.[7] Of course, the extent to which these areas are improved depends on the subsequent use of the released land, and there may be deterioration of the environment at the new railway location.

The release of urban land and the improvement of the environment in areas previously adjacent to railways may make possible redevelopment of large areas, the net benefit of which might exceed benefits (4) and (5) alone. Among other things, there might be a reduction of blight and slums. If slums represent suboptimal resource use due to externalities, redevelopment of slums may entail benefits of improved resource allocation.[8]

Apart from benefits (1) - (5),[9] attempts are sometimes made to justify proposals for railway relocation on the grounds that they would revive commercial activities in the central business district (CBD) and augment the financial resources (tax revenues) of the city. However, even if railway relocation has such effects, these involve primarily transfer payments or changes in the distribution of income between communities rather than aggregate consumption benefits.[10]

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[7]Some of the external diseconomies may not be reversible if people object to the high embankments, etc., even if there are no trains.

[8]For a discussion of the causes of slums and the benefits of slum clearance, see J. Rothenberg [1967], especially ch. III.

[9]In addition to benefits (1) - (5), we may list the following: a railway installation bisecting a city makes the rational provision of municipal services extremely difficult and may cause delays to ambulance and fire fighting equipment. Railway relocation would overcome these problems.

[10]See Rothenberg, op. cit., ch. IV. This ignores possible externalities associated with a prosperous CBD.

In Chapter I we outlined alternatives to either the status quo or relocating all railway activities outside the urban area. The benefits of alternative (2.a), consolidation of through service onto a smaller number of rail lines, and alternative (2.b), removal of through services but maintenance of local services to industries, are similar in nature to the benefits of alternative (2.c) listed above. However, the magnitude of the benefits of these alternatives would probably be smaller than those of (2.c). The chief reason is that some railway facilities will remain in the urban area and benefits of railway relocation cannot be fully realized.

A.2 Costs of Railway Relocation Compared with Status Quo

We may distinguish five categories of aggregate consumption costs of railway relocation, namely:

1. Capital costs;

2. Railway operating costs;

3. Transportation and relocation costs for railway users;

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

5. Delay in traffic while construction is in progress.

Each of these is discussed in turn.

2.1 Capital costs

Capital costs include costs of (a) acquiring properties for new railway facilities; (b) construction of new railway facilities, e.g., tracks, yards, signals, grade separations; (c) removing old track and installations; and engineering. To obtain net capital costs, the salvage value of existing facilities should be deducted.[11]

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[11]As will be elaborated in Chapter III, the capital costs of

2.2 Railway operating costs

The main items of railway operating costs are: (a) crew wages; (b) fuel; and (c) maintenance and other operating costs of locomotives, cars, tracks, yards, and other structures. These operating costs may be increased if railway relocation reuslts in longer track mileage and running times. However, railway relocation may reduce railway operating costs because of faster train speed, reduction in level crossing maintenance, and more efficient yards and more modern equipment and facilities.

2.3 Transportation and relocation costs for railway users

Transportation costs for firms and households which use the railway will increase if relocation and discontinuation of local service move the railway away from them. Some industries which are located near the old railway may move and incur relocation costs. However, this will not be a dead loss to industries which find their present locations undesirable. Their new locations and new set-ups may improve their operating efficiency and save transportation costs.

For inter-city rail passengers, relocation of railway man mean longer travelling distance to and from a rail terminal. For intra-city rail commuters, railway relocation may result in reduced or increased commuting time depending on the change in route miles and speed of the train.

2.4 Transportation and relocation costs for non-users

Employees of railway companies and industries which relocate may

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obtaining the stream of net benefits is not the capital cost of relocating the railway. This cost must be adjusted for the fact that the existing railway facilities would need to be replaced within the period of study.

have to travel longer distances to work and thus incur additional commuting costs or move and thus incur relocation costs.

2.5 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.

These five categories of costs also apply to alternatives (2.a) and (2.b). However, the magnitudes of the costs would be different if either alternative (2.a) or (2.b) was chosen.

B. Benefits and Costs of Grade Separation

So far we have compared alternative (2), relocation, with alternative (1), maintaining the status quo. Instead of relocation, however, measures could be taken to reduce some of the adverse effects of railway facilities on the urban community. For example, tunnels and other barriers can be built to reduce railway noise and visual pollution. More advanced signal systems can be implemented to enhance motorist and pedestrian safety. Grade separations can be constructed at level crossings to reduce road-rail traffic conflict. All of these measures can be taken together with any railway relocation scheme. However, the benefits and costs of such measures should be considered separately because, under certain conditions, these measures can be regarded as alternatives to and not as part of railway relocation. We shall now consider the benefits and costs associated with construction of grade separations.

B.1 Benefits of Grade Separation Compared with Status Quo

Some of the benefits of relocation can be achieved (to a different degree) by building grade separations at more road-rail corssings, namely:

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

2. Net benefit of generated travel;

3. Reduction in accident rates; and

4. Reduction in air pollution at level crossings.

It is unlikely that a grade separation can release land for redevelopment or improve areas abutting railway facilities to any significant extent. All of these items, except the last, were discussed above in the context of railway relocation.

1.1 Reduction in air pollution at
     level crossings

The process of decelerating, idling, and accelerating at level crossings increases the air pollution at those locations. A grade separation may eliminate this source of air pollution, and so benefits the surrounding area.

B.2 Costs of Grade Separation Compared with Status Quo

There are three categories of costs:

1. Capital costs;

2. Railway operating costs. Railway operating costs may be reduced because of increased train speed and reduced signal operating and maintenance costs; and

3. Delay in traffic while construction is in progress.

The other two items of cost associated with railway relocation, i.e., transportation and relocation costs for railway users and non-users would probably not arise with grade separation.

Table II.1 provides a summary of the benefits and costs associated with railway relocation and grade separation as compared with the status quo. The basic evaluation criterion employed in this study is that an urban railway relocation project is justified only if the social benefits are greater than the social costs.

TABLE II.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.† 2. Net benefit of generated travel. 3. Reduction in accident rates.† 4. Land released for redevelopment. 5. Improvement of areas abutting railway facilities.†	1. Capital costs. 2. Railway operating costs. 3. Transportation and relocation costs of railway users. 4. Transportation and relocation costs of non-users. 5. Delay in traffic while construction is in progress.
Grade Separation (alternative 3)	1. Savings in travel time and vehicle operating expenses.† 2. Net benefit of generated travel. 3. Reduction in accident rates.† 4. Reduction in air pollution at level crossings.†	1. Capital costs. 2. Railway operating costs. 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 the old railway site less adverse effects at the new railway site.

Chapter III

MEASUREMENT OF BENEFITS AND COSTS:
THEORETICAL ANALYSIS

A.   Introduction

In this chapter we analyze the social benefits and costs of railway relocation in greater detail and formulate methods for estimating them. As we shall see, all of the benefits and costs which we have identified can be quantified conceptually, but it is extremely difficult if not impossible to put a dollar value on some of them.

Since the benefits and costs of grade separation are similar in nature to those of railway relocation, no separate analysis of the former is included.

In general, the analysis is expressed in terms of the benefits derived by moving the railway from its existing location. The same methods can be used to estimate the increased costs associated with the new location. The benefit of relocation is the net amount of these two components.

B.   Benefits and Costs of Railway Relocation

B.1   Benefits of Railway Relocation Compared with Status Quo

1.1   Savings in road travel time and vehicle
       operating expenses

There are three distinct reasons for changes in motor vehicle[12] travel times and operating expenses as a result of railway relocation projects, namely:

(a) changes in delays imposed on motor vehicles at road-rail level

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[12]Pedestrians and bicycles are also affected, but we ignore them in this study because of lack of data.

crossings because of:

    (i)   elimination of level crossings, and

    (ii) changes in rail traffic at level crossings which are not

         eliminated;

(b) changes in road vehicle flows and hence congestion because of:

    (i)   changes in number of vehicle trips due to the changes in

         the cost of travel as a result of benefit (a), and

    (ii) changes in truck traffic between industries and rail terminals

         if local rail service to the industries is discontinued; and

(c) changes in departure times, routes, and origins and destinations by

    vehicles which ahve previously chosen alternative departure times,

    routes, and origins and destinations in order to avoid delays at

    level crossings.

Generally, one would expect (a) and (c) to involve savings in motor vehicle travel costs while (b) would probably involve an increase in travel costs. Some of these changes will occur regardless of which policy alternative (Chapter I; 2.a, 2.b, 2.c, 3) is followed. In the remainder of this section we discuss how the changes in motor vehicle travel times and operating expenses resulting from changes (a), (b.ii), and (c) may be estimated.[13] Change (b.i) will be discussed separately in section B.1.2 below.

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[13]We shall consider each of the changes in a partial equilibrium framework and then find the sum of the effects. It is quite conceivable that the effects of the various changes are interrelated and hence the aggregate effect in a general equilibrium framework may not equal the sum of the individual partial equilibrium effects. While it would be preferable to use a general equilibrium urban land use and transportation model to simulate the changes and assess the aggregate effects, this is not possible at present because model construction is still in its infancy and such a model is not available to us. At present the most we can expect from these models is a forecast of urban

(a) <u>Changes in delays imposed at level</u>
<u>crossings</u>

The cost savings include both time and vehicle operating costs. Let us consider the time cost first. We begin by developing a formula for the total number of vehicle hours of delay imposed on the traffic moving in one direction by a single train at a single crossing assuming there is one lane of road traffic. The delay will be broken into two parts: (i) the amount of time that vehicles lose while they decelerate and remain stopped, and (ii) the amount of time vehicles lose while they accelerate back to their normal speed.

As a train approaches a 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 also that the one-way flow of traffic on the road is F vehicles per hour.

In this case, the total number of vehicles that will be stopped by the train is approximately the integer closest to:[14]

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motor traffic movements. These models would have to be greatly modified in order to yield specific information relevant to railway relocation projects.

[14]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

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

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:[15]

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

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:

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

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

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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).

[15]The preceding calculations ignore any delays imposed on vehicles which slow down but do not stop as a result of the closing of the crossing. In addition, the formula does not take into account delays caused when backed-up traffic blocks nearby sidestreets, driveways, etc. The formula also does not take into account changes in routes induced by finding that there is a train at the crossing. More elaborate formulas concerning traffic flow have been developed by traffic engineers. The simple formula developed here is sufficient for our purpose in this study.

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, 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 by eliminating the deceleration and stopping processes will be:[16]

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

where $Q_{jitkd} = G_{jitkd} C_{tkd}/(1 - AG_{jitkd})$. This formula can be

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[16]We do not specify the maximum value of the subscripts in the formula because all subscripts are variables which take different maximum values at different crossings. We do not distinguish between rush and non-rush hours, although such a distinction can be made simply by adding another subscript.

simplified to:[17]

$$H_{ld} = \sum_k \sum_t \sum_i \sum_j Q_{jitkd} \left(\frac{C_{tkd} - A}{2} \right)$$

It may be noted that Q_{jitkd} is equal to the number of cars stopped and $(C_{tkd} - A)/2$ is approximately equal to half the period a crossing is closed.

The total vehicle hours saved during day d by eliminating the acceleration process is

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[17]
$$\sum_{r=1}^{R} n = \frac{R^2 + R}{2}$$

Therefore
$$\sum_{n=1}^{GC/(1-AG)} (n - 1) = \left[\left(\frac{GC}{1-AG} - 1 \right)^2 + \left(\frac{GC}{1-AG} - 1 \right) \right] / 2$$

$$= \frac{G^2C^2 - GC(1-AG)}{2(1-AG)^2}$$

Therefore
$$\frac{GC}{1-AG} \left(C - \frac{1}{2G} \right) - \sum_{n=1}^{GC/(1-AG)} (n - 1)\left(\frac{1}{G} - A \right)$$

$$= \frac{GC}{1-AG} \left(C - \frac{1}{2G} \right) - \frac{G^2C^2 - GC(1-AG)}{2(1-AG)^2} \left(\frac{1-AG}{G} \right)$$

$$= \frac{GC^2}{2(1-AG)} + \frac{C(1-AG) - C}{2(1-AG)}$$

$$= \frac{GC(C-A)}{2(1-AG)}$$

$$= \frac{GC}{1-AG} \left(\frac{C-A}{2} \right) .$$

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

where T_{jitkd} = the time (in hours) taken to accelerate from rest to the normal speed in direction i in lane j at crossing k as train t passes during day d.

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, 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. H_1 consists of both idling time and slowing down time. However, the latter is likely to be a small portion of the total,[18] and hence for simplicity H_1 will be assumed to be equal to idling time. Then the idling cost (G_1) may be estimated using the following formulae:

$$H_1 = h_1^p + h_1^c + h_1^t$$

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

where h_1^p, h_1^c, h_1^t refer to the hours of idling time of passenger, commercial,

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[18]This is shown in the empriical results of Chapter IV.

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. It can be seen that $K_2^p + K_2^c + K_2^t = \sum_d \sum_k \sum_t \sum_i \sum_j Q_{jitkd}$.

The total savings in vehicle operating expenses per annum as a result of railway relocation will be $G_1 + G_2$.

The savings in time ($H_1 + H_2$) and vehicle operating expenses ($G_1 + G_2$) are due to elimination or reduction in railway service.

We noted, in Chapter II, that vehicles traversing level crossings at normal speeds may suffer mechanical damage. To minimize the possibility of damage most motorists reduce their speed for level crossings. The data needed to estimate directly the mechanical damage that would result from travelling over level crossings at normal speeds are not available.

Rather we will estimate the potential damage indirectly. We will assume that all motorists slow down for level crossings. We will assume that they slow down to such an extent that the risk of mechanical damage is the same as that involved in travelling regular streets at normal speeds. Then the cost of the deceleration-acceleration cycle may be taken as a measure of the amount of mechanical damage that would have been caused by

the level crossing. This is also the value of the benefit obtained by eliminating the level crossing.

In addition, some types of commercial and public transit vehicles are required by law to stop at all level crossings. Removal of a level crossing results in a cost saving for those vehicles.

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 saving in vehicle-hours as a result of the removal of K level crossings will be

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

In addition, the slowing down and speeding up process also increases vehicle operating expenses. Hence the 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 deceleration and acceleration process at level crossing k on day d.

(b) Changes in road vehicle flows

To estimate the change in travel costs arising from changes in truck traffic between industries and rail terminals (i.e., b.ii above), we have to know how truck traffic would change as a result of railway relocation. A net increase in truck traffic is likely to increase congestion, especially during rush hours. The resulting increase during day d in time costs (H_{4d})

and vehicle operating expenses (G_{4d}) for other traffic should be deducted from the other savings in travel costs resulting from railway relocation.

Let R_d be the number of vehicles delayed by additional truck traffic and b_{rd} the time in hours the rth vehicle is delayed during day d. Then vehicle hours delayed during day d will be

$$H_{4d} = \sum_{r=1}^{R_d} b_{rd}$$

The additional vehicle operating cost is

$$G_{4d} = \sum_{r=1}^{R_d} a_{rd}$$

where a_{rd} is the extra operating cost of vehicle r on day d. In one year the vehicle hours delayed will be

$$H_{4d} = \sum_{d=1}^{365} H_{4d}$$

and the additional vehicle operating expenses are

$$G_4 = \sum_{d=1}^{365} G_{4d}$$

(c) Changes in departure times, routes, origins, and destinations

First let us turn to departure times. With the removal of level crossings, people do not have to leave their homes early to allow for a margin of safety. If there are M vehicles which leave early for work every day, the annual savings in time costs will be

$$H_5 = 260 \sum_{i=1}^{M} c_i$$

where c_i is the time in hours that vehicle i leaves early every working day. We assume that there are 260 working days per year and that individuals are indifferent between travelling and waiting at their place of employment when they arrive early for work.

Now let us turn to those who change routes, origins, or destinations as a result of railway relocation.

Suppose there are D vehicles that change routes, origins, or destinations per year. Total vehicle-hours saved per year (H_6) is

$$H_6 = \sum_{d=1}^{365} \sum_{k=1}^{D} f_{kd}$$

where f_{kd} is the difference in time in hours between the original and new routes, origins, or destinations for vehicle k during day d. Reduction in vehicle operating costs per year will be

$$G_6 = \sum_{d=1}^{365} \sum_{k=1}^{D} c_{kd}$$

where c_{kd} is the reduction in operating cost of vehicle k during day d.

(d) Value of vehicle-hours saved

In subsections (a)-(c) above we have shown how savings in vehicle-hours per year may be estimated. Using estimates of the breakdown of vehicles by type and the number of people per vehicle for each type, we may convert vehicle-hours into man-hours. 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.[19] For the purpose of this study, it appears that travel time should be disaggregated by income (or hourly wage) of the traveller and by trip purpose (commuting, business, recreation-social, shopping, other), and that a different value per hour should be placed on time savings in each category.[20]

Since we do not know much about the value of time for different kinds of trips, we will make the further assumption that the value of travel time is the same regardless of trip purpose. Hence the value of man-hours saved per year is

$$K = \sum_i v_i X_i$$

where v_i = value of travel time per man-hour of people with income i;

X_i = man-hours saved for people with income i.

v_i is assumed to be a constant proportion (d_i) of the wage rate (w_i) of group i. Thus

$$K = \sum_i d_i w_i X_i$$

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[19]For example, see Beesley [1965], Lee, Dalvi [1969], Mohring [1976].

[20]Other variables that may affect the value of time include the family status (e.g., male worker and housewife) and age (adult and child) of the traveller. The distinction between walking, waiting and in-transit time is not important to us since we are mainly concerned with in-transit time.

(e) Time horizon

So far we have concerned ourselves with savings in vehicle hours and vehicle operating expenses within a single year. It is necessary to consider these over the time horizon of the project. This introduces the following questions: (i) What discount rate should be used? (ii) What is the appropriate time horizon? (iii) How will rail and road traffic change over time?

Question (i) has received much attention in the literature, but the problem is by no means solved. For the purposes of this study, we will use different discount rates ranging from 4 to 10 per cent per year to assess the sensitivity of various estimates to the discount rate used.

With respect to question (ii) time periods ranging from 20 to 50 years are most often used in evaluation of transportation investments depending on the type and scale of project.[21] We will use different time horizons ranging between 30 and 100 years to determine the sensitivity of the estimates.

Question (iii) is perhaps the most difficult one to answer because existing traffic forecasting techniques leave much to be desired. In practice, simple projections would probably have to be used in most cases. Again we will carry out sensitivity analysis.

Once we have answered questions (i) - (iii), we can easily extend our formula to cover longer periods of time. Let

K_t = total value of travel time delayed in year t;

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[21]For example, Beesley and Foster [1963] used 50 years, but they also did sensitivity analysis with the time horizon extended to 90 years and to infinity. In the U.K. Ministry of Transport study of the Channel tunnel, project life was assumed to be 50 years. In his study of port investment, Ross [1967] suggested 50 years to be the time horizon. The U.S. Department of Transportation Guidebook [1974] suggested 25 years for railway relocation projects.

G_t = additional vehicle operating expenses incurred in

year t ($G_t = G_1 + G_2 + G_3 + G_4 + G_6$); and

r = discount rate per year (assumed constant over time).

The total savings in travel time and vehicle operating expenses in terms of dollars resulting from railway relocation over a period of N years will be

$$D = \sum_{t=1}^{N} \frac{K_t + G_t}{(1+r)^t}$$

D will be the total amount of savings of travel time and vehicle operating expenses if the railway relocation project eliminates all the existing road-rail traffic conflicts.

1.2 Net benefit of generated travel

In section B.1.1 above we considered only cost savings to existing traffic. As long as the demand curve for urban travel is not perfectly price inelastic, the reduction in travel cost resulting from railway relocation will generate additional traffic. To estimate this 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 may have to be ignored in practice.

1.3 Reduction in accident rates

1.3.1 Estimating the number of road-rail level crossing accidents

Relocation of the railway will eliminate or reduce the number of accidents at level crossings. In order to estimate this item of benefit we must know how many accidents will be avoided over the project life following railway relocation. Hence we should know something about the determinants of accidents at railway level crossings. We postulate that the number of accdients occurring at crossing i per time period is a function of a number of factors:

$$A_i = f(TS_i, TV_i, MS_i, MV_i, TP_i, V_i, NT_i)$$

where A_i = number of accidents per time period at crossing i;

TS_i = average train speed at crossing i;

TV_i = volume of rail traffic at crossing i;

MS_i = average speed of vehicles passing crossing i;

MV_i = volume of vehicle traffic at crossing i;

TP_i = type of protection at crossing i;

NT_i = number of railway tracks at crossing i; and

V_i = visibility conditions at crossing i.

We expect the first four variables to be positively related to A_i, i.e., the higher the volume of train and vehicle traffic and the faster the speed of each mode, the more accidents will occur, other things being equal. The type of protective devices range from no protection at all to grade separated crossing. We expect more accidents to occur at crossings which have no protection or have "passive" protection only, other things being

equal.[22] The more railway tracks, the more likely an accident is to occur.
Poor visibility increases the chance of accidents. Given sufficient data
the above function may be estimated and the results can be used for prediction
purposes.

For valuation purposes, it is necessary to distinguish accidents of
different severity, namely: fatal injury, non-fatal injury, and property
damage only (PDO). Given adequate data a separate function may be estimated
for each type of accident.

1.3.2 Valuation of reduction in railway crossing accidents

To our knowledge no study has been done with respect to the valuation
of railway crossing accidents though many studies have been done to value
highway accidents. Since the problem of valuation is essentially the same
for both kinds of accidents, we can refer to the results of highway traffic
accident studies.

Various methods have been formulated to measure the costs of highway
accidents.[23] According to Mishan, the basic rationale of the economic
calculus used in cost-benefit analysis is the notion of a potential Pareto
improvement: "one in which the net gains can be so distributed that at least
one person is made better off, with none being made worse off."[24] The
introduction of a specific investment project will make some community member

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[22]Passive protection includes crossbuck, crossbuck with track indication,
railway advance warning sign. Active protection includes flashing light
signals without or with automatic gates.

[23]For a critique of some of the methods, see Mishan [1971].

[24]Ibid., p. 225.

better off and others worse off. The person who is made better off would be willing to pay a certain amount rather than forego the project. This amount may be regarded as his compensating variation (CV). Similarly, the person who is made worse off would have to be paid a certain amount to put up with the project. If the net sum of all n individuals' CV's is positive, there is a potential Pareto improvement.

To be consistent with the criterion of a potential Pareto improvement, it is necessary that the loss (or saving) of a person's life be valued by reference to his CV. Under conditions of certainty, probably no sum of money is large enough to compensate a man for the loss of his life under normal circumstances. However, in practice we are dealing with reduced (or increased) risk of death rather than certain death. Hence we can concentrate on the willingness to pay for reductions of the risk of death of those who may be affected. The same argument holds for less severe accidents, i.e., non-fatal injury and property damage only accidents.

The above approach is sound conceptually, but in practice it is extremely difficult, if not impossible, to determine people's willingness to pay for small changes in probabilities of death or injury.

Most empirical studies have followed a different approach. The essence of this conventional approach is to measure the ex post costs associated with accidents. For example, the following cost items are often included:[25] (i) vehicles, goods and other property damaged; (ii) time (including future working time of the injured or dead) lost by all persons affected; (iii) suffering by all persons concerned; (iv) personal services,

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[25]For more detailed discussion of these cost elements, see Winfrey [1969] and Abramson [1973].

e.g., medical and legal services; (b) transportation, e.g., ambulance services, extra travel, and delays resulting from the accident for all persons.

Given appropriate data it is relatively straightforward to put a dollar value on cost elements (i), (iv), (v) above. It is almost impossible, however, to put a dollar value on suffering. Hence this item is often ignored in practice. As for the valuation of time lost, the main concern is often the number of working days lost without much attention being paid to leisure time. Thus, in the case of fatal injury the economic value of a person's life is taken to be the discounted earnings over the life span of that individual. This is the so-called "gross product" approach.[26]

Since there is no reason to expect that the ex post costs estimated to be equal to the ex ante costs that the society is willing to pay for the reduction in the risk of traffic accidents. We are left with three alternatives in valuating the reduction in accidents at level crossings.

(1) Follow the conventional approach, and estimate the ex post costs but note the limitations and implications of these measures.

(2) Present data on the expected reduction (or increase) in the number of accidents (fatal, non-fatal and PDO) and let the decision maker assign his own values.

(3) Present data on the expected reduction (or increase) in the number of accidents and perform sensitivity analysis by assuming different dollar values for the reduction of accidents.[27]

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[26]For examples, see Ridker [1967], Dawson [1967], Joksh [1975].

[27]Reduction in accidents may be treated as a residual category of benefit such that different values may be assigned to this category in sensitivity analysis.

Like other categories of benefits of railway relocation, the value of reduction in accidents should be calculated over the life of the project and discounted.

1.4 Land released for redevelopment

As a result of railway relocation, some railway land[28] is made available for other uses. We must determine the social benefit from release of this land.

The benefit from release of land is often taken to be the average market price per acre times the number of acres of land released.[29] However, for various reasons, market prices may not correctly measure the social benefit from the release of land. This can be demonstrated with a simple model.

Let us make the following assumptions concerning the market for urban land in the vicinity of the railway's initial location:

(a) land in the vicinity of the railway is homogeneous;

(b) the supply curve of relevant urban land is perfectly price inelastic;

(c) the demand curve for relevant urban land is negatively sloped and linear;

(d) there is no change in demand for relevant urban land as a result of railway relocation;

(e) public use of relevant land is exogenously determined;

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[28]Land released by industries will be considered in section B.2.3 below. However, the theoretical analysis presented here also applies to released industrial land.

[29]For example, this is the approach used by LUTS (1974). The Winnipeg Railway Study (1973) follows a more sophisticated approach, allowing for different types of land and differences in the time when the land is expected to be released.

(f) there is no zoning; and

(g) the urban land market is perfectly competitive.

Some of these assumptions will be relaxed as we go along.

In Figure III.1, S_p is the supply curve of urban land to private use before railway relocation and D_p is the private demand curve for urban land.[30] The equilibrium price of land is P_o. Now suppose that railway relocation increases the supply of urban land to private use so that the supply curve shifts from S_p to S_p'. Then the social benefit (as indicated by users' willingness to pay) of the land released is equal to ABL_1L_o, which is equal to

$$(L_1 - L_o)(P_o + P_1)/2$$

Thus the pre-relocation equilibrium price (P_o) overstates and the post-relocation equilibrium price (P_1) understates the benefit from the release of land.

Now let us relax assumption (d) above. Railway relocation may affect not only supply of but demand for urban land. There are three major categories of private land use in an urban area: residential, commercial, and industrial. The existence of the railway may affect the demand for land in each of these categories in surrounding areas. Railway pollution -- noise, air, visual -- would probably reduce the demand for residential and commercial land. On the other hand, railways may confer external economies (e.g., increased accessibility to interurban transportation) on some industries. This might increase the demand for industrial land nearby. We do not know, a priori, in which direction the aggregate demand curve for land (D_p) for

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[30]We are referring to income compensated demand curves.

Figure III.1

Change in Supply of Urban Land
Following Railway Relocation
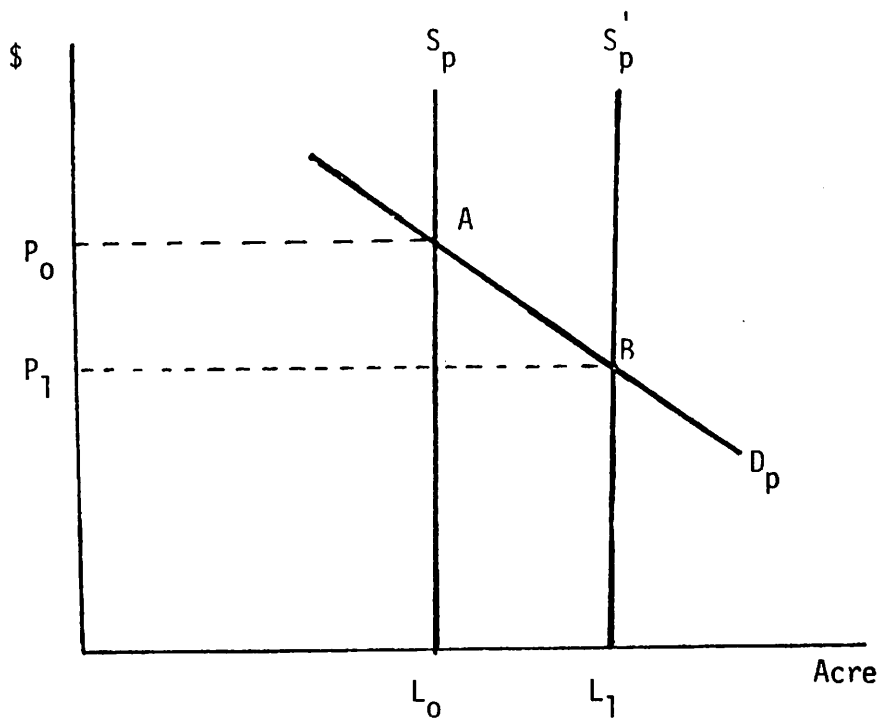
the three groups of users will shift as a result of railway relocation.

In Figures III.2(a-d), various possibilities are depicted. The shaded area

in each diagram indicates the social benefit of the land released. In

Figures III.2(a) and III.2(b), both P_0 and P_1 understate the benefit. In

Figure III.2(c), P_1 understates and P_0 may overstate the benefit. In

Figure III.2(d), P_0 overstates and P_1 understates the benefit. Thus true

social benefit would be underestimated by P_1 and may be either overestimated

or underestimated by P_0. The figures also suggest that if the new equilibrium

land price is expected to be higher than the old equilibrium price, then both

prices underestimate the true social benefit of the released land.

The above analysis shows that market prices generally do not give an

exact measure of the benefits of the released land. However, for a small

relocation project which does not significantly affect D_p and S_p, the current

market price of land (not land near railways but other comparable land which

is not affected by railway externalities) may be approximately correct.[31]

The problems raised above concerning the use of market price as a

measure of value of the land released indicates that we should use this

measure with caution. Unfortunately, since it would be difficult to estimate

the demand curves for urban land required to derive the theoretically correct

measures for willingness to pay for the land released by railway relocation,

in practice one probably must rely on market prices prevailing prior to

railway relocation.

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[31]So far we have assumed that there is no zoning. Relaxation of this
assumption gives an additional reason why market price may not be a correct
measure of benefit from the release of land. Another possible source of
error in using market price as a measure of social value has been suggested
by Solow [1973].

Figure III.2

Change in Demand for Urban Land
Following Railway Relocation

(a)

(b)

(c)

(d)
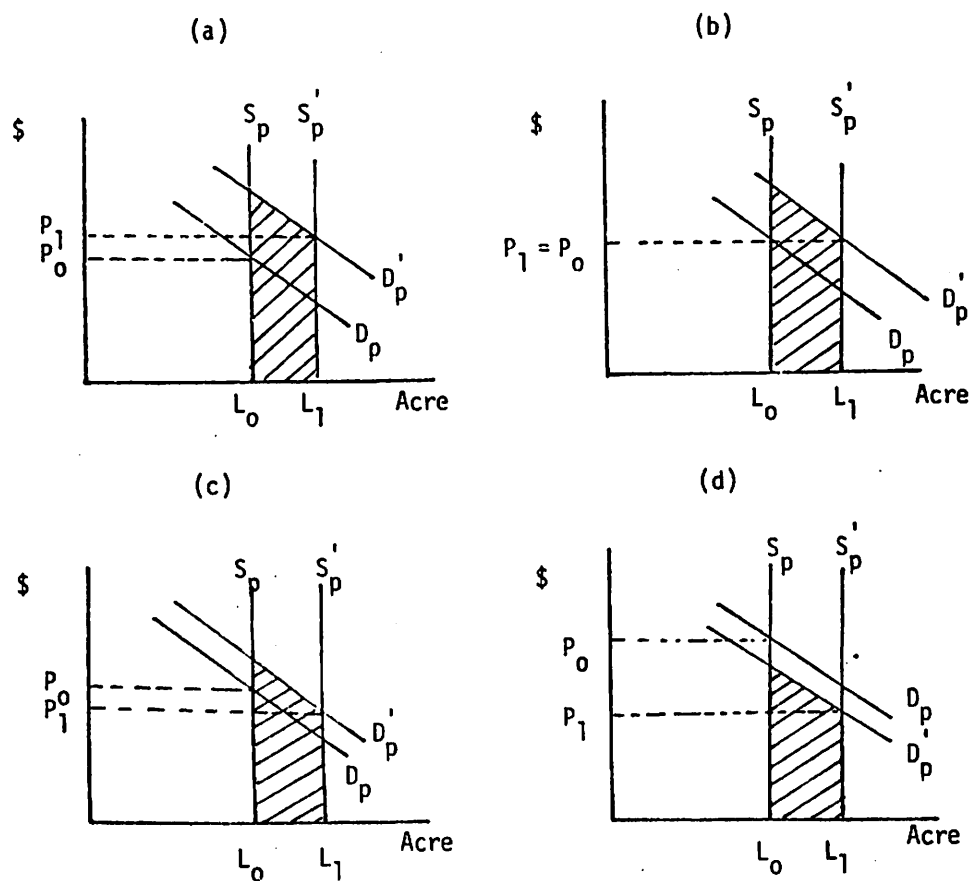
Conceptually the market price of a piece of land is its capitalized net rental value over an infinite time horizon, i.e.,

$$P = \sum_{t=1}^{\infty} \frac{R_t - C_t}{(1 + i)^t}$$

where P = market price of land

R_t = rental value of the land at time t

C_t = costs of upkeeping the land at time t

i = private discount rate.

Hence if we assume that the project life is infinite, the market price can be used as a measure of the value of the land released subject to the qualifications discussed above. However if the project life is assumed to be finite, e.g., 30 years, because all railway service is expected to terminate in 30 years, then so far as released land is concerned the benefit is that existing railway land is released now rather than in 30 years. The benefit of this is the discounted value of net rents over the next 30 years.

1.5 Improvement of areas abutting railway facilities

Railways impose air, "visual," and noise pollution on people in their neighbourhoods. In what follows we attempt to estimate, in terms of dollars, the detrimental effects of railways on surrounding residential areas.

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 will be willing to pay for removal of the

railway. Suppose there are R people and individual i is willing to pay WTP_{it} dollars during period t. Then the aggregate discounted value of benefits is

$$B = \sum_{t=1}^{N} \sum_{i=1}^{R} \frac{WTP_{it}}{(1+r)^t}$$

where r is the discount rate per time period and N years is the time horizon of the project. In this study N is assumed to range between 30 and 100 years.

It is impossible to measure B directly by asking people what they would be willing to pay. Among other things people may not reveal their true preferences, and the questionnaire approach may therefore be unreliable.

Under certain circumstances, however, an indirect measure of the benefits due to removal of spillovers may be derived from data on property values. Use of such data is appropriate to the extent that externalities are capitalized in property values. The available evidence from empirical studies suggests that externalities are, at least partially, capitalized.[32]

However, only under rather restrictive assumptions does the difference in property values between two areas provide an accurate measure of willingness to pay for removal of spillovers.[33] Suppose that properties in two areas are alike except that railways impose externalities in one area. Under perfect competition and with perfect mobility of households, the difference in property values (per property or per acre) between the two areas prior to

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[32]See, for example, Anderson and Crocker [1971], Czamanski [1966], Knetch [1964], Kitchen and Hendon [1967], Nourse [1963, 1967].

[33]This point is mentioned by Edel [1971] and is the central issue in Freeman [1974] and Lind [1973].

railway relocation will measure the willingness to pay for removal of the externalities by the _marginal_ household. Only if all households living in the area affected by railway externalities have the same willingness to pay for removal of the externalities as the marginal household will the difference in property values provide an accurate basis for calculating the aggregate willingness to pay for removal of the externalities. In fact, one would expect that most of the households living in the area affected by railway externalities would not be willing to pay as much as the marginal household for removal of the externalities, since the competitive market will allocate polluted properties to those whose willingness to pay for avoidance of pollution is least.

Suppose we rank the combined population of the two areas according to increasing willingness to pay per acre to remove the pollution. JK in Figure III.3 indicates the marginal willingness to pay per acre as a function of number of acres of polluted land. The person who cares least is willing to pay OJ per acre and the person who cares most will pay QK per acre. OQ is the total supply of land which is composed of OF acres of polluted land and FQ acres of non-polluted land. The competitive equilibrium rent differential between the two types of land is OH, and those willing to pay less than OH will occupy the polluted land. The total willingness to pay for removal of pollution by those living on the polluted land is indicated by OFGJ. However, the difference in the value of the OF acres at the two prices is OFGH, which will normally exceed OFGJ.

The same conclusion can be reached by following an alternative approach developed by Freeman [1974]. Freeman was concerned with property values and air pollution. His model can be used to illustrate the relationship between property values and railway externalities.

Figure III.3

Demand for and Supply of
Railway Polluted Land
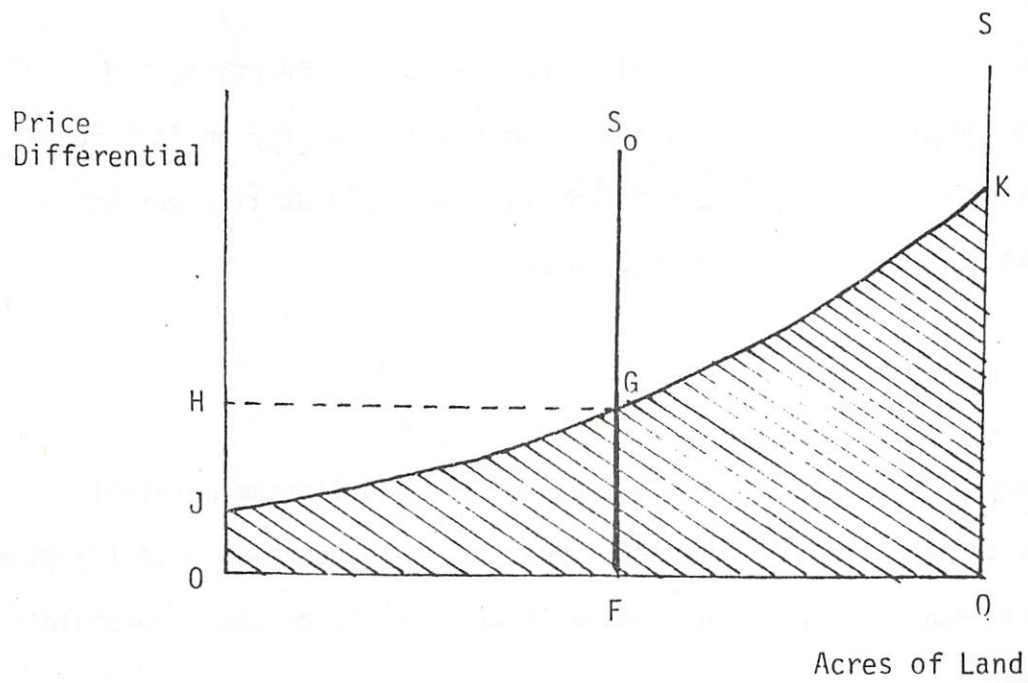
Assume that the market for residential properties is in equilibrium and that

$$V = V(Q,...),$$

where V is the market value of a property, which is a function of distance from the railway (Q). Figure III.4a shows one possible form of this partial relationship. Q^* is the distance from the railway at which the externality becomes zero.

Figure III.4b shows the marginal purchase price function, $R(Q) \equiv V'(Q)$. $D_i(Q)$ is the demand curve for distance from the railway for an individual household i. The first order conditions for household utility maximum require that the household live at Q_i where:[34]

$$D_i(Q_i) = R(Q_i)$$

Thus $R(Q)$ may be interpreted as the locus of the equilibrium marginal willingness to pay of all households. Only if all households have identical marginal willingness to pay functions will $R(Q)$ itself be each household's demand curve.[35]

In Figure III.4, the benefit of removing the railway so far as properties at distance Q_i are concerned, would actually be ABDE, but our measure from the observed distance from railway-property value relationship

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[34]The second-order conditions require that the demand curve cut the marginal purchase price curve from above.

[35]A sufficient condition is equal incomes and identical utility functions for all households.

Figure III.4

The Relationship Between the Property Valuation Function
and Willingness to Pay for Distance from Railway
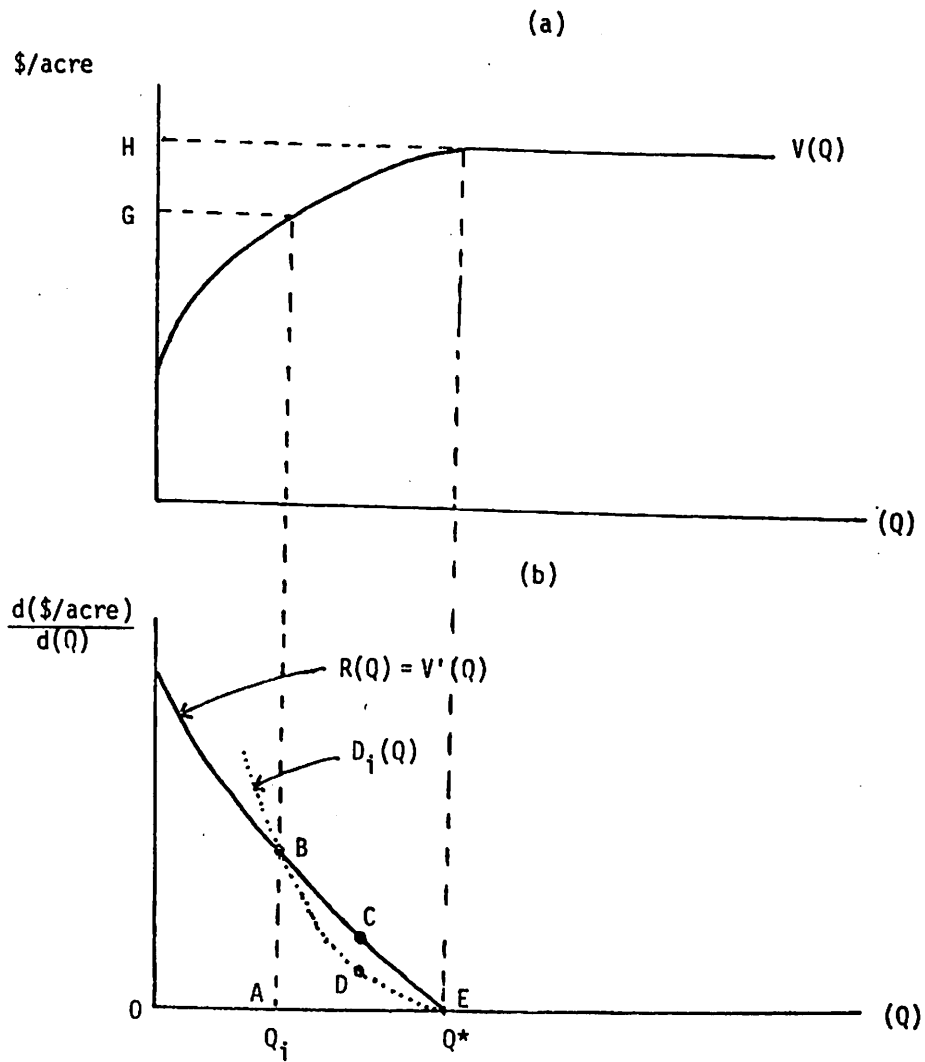
would be ABCE ≡ GH, which exceeds ABDE and hence is an overestimate.

Thus, so far as these considerations are concerned, one would expect use of differences in property values to lead to an overestimate of the aggregate willingness to pay for removal of railway externalities. Unfortunately, there does not appear to be any practical alternative to use of property values, and there is no practical way to measure the extent of the bias from use of property values.

There are two complementary approaches that can be used to estimate the differences in property values. One is the "controlled areas" approach.[36] Areas with similar characteristics other than the externalities in question are chosen, and the property values in areas not affected by spillovers are compared with those in areas affected by the spillovers. The difference in values per property (or per unit area) times the number of properties (or total area) may be regarded as a measure of the benefits of removing railway spillovers. The main difficulty of this approach is to find satisfactory control areas. The difference in property values may be due to factors other than the spillovers under consideration.

Another approach is regression analysis based on cross-sectional data. This approach, which we shall follow in this study, provides better control of the effect of other factors on property values.[37]

For single-family residential properties one can estimate the following function:

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[36] For examples, see Nourse [1963, 1967] and Crowley [1973].

[37] See, for example, Crecine, Davis, Jackson [1971], Davis [1974], Edelstein [1974], Emerson [1972], Grether and Mieszkowski [1974].

$$P = f(X_1, \ldots, X_n)$$

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. We shall discuss the specification and estimation of this equation in detail in Appendix 1. One of independent variables, say X_i, will be distance from the railway. Our main hypothesis will be that because of railway externalities:

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

B.2 Costs of Railway Relocation Compared with Status Quo

In this section we turn to estimation of the costs of railway relocation. We shall discuss the various categories of capital and operating costs. We do not intend to deal with the estimation methods for these costs in any detail since they fall mainly within the realm of civil engineering rather than economics. However, it is up to the economist to make sure that all the correct opportunity costs are included and that nothing is left or double counted.

2.1 Capital costs

The main items of capital costs are:[38]

(1) Property acquisition and related costs: right-of-way acquisition, assemblage costs, severance damages and damages to improvements.

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[38]The exposition of the list of capital costs follow that of U.S. Department of Transportation [1974].

(2) Site preparation costs: demolition costs, utility relocation and protection, grading and riprap.

(3) Track work and track structure costs: temporary relocation, track including ballast, turnouts, tunnels and subways, bridges and trestles, elevated structures, culverts.

(4) Right-of-way protection: fences, signs.

(5) Railroad buildings and facilities: station and office buildings, roadway buildings, water stations, fuel stations, shops and engine houses.

(6) Signals and communications systems: automatic block signals, centralized traffic control, interlocking plants, and telegraph lines.

(7) Highway crossing and crossing warning devices: flashing light signals, automatic gates, grade crossings and grade separation.

(8) Engineering.

(9) Contingencies.

(10) Railroad removal costs, tracks, structures and buildings.

Cost item (9), contingencies, is a provision for unforeseen costs. It is not clear whether this item should be included in the calculation of real social costs because it may or may not occur. However, in engineering cost studies, this item (usually assumed to be 10% of total costs estimated) is always included.

To be deducted from the above capital costs is the salvage value of certain items such as rails, ties, tie plates, joints, signal material, etc., from the old location.

In addition to the salvage value of the existing line there is

Another source of savings which must be considered. It must be realized that the capital costs of obtaining the stream of benefits is not the capital cost of relocating the railway. This cost must be adjusted for the fact that the existing railway facilities have been used and would need to be replaced with a certain period of time simply to maintain the status quo. In adopting the relocation these capital expenditures are avoided. Hence the capital cost of the relocation proposal must be adjusted to reflect these savings.[39]

Another point to note about capital costs is that the land acquired for constructing new railways and yards can be released for other use at the end of the life of the project assumed. Hence it is the capitalized rental value of the land over the life of the project and not its market value that should be counted as a capital cost. However, if the life of the project is long, the difference between the two may be small.

2.2 Railway operating costs

Relocating the rail network in an urban area may either increase or decrease specific railroad operating costs. These changes must be considered in the evaluation of a railway relocation project. However, the existence of both joint and common costs, costs that exhibit wide variability under different service conditions, and the unique accounting system of the railway companies have all combined to render refined railroad cost analysis extremely difficult if not impossible.

We may distinguish three general categories of operating costs,[40]

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[39]Poon [1976] discusses how these savings may be measured conceptually.

[40]For more detailed discussion of operating costs, see the U.S. Department of Transportation, op. cit., and Poole [1962].

namely: (a) linehaul costs, (b) terminal costs, and (c) freight and passenger car expense.

(a) Linehaul costs are the costs of operating trains over the railway. These include: (i) train and engine crew wages, (ii) maintenance of locomotives, (iii) maintenance of way and structures, (iv) locomotive fuel, and (v) dispatching, caboose, and miscellaneous train expenses.

(b) Terminal costs include: (i) wages of switch engine crews, (ii) fuel, maintenance, and depreciation of switch engines, (iii) station clerical expense for billing, dispatching, crew calling, yard supervision, etc., (iv) maintenance of yard tracks and structures. The costs in categories (a) and (b) are analogues except that the usual causes of variation are different. Category (a) costs usually vary with distance while category (b) costs often vary with time.

(c) Freight car expense refers to principal and interest payments in owning freight and passenger cars.

As a result of railway relocation, there would be changes in route length, gradient, curvature, and the type of railway facilities and structures.

2.3 Transportation and relocation costs for railway users

In Chapter II we mentioned two groups of railway users, industries and passengers. If the passenger terminal were relocated, some passengers would have to travel a longer distance and others a shorter distance to reach the terminal.[41] The change in transportation costs for passengers over the time

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[41]If railway relocation affects commuter rail service, then the change in commuting distance and hence travel costs should also be considered.

horizon of the project will be

$$E = \sum_{t}^{N} \sum_{i}^{P_t} e_{it}/(1+r)^t$$

where e_{it} is the difference in transportation costs (value of time and money) for individual i before and after railway relocation for year t. P_t is the number of individuals affected in year t. N is the project life in years.

Let us turn to transportation and relocation costs incurred by industries. For those industries which do not move as a result of railway relocation, there would be changes in transportation costs. These transportation cost changes can be broken down into two parts: (i) capital costs such as reconstruction of loading areas, and (ii) shipping costs due to additional trucking to the rail terminal or change to trucking (or other modes altogether).[42] Suppose there are F_1 such firms affected. The change in total transportation costs for these firms in N years will be

$$I_1 = \sum_{i}^{F_1} C_i' + \sum_{t}^{N} \sum_{i}^{F_1} \frac{C_{it}''}{(1+r)^t}$$

where C_i' = once for all transportation adjustment costs for firm i;

C_{it}'' = change in shipping costs for firm i during year t.

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[42] For firms that do not relocate the social costs of the various modes of transportation are implicitly assumed to be equal to the freight rates. Given the manner in which freight rates are established and the fact that these firms ship small volumes by rail, it is conceivable that the social costs of transportation may not be equal to the freight rates. However, it is extremely difficult to measure the true social costs of transportation.

For these industries which relocate, four types of costs may be incurred: (i) moving costs; (ii) net replacement cost (gross replacement costs of new site,[43] buildings and equipment less the market value of original site, buildings and equipment); (iii) change in shipping costs, and (iv) change in operating costs due to more modern plant and machinery. If there are F_2 such firms then the total relocation and transportation costs incurred in N years will be

$$I_2 = \sum_i^{F_2} MC_i + \sum_i^{F_2} NRC_i + \sum_t^N \sum_i^{F_2} \frac{C_{it}'''}{(1+r)^t} + \sum_t^N \sum_i^{F_2} \frac{O_{it}}{(1+r)^t}$$

where MC_i = moving costs of firm i;

NRC_i = net replacement costs for firm i;

C_{it}''' = change in shipping costs for firm i during year t;

O_{it} = change in annual operation costs (excluding shipping costs) of firm i.

2.4 Transportation and relocation costs for non-users

The other group of people affected are employees of firms which relocate, including railway workers. Some workers would have to commute a longer distance and others a shorter distance to and from work. Over the life of the project, the total change in commuting costs for these workers will be

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[43]For firms that must relocate, the analysis is simplified if the firms are treated as renting the site, which is often the case. Industrial land released and acquired may then be considered separately.

$$Q_1 = \sum_{t}^{N} \sum_{i}^{U} \frac{u_{it}}{(1+r)^t}$$

where u_{it} is the difference in commuting costs for individual i before and after railway relocation in year t. U is the number of workers affected.

Other workers may relocate when their work place changes. They incur moving costs and change in transportation costs. Let there be V such workers, then the total cost incurred in N years will be

$$Q_2 = \sum_{i}^{V} M_i + \sum_{t}^{N} \sum_{i}^{V} \frac{v_{it}}{(1+r)^t}$$

where M_i = moving costs for individual i;

$\quad\quad v_{it}$ = change in transportation costs for individual i's family during year t.

2.5 Delay in traffic while construction is in progress

We are familiar with the noise and delays caused by construction work. Railway relocation projects may take up to a decade to complete and hence cause a lot of inconvenience for many people. We can identify three categories of externalities associated with construction of road and rialways: (a) noise and air pollution, (b) additional transportation costs for motorists because of rerouting of traffic, and (c) additional congestion costs on the roads because of increased truck traffic linked to construction.

Given sufficient data, externalities (b) and (c) can be estimated in a manner similar to that discussed in section B.1.1 above. However, there is probably no alternative way to estimate (a) except by asking people how much they would be willing to pay to put up with the additional air and noise

pollution.   The approach discussed in section B.1.5 above cannot be followed because noise and air pollution caused by construction are transitional and hence would not be capitalized permanently in property values.

Chapter IV

RAILWAY RELOCATION IN LONDON:
A CASE STUDY

A.   Introduction

In this chapter we present an economic evaluation of railway relocation in London, Canada. In the remainder of this section, we give a description of the existing railway network and three proposed railway relocation schemes. In section B we present the estimates of benefits and costs of railway relocation. In section C we show the estimated benefits and costs of grade separation. In section D we bring together the results of the previous sections and attempt to draw some policy conclusions based on our empirical findings.

The City of London had a population of 223,000 people and an area of 62 square miles according to the 1971 Census. There are two railway companies, the Canadian National Railways (CNR) and the Canadian Pacific Railways (CPR), operating four main lines within the London area. The four lines are:[44]

CNR   1.   Toronto-Woodstock-London-Windsor or Sarnia (Dundas and

Strathroy Subdivision)

2.   Toronto-Stratford-London (Thorndale Subdivision)

3.   St. Thomas-London (Talbot Subdivision)

CPR   4.   Toronto-Woodstock-London-Windsor (Galt and Windsor Subdivision)

These lines are illustrated in Figure IV.1.

In the recent London Urban Transportation Study (LUTS) by DeLeuw Cather [1974], some consideration was given to railway relocation schemes.

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[44]The information concerning the existing railway network is based on DeLeuw Cather [1974].

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Figure IV.1

Existing Track Layout and Typical Daily Rail Traffic
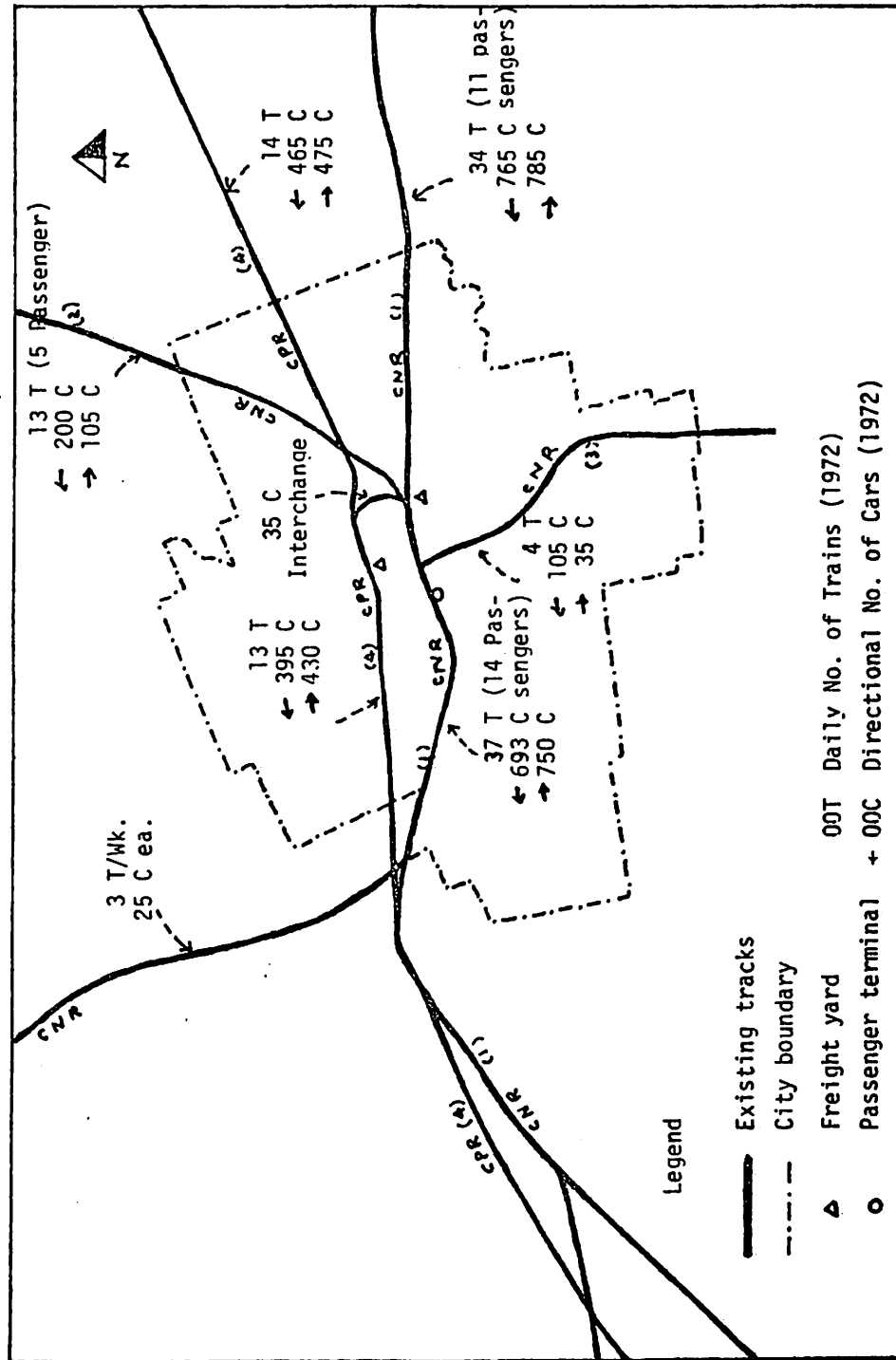
Source: DeLeuw Cather [1974].

After preliminary investigation,[45] two schemes were recommended for further study, the CNR scheme (Figure IV.2) and the Southern scheme (Figure IV.3). These two schemes resemble alternatives (2.a) CONSOLIDATION, and (2.b) PARTIAL RELOCATION, respectively in Chapter 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 purposes of comparison, we propose another alternative, the Complete Removal scheme (Figure IV.4), which resembles alternative (2.c) TOTAL RELOCATION, in Chapter I. 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. In the following section we attempt to estimate the benefits and costs associated with these three relocation schemes: the CNR scheme, the Southern scheme, and the Complete Removal scheme.

B.   Benefits and Costs of Railway Relocation

In this section we measure the benefits and costs of railway relocation for the three relocation schemes. We shall take 1972 as the base or "present" year forthe analysis. All estimated benefits and costs will be in terms of 1972 dollars. The categories of benefits and costs will be presented in the same order as in Chapters II and III.

Due to lack of data, we were unable to estimate some of the less important categories of benefits and costs. Also, in some cases, a good

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[45]The consultants who prepared the LUTS report suggested 16 schemes and the Railway Committee of the city government decided to retain two schemes for future study. It appears that the major criteria used in their choice were compatibility of land use and maintenance of railway service to local industries.

Figure IV.2

Railway Relocation: The CNR Scheme

Legend

—— New track
— — Track to remain
█▬█ Track to be removed
—··—··— City boundary

Grade Separations
◊ Reconstruction
● New
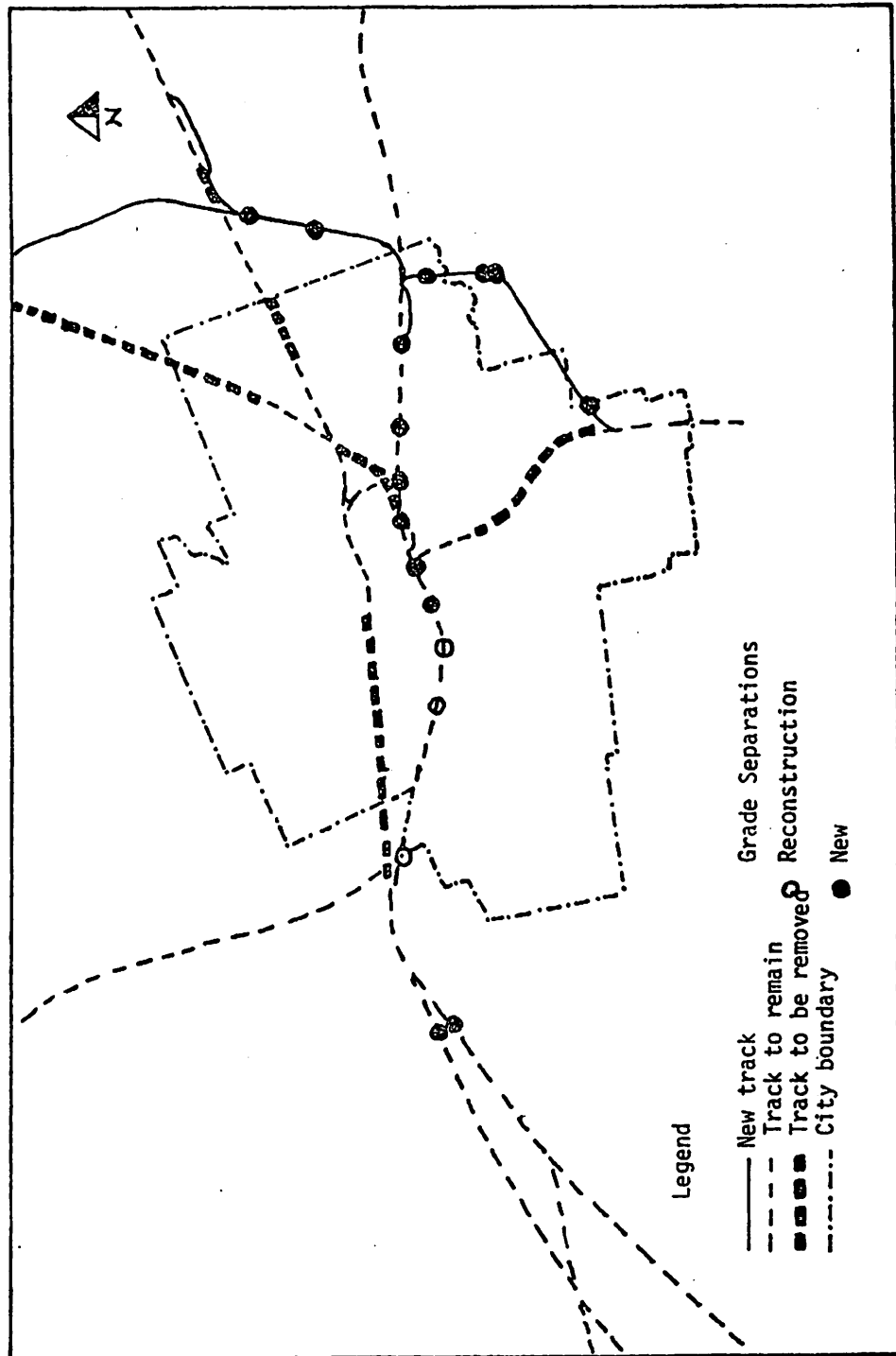
Source: DeLeuw Cather [1974].

Figure IV.3

Railway Relocation: The Southern Scheme

Legend

—— New track
- - - Track to remain
■■■■ Track to be removed
·—·—· City boundary

Grade Separations

● New
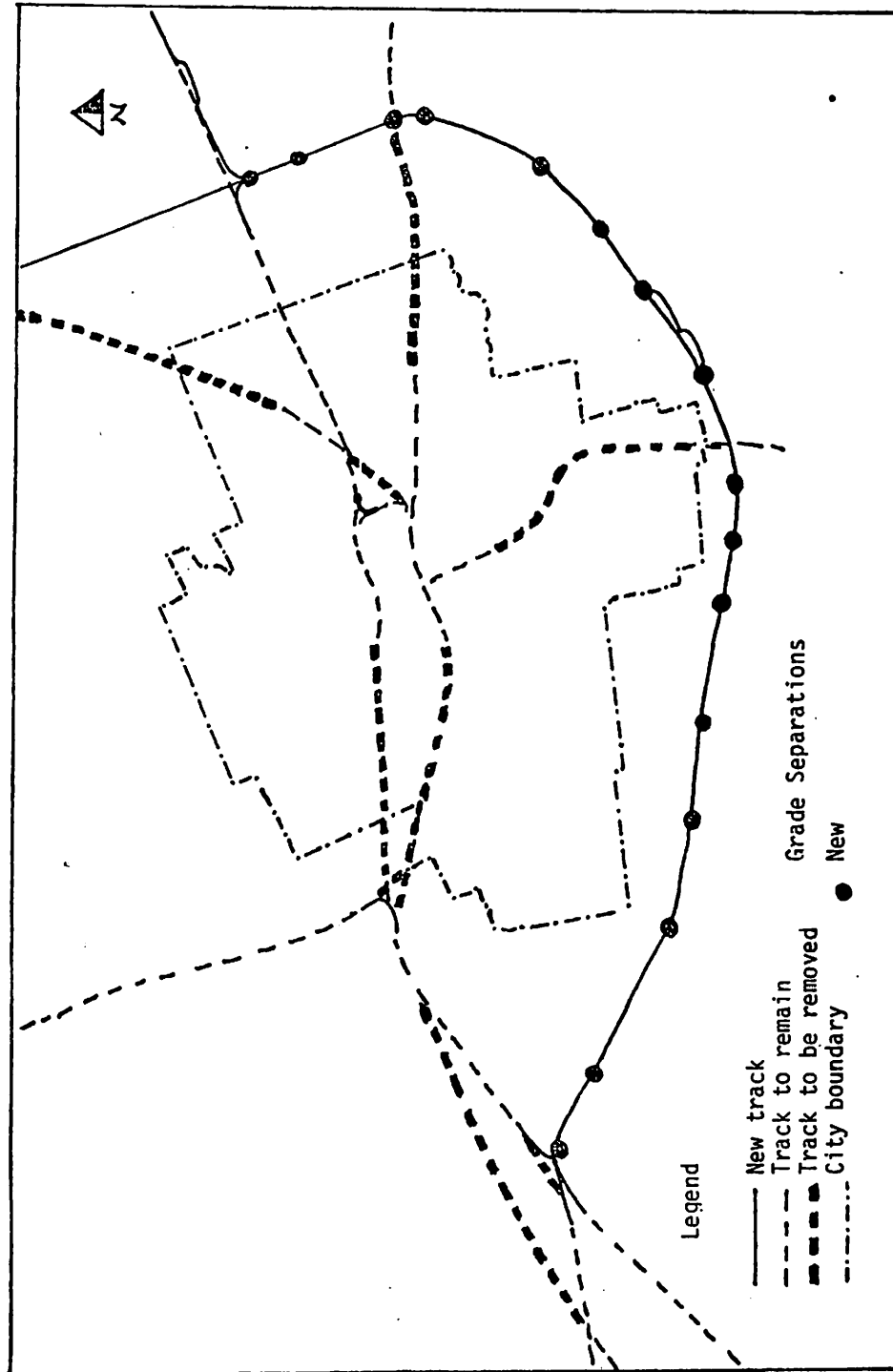
Source: DeLeuw Cather [1974].

Figure IV.4

Railway Relocation: The Complete Removal Scheme

Legend

——— New track
——— Track to be removed
—··—··— City boundary
●   New grade separations

New Yard

New Yard

N
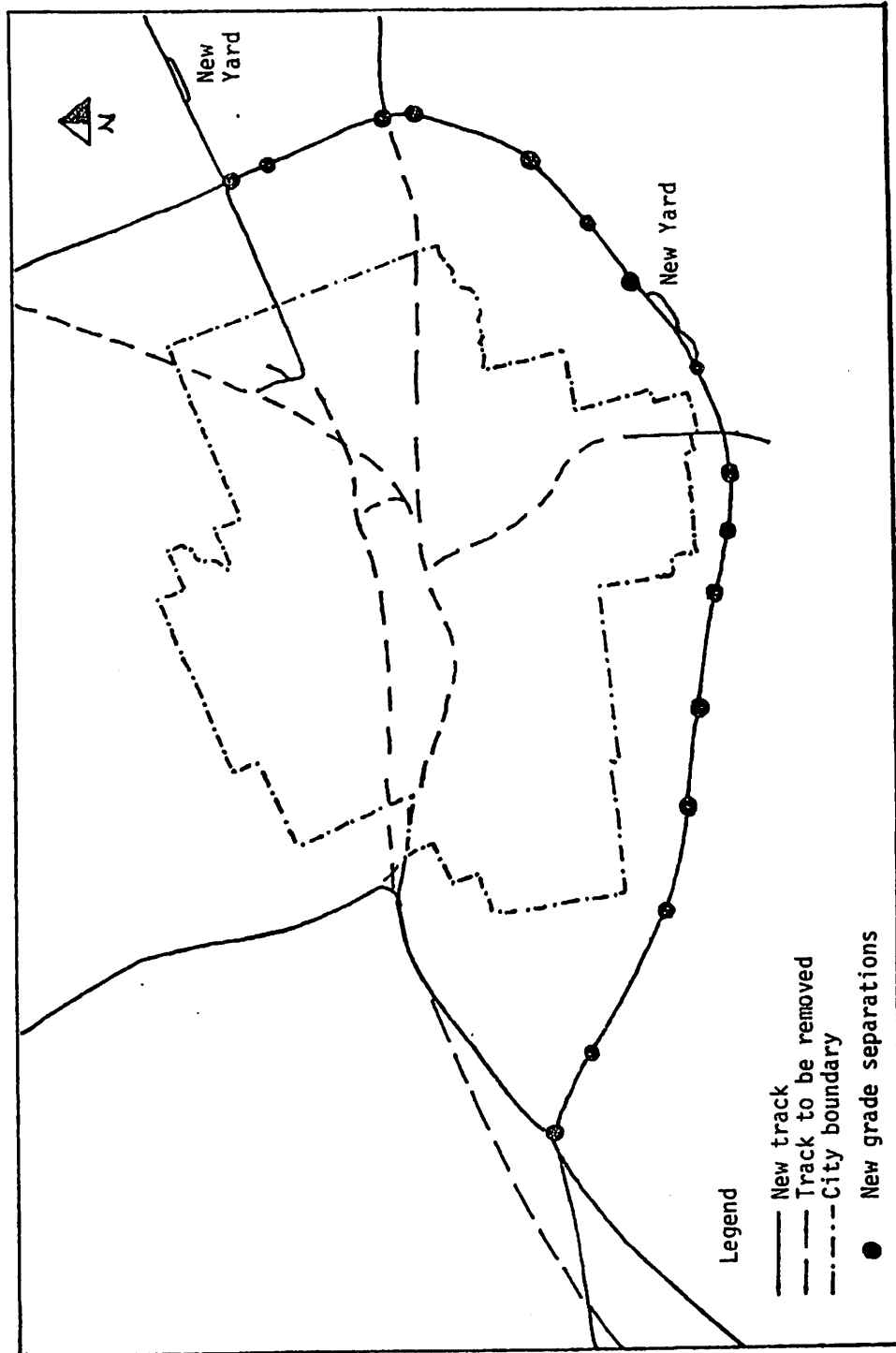
Source: DeLeuw Cather [1974].

point estimate of a parameter is not available and we resort to sensitivity analysis in an attempt to establish a confidence interval for a category of benefits or costs. A summary table of all the key parameters is given in the last section of this chapter (Table IV.10).[46]

B.1 Benefits of Railway Relocation Compared with Status Quo

  1.1 Savings in road travel time and vehicle
       operating expenses

(a) Existing road-rail conflicts

As can be seen in Figure IV.1, the existing railway network in London is such that most of the main roads intersect with the railway lines. At present there are more than 50 railway level crossings within the city. Conflict between vehicle and rail traffic is unavoidable at these crossings.

One result of all the proposed railway relocation schemes is that some or most of the level crossings will be eliminated. Under the CNR scheme (Figure IV.2) the existing CPR lines within the city would be removed and all CPR traffic would be consolidated onto the CNR Dundas-Strathroy route which has double tracks. Also the CPR main yard would be relocated outside the city and the CNR yard would be relocated to the southeast corner of London. In addition, 6 new grade separations would be constructed along the Dundas-Strathroy line. Altogether 14 level crossings within the city would be removed, and train traffic would be reduced at others. However, because of the consolidation of the CPR traffic, level crossings along the Dundas-Strathroy line which are to remain after the relocation would experience increased train traffic.

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[46]For a discussion of the parameter values, see Poon [1976], Chapter IV.

Under the Southern and Complete Removal schemss, both the main line and the yards would be relocated outside the city, and grade separations would be constructed at all major highway-railway intersections along the main line at the new site. Hence conflicts between vehicle and rail traffic can be expected to be minimal, at least at present. Vehicular delays caused by level crossings within the city would be greatly reduced.

In what follows we present the estimates of savings in travel time and vehicle operating expenses as a result of the removal of level crossings and the changes in rail traffic for the three relocation schemes.

(b) **Estimated savings in road travel time**
   and vehicle operating expenses

In Chapter III we have identified various sources of savings in road travel time (H_1, H_2, H_3, H_4, H_5, H_6) and vehicle operating expenses (G_1, G_2, G_3, G_4, G_6) where

H_1 = annual savings in vehicle hours without undergoing the deceleration and idling processes at level crossings due to the presence of trains;

H_2 = annual savings in vehicle hours without undergoing the acceleration process (back to normal speed) after being stopped by trains at a level crossing;

H_3 = annual savings in vehicle hours without undergoing the slowdown speed change cycle at level crossings in the absence of trains;

H_4 = annual savings in vehicle hours due to changes in congestion resulting from changes in truck traffic in the urban area (likely to be negative);

H_5 = annual savings in vehicle hours for not leaving home early;

H_6 = annual savings in vehicle hours due to changed routes, origins, or destinations.

The G_i's are the counterparts of the H_i's in terms of savings in vehicle operating expenses.

Due to lack of data, we do not intend to estimate H_4, H_5, H_6, G_4 and G_6. Since H_4 and G_4 are likely to be negative, the failure to measure H_4, G_4 and H_5, H_6, G_6 (which are positive) may partially cancel. However, H_4 and G_4 are not likely to be significant for the CNR and Southern schemes because rail service is retained to most local industries and no major change in truck traffic is expected. Hence for these two schemes, the failure to include estimates for H_5, H_6 and G_6 would give a downward bias to the estimate of aggregate savings in road travel time and vehicle operating expenses.

For the Complete Removal scheme, H_4 and G_4 could be quite significant and it is difficult to determine in which direction our results would be biased.

As indicated in Chpaters II and III, the savings in travel time and vehicle operating expenses (as well as other benefits) should be calculated on a "net" basis, i.e., savings at old railway site less costs at new site. Since the new railway sites under the three relocation schemes are mainly farmland and all the highway-railway crossings at the new site would be grade separated, the increase in travel time and vehicle operating expenses at the new site would be negligible and hence would be ignored.

(c) The dollar value of savings in travel time

It is difficult to assign a dollar value to the travel time saved due

to the lack of knowledge in this area. Most of the empirical studies done to date deal with the value of commuting time, which has been found to range anywhere between 20 per cent and 50 per cent of wage rates.[47] Findings with respect to other variables are scarce and the results cannot be applied with confidence.

In light of the difficulties in assigning a proper dollar value to the travel time saved, we shall perform some sensitivity analysis. According to Statistics Canada, the hourly wage rate in 1972 for a composite industrial worker[48] in London was approximately $3.60. Should the value of travel time range between 20 per cent and 50 per cent of the average wage rate, the value of travel time would range between $.72 and $1.80 per man hour in London. The fact that much travel is not to work and is by children would probably mean the high value, i.e., $1.80 per man hour, would have to be adjusted downward. Hence we shall assume the value of travel time for passenger car and public transit users to be $.70, $1.25, or $1.80 per man hour. The value of travel time for commercial vehicle users is assumed to equal $5.00 per man hour.[49]

(d) Savings in road travel time and vehicle operating expenses

Table IV.1 shows the estimated present discounted value of savings in travel time and vehicle operating expenses.[49a] It can be seen that the range

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[47]See Mohring [1976].

[48]Include both hourly rated and salaried workers.

[49]The value of travel time is assumed to equal the average wage rate of truck drivers. Data on wage rates of truck drivers were obtained from the Ontario Trucking Association. The average hourly earnings for transportation and communications industries was around $4.2 in 1972 excluding fringe benefits. See Statistics Canada.

[49a]In Appendix C in Poon [1976], we show in detail how H_1, H_2, H_3, G_1, and G_3 are measured.

TABLE IV.1

Present Discounted Value of Savings in Travel Time
and Vehicle Operating Expenses ($ million)

Value of Travel Time	CNR			Southern			Complete		
	L	M	H	L	M	H	L	M	H
A	2.18	3.91	13.30	2.05	3.67	12.48	3.43	6.13	20.86
B	2.64	4.72	16.07	2.51	4.48	15.25	4.05	7.24	24.64
C	3.10	5.54	18.84	2.97	5.32	18.08	4.67	8.35	28.42

Notes: L, M, H refer to the values (low, middle, high respectively) of the parameters
used in deriving the estimates. For the set of low, middle, and high parameters
used, see Table IV.10 below. Values of travel time ($ per hour) assumed under
A, B, and C are as follows:

	A	B	C
Passenger car and transit users	.70	1.25	1.80
Commercial vehicle users	5.00	5.00	5.00

of the estimated savings in travel time and vehicle operating expenses is very wide. This is to be expected since a high discount rate combined with a short project life will yield results very different from a low discount rate combined with a long project life.

1.2 Net benefit of generated travel

We do not estimate this item of the benefits due to the lack of data. It is likely to be positive but small.

1.3 Reduction in accident rates

(a) Accidents at road-rail crossings

Every year people are killed and injured and property is damaged in accidents at railway-highway crossings. During the 1958-1972 period, there were 671 fatal accidents, 2,404 non-fatal injury accidents, and 3,831 property damage only (PDO) accidents at railway-highway crossings in Ontario.[50] The average number of railway-highway crossing accidents per year in London during the 1969-1974 period was 13.7.[51]

It can be expected that the number of accidents would be reduced under all three proposed relocation schemes due to the elimination of level crossings and the reduction of train traffic or the construction of grade separations. Before we estimate the reduction in the number of accidents, it is necessary to estimate the number of accidents which would occur under the status quo.

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[50]Based on Statistics Canada, _Motor Vehicle Traffic Accidents_, various years.

[51]Canadian Transport Commission, unpublished data.

In Chapter II. we proposed a road-rail crossing accident function which, if estimated, could be used for prediction purposes. We are unable to estimate such a function because of the lack of sufficient data. All we can do is to perform some simple projections based on the past data on railway-highway crossing accidents in Ontario and Canada. We assume that the growth rate of railway crossing accidents in London will be 0, 1 and 2 per cent per annum. We use the average number of accidents per year for the 1969-74 period instead of the number of accidents in 1972 as the basis for projection because the former is probably a better estimate than the latter.

To calculate the reduction in the number of accidents for each of the railway relocation schemes we assume that the Complete Removal scheme would eliminate all accidents and that the reduction in road-rail crossing accidents by the CNR and Southern schemes would be proportional to the annual vehicle hours saved.

Since the new sites of railway facilities for the three relocation schemes are mainly farmland and all new highway-railway crossings would be grade separated, we assume that the increase in accidents at the new sites is nil.

(b) <u>Valuation of accident reduction</u>

In Chapter III we discussed several approaches to accident cost evaluation. The conceptually sound approach is unfortunately very demanding in data requirements and no study done along this line has derived results which can be applied. Thus we have to turn to the results of more "conventional" approaches.

To the best of our knowledge, no study has attempted to determine the costs of road-rail crossing accidents <u>per se</u>. Quite a number of studies have

been done, however, to determine the costs of motor vehicle accidents.[52] The essence of all these studies is to determine _ex post_ costs associated with vehicle accidents; for example, property damage, treatment of injuries, loss of use of vehicle, value of time lost, legal and court costs, and value of output lost, etc. The estimates of these studies tend to vary because of different costs included or excluded. The variation tends to be the greatest in the case of fatal accidents, due to the different assumptions made with respect to the inclusion or exclusion of future income of the deceased, the discount rate, and the time horizon used. Table IV.2 shows some of the results of these studies.

It is difficult to choose among these estimates. Hence, we present a range of estimates based on the highest and the lowest estimated costs of each category of accident as shown in Table IV.2. It must be emphasized again that these are _ex post_ economic costs associated with accidents and they may not bear any relationship to the amount which the society is willing to pay for the reduction of these accidents.

We apply the following formula to get the present discounted value of a reduction in road-rail crossing accidents:

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

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

C_i = cost per type i road-rail accidents;

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

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[52]See Abramson [1973] and the studies cited therein.

TABLE IV.2

Estimated Costs of Motor Vehicle Accidents
by Type (dollars)[a]

Name of Study	Estimated Cost per Accident		
	Fatal	Non-fatal Injury	PDO
Illinois (U.S.A.)	10,837	2,081	239
Texas (U.S.A.)	52,864	2,019	352
Societal (U.S.A.)	247,328	11,796	527
N.S.C. (U.S.A.)	54,752	3,264	462
I.I.I. (U.S.A.)	50,675	3,000	600
Ontario (Canada)	128,384[c]	2,010	> 200
M.O.T. (U.K.)[b]	12,162	822	248

Sources: P. Abramson, KLD Associates, Inc. [1973].
          J. A. Cassils [1971].
          R. Winfrey [1969].
          R. F. F. Dawson [1967].

Notes: (a) All costs are updated to 1972 dollar values using the
             consumer price index for each country.
        (b) The discount rate used was 6 per cent in this study;
             in all other studies, 4 per cent was used.
        (c) In the original study, the value of non-discounted
             lost output was $231,000.

r = discount rate;

N = project life in years.

The estimated present values of reductions in accidents for the three relocation schemes under different assumptions are shown in Table IV.3.

So far we have not mentioned reduced damage to locomotives and rolling stock, etc. as a result of reduced accidents. We cannot estimate these benefits separately due to lack of data. However, we believe that they are incorporated, at least in part, in the estimates presented above.

1.4 Land released for redevelopment

As can be seen in Figures IV.2, IV.3, and IV.4 above, the existing railways occupy some of the prime land in the urban area. Part or all of this land is expected to be released for other uses under the proposed relocation schemes. As we have discussed in Chapter III, it is not an easy task to measure the value of the released land. The market price, which turns out to be the only practical tool, may not give an accurate indication of the true social value of the released land. The estimates (million dollars) given below are based on land transaction data in London during the 1969-1972 period.

	CNR	Southern	Complete
Low	5.50	5.80	5.80
Middle	6.72	8.03	8.76
High	7.93	10.26	11.73

TABLE IV.3

Present Value of Reduction in Road-Rail Crossing Accidents

($ million)

Cost ($) Per Accident	CNR			Southern			Complete		
	L	M	H	L	M	H	L	M	H
A'	.18	.32	.87	.20	.34	.93	.23	.40	1.08
B'	.87	1.46	3.98	.93	1.56	4.25	1.08	1.82	4.95
C'	3.95	6.67	18.15	4.21	7.11	19.35	4.91	8.28	22.54

Notes: L, M, H indicate respectively low, middle, and high parameter values (other than the cost per accident) used. For the set of parameter values, see Table IV.10 below. Cost per accident is assumed to be as follows:

	A'	B'	C'
Fatal	$10,800	$55,000	$262,000
Non-fatal	820	3,000	11,800
PDO	200	350	600

1.5 Improvement of areas abutting
railway facilities

(a) What would be estimated

Under all three proposed relocation schemes, some or most of the existing railway tracks would be removed from the urban area and as a result we could expect some reduction in railway, air, noise, and "visual" pollution. In this section we estimate the value of the environmental improvement in areas abutting railway facilities following railway relocation. Let us be clear about what is included in and excluded from our estimates.

First, we shall be concerned with residential areas only. The removal of the railway is likely to confer environmental benefits on institutions, offices and commercial stores in the surrounding areas as well. However, due to lack of data we cannot estimate these benefits. We expect these benefits to be positive but relatively small compared with those conferred on residential properties. Compared with the number of residential properties, the number of institutions, offices and industries located near railways in London is small. In addition, most people stay in their working places only 8 hours a day and 5 days a week. Nevertheless, exclusion of these benefits would mean that the estimated value of removal of railway externalities would be biased downward.

Second, we consider the residential areas with removed tracks only. Under the CNR and Southern schemes, there are sections of railway lines which would remain, but with reduced rail traffic, after relocation. We do not estimate the benefits which could possibly arise due to reduced train volumes. On the other hand, we also do not consider the possible increase in railway externalities along the Dundas-Strathroy corridor due to increased rail traffic under the CNR scheme. The main reason for not considering the

environmental impact to a change in rail traffic is that we really do not know what allowances should be made for these possible benefits or costs. The empirical evidence which we have tends to suggest that it is the presence of railways rather than the volume of rail traffic that is capitalized in property values.

Third, we do not consider the possible adverse environmental impacts at the new location of the railway. This exclusion is unlikely to affect our estimates significantly since the new site is mainly farmland.[53]

Fourth, we assume that the subsequent use of the land released from railway relocation will be compatible with the existing uses in the neighbourhood. If this assumption is violated, our estimate of the value of environmental improvement as a result of railway relocation would be biased upward.

(b) Methodology

As discussed in Chapter III, we intend to measure the value of removal of railway externalities via differences in property values. Our approach is to estimate a property price equation and to use the effect of railways on property prices to derive estimates of gains.

It may be worthwhile to emphasize at this point that we do not consider gains or losses of property values per se as aggregate consumption benefits or costs of railway relocation. Rather, we take the differences in property value as a measure of railway externalities. As a result of railway relocation, part or all of these externalities might be eliminated. This represents a real gain to society regardless of how property prices behave after railway relocation.

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[53]This does not mean that railways do not impose externalities on farmland.

In the following two subsections we examine the effect of railway externalities on residential sale prices and estimate the gains to society from reduction in railway nuisance under each of the three relocation schemes proposed.

(c) Effects of railway externalities on the
     price of residential properties

Railway externalities tend to decrease with distance from the railway. Hence, if they are capitalized into property values, properties located nearer to the railway should sell at a lower price than similar properties located farther away from the railway. This is the main hypothesis we wish to test. A second hypothesis is that other things being equal, property sale prices tend to vary inversely with the volume of rail traffic. To test these hypotheses, we collected real estate sales data in different areas in the City of London. More detailed discussion of the data and sample as well as our regression model is contained in Appendix I. Here we shall examine the empirical results related to these hypotheses.

Our main conclusion is that the empirical evidence tends to support the first hypothesis but not the second. In other words railway externalities in general are capitalized into residential property values and a house located nearer to the railway tends to command a lower sale price than a similar house located farther away from the track (the estimated discount in sale prices at different distances from the railway can be seen in Table IV.4). However, the volume of railway traffic seems to have no significant effect on residential property sale prices.[54]

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[54]It seems rather incredible that people would be indifferent between, say, a location near a railway that carries 20 trains per day and a comparable location near a railway that carries 5 trains per day. This is not necessarily the implication of our result. Rather, it is conceivable that

We also find that the effect of railway externalities on property values terminates about 800 to 900 feet from the railway. This means that houses located 10 to 15 lots away from the railway would probably not sell at a discount because of the railway.

In addition, we find that the dollar discount in the sale price of a residential property for being located near a railway increases over time as property prices increase.

Now let us state some qualifications to the above findings. The above results are based on a sample which consists mainly of single-family detached homes. It is not clear whether they would apply to high-rise apartments as well. The difference in physical structure and also in ownership (owner versus tenants)[55] could mean that some of our conclusions would not hold for high-rise apartments.[56]

The estimated discount in residential sale price is meant to hold on average and the actual discount in the sale price of a specific property could be quite different from this average figure.

Due to the limitations of data we probably have not succeeded in

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buyers in general may not bother to find out exactly how many trains pass a property. After all, train volume can change over time. Hence, it could be people's ignorance and uncertainty concerning the volume of rail traffic that renders this variable insignificant in determining property sales.

[55]Because of the short-term nature of apartment living, people may care less for railway externalities. Hence it may not be fruitful trying to detect railway externalities by looking for differences in apartment rents. Condominium sale prices could be a much better indicator. However, this form of ownership was still not popular in London during the period under consideration.

[56]For example, the conclusion with respect to the distance where railway externalities terminate.

isolating the effects of some other factors on property sale prices. Hence, the distance from railway variable may pick up the effect of some correlated variables which are not included in the regression equation, such as housing quality.[57]

(d) Estimation of the value of
    environmental improvement

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

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

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.

First let us turn to the discount in property value at various distances from the railway.

The empirical relationship between property sale price (P) and distance

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[57]It is conceivable that people who do not care about railway externalities also do not care about the quality of their homes (interior and exterior), so the houses near railways may be of systematically lower quality. On the other hand, people near railways may have a greater incentive to do landscaping to cut down on railway externalities, so properties near railways have systematically better landscaping (hedges, trees). In the first case, the estimated value of the coefficient of the railway variable would be biased upward, and in the second case, the bias would be in the other direction. The first case appears to be more plausible to us.

(in 100 feet) from the railway track is found to be:

$$P = \ldots + 588.7x - 35.4x^2 \ldots,$$

Based on the above relationship, column (2) of Table IV.4 shows the increase in property value in dollars as the same house is located farther and farther from the railway. The effect of railway externalities on property value terminates about 800 to 900 feet from the track according to this relationship. Comparing two similar properties, one within 100 feet of the track, and the other over 800 feet away from the track, shows that the latter tends to sell for $2,161 more than the former. In other words, the discount of the house located within 100 feet of the railway is $2,161. Column (3) of Table IV.4 gives the discount in dollars of property value at various distances from the railway.

From the land use maps of London, we counted the approximate number of properties in each 100 foot interval from the railway. To find SB for each of the relocation schemes, we multiply the discount per property by the number of properties at each 100 foot interval from the railway. The value (millions of dollars) of environmental improvement as measured by the discount in property values for the three relocation schemes are estimated to be as follows:

CNR	Southern	Complete
1.48	2.02	3.60

The above estimate takes into consideration developed residential properties only. We have not considered future detrimental effects of existing railways on residential properties which have not yet been developed. This omission is particularly significant for certain parts of the city

TABLE IV.4

Differential in House Sale Price at Various
Distances from a Railway in 1972

(1) (x), Distance from Railway (ft.)	(2)[a] Increase in Sale Price ($) Compared to x = 0	(3)[b] Discount in Sale Price Compared to x = 850
50	$ 285	$2,161
150	883	1,563
250	1,250	1,196
350	1,627	819
450	1,932	514
550	2,167	279
650	2,329	117
750	2,424	22
850	2,446	0

Notes: (a) Based on the estimated coefficient of the distance from railway
variable of equation (b) in Table E.3a in Appendix E, Poon [1976].
(b) Based on figures in column (2).

(e.g., northwest, south) where lands are designated as residential but have not been developed. It can be argued that by putting up sound barriers and appropriate landscaping, railway externalities can be minimized in these areas. However, extra costs would be incurred. The removal of the railway would render these outlays unnecessary and hence represents a gain. It is essential, therefore, that some estimates of the future gains on presently undeveloped land be included. These estimated values (million dollars) are as follows:

Discount Rate (%)	CNR	Southern	Complete
4	.90	1.32	1.32
7	.72	1.05	1.05
10	.60	.87	.87

The total benefits ($ million) from the removal of railway externalities on developed and undeveloped residential properties are shown in Table IV.5.

B.2 Costs of Railway Relocation Compared with Status Quo

2.1 Capital costs

LUTS has made some cost estimates of the CNR and Southern schemes. We are not in a position to construct these costs ourselves since the estimation of these costs falls largely within the sphere of civil engineering. However, we still want to know whether these estimates are reasonably accurate.

Our first consideration is whether all the physical units, e.g., cubic yards of earth to be excavated, miles of tracks to be laid, square feet of buildings to be constructed, have been measured accurately. Since we were not involved in the measurement of these units, we will have to take the measurements of LUTS as accurate.

TABLE IV.5

Benefits from the Removal of
Railway Externalities

($ million)

Discount Rate %	Scheme		
	CNR	Southern	Complete
4	2.38	3.34	4.92
7	2.20	3.01	4.65
10	2.08	2.39	4.47

Our second consideration is whether the unit prices used to arrive at the capital costs are reasonable. We compare the unit capital prices used by LUTS and those suggested by the U.S. Department of Transportation (42). Most of LUTS' unit prices fall within the low-high range suggested by the U.S. study. In order to establish a confidence interval for the capital estimates we employ some of the extreme unit prices suggested by the U.S. study and derive cost estimates for the three relocation schemes.[58]

Our third consideration is whether the costs have been measured correctly, without omission or double counting. Checking against the list presented in Chapter III, we find that most of the costs have been included. However, the land cost for new railway and yards is the market value of land and not the capitalized rental value of land over a finite time period. Since the land cost is a relatively small item, it does not affect the total capital costs estimated to any significant extent.

As one might expect, LUTS has not made adjustments for possible savings in replacement costs. In order to measure these savings we have to know the service life expectancy of all railway facilities and the age of existing facilities. In addition, information on depreciation and salvage value is also required. Since such data are not available to us, all we can do is to make some simplifying assumptions in order to arrive at "guess-timates" of such savings.[59]

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[58] The high unit price of engine house and cut to fill suggested by the U.S. study are respectively $10 million and $7.0/cu.yard. These prices seem too high for London. We change them to $1.5 million and $4/5/cu.yard respectively.

[59] For calculation of these savings, see Poon [1976], Appendix F.

If the estimated replacement cost savings were deducted then the capital costs of the relocation schemes would be the following:

	CNR	Southern	Complete
Low	15.23	21.10	> 21.10
Medium	25.54	36.79	> 36.79
High	43.39	64.88	> 64.88

2.2 Railway operating costs

As in the case of capital costs we rely mainly on the estimates made by LUTS. We have to take LUTS' measurements of physical units (e.g., track miles, number of switch assignments) for granted. We are able to check some of the main unit prices used by LUTS against those of the U.S. study. Except for maintenance cost of main track, other items of costs are within the range provided by the latter. However in checking whether most of the changes in operating costs have been included, we found that the estimates of LUTS are based on very limited railway operation data. It seems to us that LUTS has underestimated the reduction in operating costs under the CNR scheme and overestimated the increase in operating costs under the Southern scheme.

We attempt to derive some cost estimates following the methodology developed by the U.S. study. Table IV.6 gives the estimated present value of changes in operating costs over different time horizons with different discount rates. These estimates are based on the assumption that the annual changes would be constant over the relevant period of time. It is quite likely that this assumption is too simplistic because some of the resulting changes, e.g., maintenance costs of some railway facilities and structures, tend to vary with time and train traffic. However, due to the complex

TABLE IV.6

Present Discounted Value of Changes in
Railway Operating Costs

(millions of dollars)

Scheme P.Life (Yr) Disc. Rate (%)	CNR			Southern		
	30	50	100	30	50	100
High						
4	-1.04	-1.28	-1.47	8.21	10.20	11.64
7	-.74	-.82	-.86	5.89	6.55	6.78
10	-.56	-.59	-.60	4.48	4.71	4.75
Middle						
4	-1.64	-2.04	-2.32	4.44	5.52	6.29
7	-1.18	-1.31	-1.35	3.19	3.54	3.67
10	-.89	-.94	-.95	2.02	2.54	2.57
Low						
4	-2.25	-2.79	-3.12	.69	.76	.98
7	-1.61	-1.79	-1.25	.49	.55	.57
10	-1.22	-1.29	-1.30	.38	.40	.40

nature of railway operating costs and lack of data, we cannot do much else.

2.3 Transportation and relocation costs for railway users

(a) Railway passengers

There are two groups of users that will be affected, namely, passengers and industries. Under the CNR scheme, the existing passenger terminal would be retained and hence there would be no change in passenger travel costs. Under the Southern and Complete Removal schemes, a new passenger terminal would have to be built somewhere outside the city in the southeast direction. Since the majority of the population would live north of the new station, it is likely that passenger travel costs would increase.

To estimate these increases in passenger travel cost we make the following assumptions. (a) The new passenger terminal would be located approximately three miles south of the existing terminal. This is roughly the distance from the existing terminal to the city boundary at the south. (b) Half of the passengers embarking or disembarking at the terminal would experience a net increase in travel time and vehicle operating expenses as a result of relocation of the terminal. This assumption seems reasonable given the population distribution pattern in London.[60] (c) The average speed of vehicles is 20 miles per hour in the urban area. Given these assumptions we may proceed to calculate the increase in travel time and vehicle operating expenses. Table IV.7 shows the present discounted value of the increase in railway passenger travel costs as a result of relocation of the passenger terminal.

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[60] The existing passenger terminal is located near the center of the city. Relocation would result in increase of travelling costs for passengers who live north of the existing terminal.

TABLE IV.7

Increase in Travel Time and Vehicle Operating
Expenses for Railway Passengers*

(millions of dollars)

Value of Travel Time $/Man-Hour	Low	Middle	High
.70	.64	.94	1.68
1.25	.80	1.17	2.08
1.80	.95	1.40	2.49

*Trend in railway passenger traffic
assumed to be zero.

(b) Industries

Under the CNR and the Southern schemes, only 4 firms (with total annual revenue cars equal to 22) would lose local service but none of them is expected to relocate. Hence no significant industry relocation cost would be incurred. Under the "Complete" scheme, however, a great number of firms would be affected. Some of them may have to relocate, thus incurring relocation costs. Those which remain at the existing location, may shift from rail to truck or may continue to use rail by trucking their goods to rail freight terminals. In either case, truck traffic is likely to increase, resulting in more congestion on the roads.

We are unable to estimate the increase in congestion costs due to the lack of data. However, we shall attempt to derive some rough estimates with respect to the increase of industry relocation costs.

According to LUTS, approximately 100 firms are served by railways in London. However, only 30 firms generate more than 100 rail cars annually. We shall assume the maximum number of firms to relocate as a result of discontinuation of rail service is 30. It is impossible to determine the relocation costs for individual firms because of the lack of data. However, two other studies have found that the average cost of relocation and paying damages ranges between $100,000 and $200,000 per firm.[61] The average cost for London could be higher because of larger firms involved and/or higher land costs, etc. THus we assume that the upper bound of the average cost for relocating and paying damages to a firm is $300,000 in London. Table IV.8 presents some estimates of relocation costs of industries under different assumptions with regard to the number of firms relocated and the average

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[61]Dillon, M. M. Ltd., [1972, 1973].

TABLE IV.8

Relocation Costs of Industries
($ million)

Cost Per Firm	No. of Firms Relocate		
	10	20	30
.1	1	2	3
.2	2	4	6
.3	3	6	9

cost of relocation per firm.

2.4 Transportation and relocation costs
for non-users

As mentioned above, the CNR and Southern schemes would have minimal impact on industry. Hence not many employees of industries would be affected. Under the Complete scheme, a number of industries may relocate and hence some employees may have to relocate as well. However, since London is not a big city, those affected employees may choose to commute a longer distance to work rather than to relocate. Thus the Complete scheme would probably increase the commuting costs of the employees of industries which have to relocate. No estimate is made for this item of relocation costs.

2.5 Delay in traffic while construction
is in progress

Delay in traffic while construction is in progress applies to all three schemes. The CNR scheme probably imposes the least amount of disruption to traffic, because it is the smallest project among the three. Due to the lack of appropriate data we cannot estimate this item of cost.

C. Benefits and Costs of Grade Separation

Instead of railway relocation, grade separations may be built to minimize road-rail conflicts. According to LUTS and Margison and Associates [1966], 19 new and 9 reconstructed grade separations would be warranted within the City of London by 1985.[62] The locations of the existing and proposed grade separations are shown in Figure IV.5. In what follows we

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[62]It is not clear why these grade separations are warranted.

Figure IV.5

Grade Separations: New and Reconstructions

Legend

Grade Separations

○ Reconstruction ——— Existing track

● New —·—·— City boundary
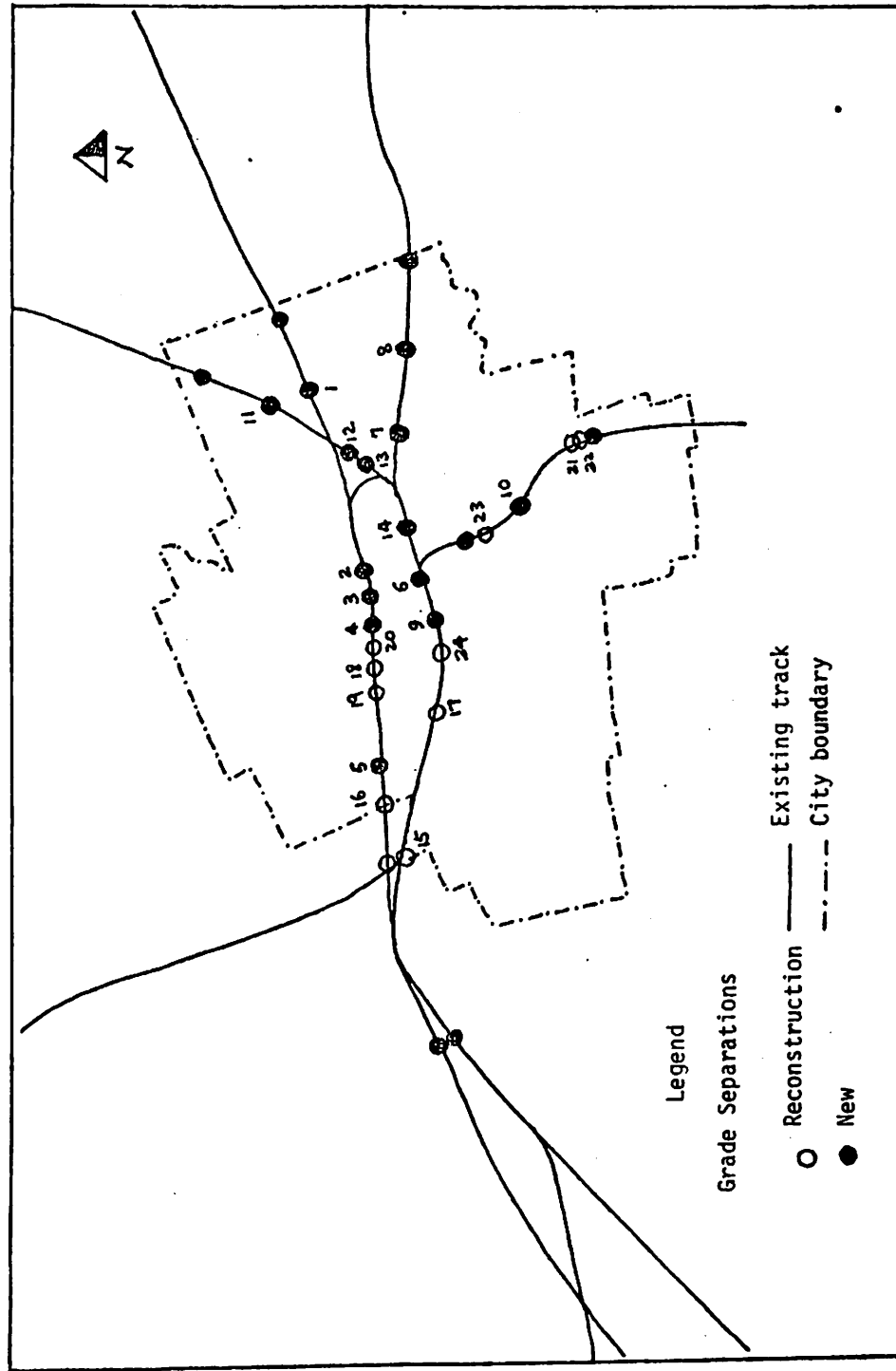
Source: DeLeuw Cather [1974].

attempt to evaluate the benefits and costs of the individual grade separations. Among the 19 new grade separations, 4 are for future roads. We shall exclude these 4 from consideration, since no vehicle traffic data are available.

C.1 Benefits of Grade Separation Compared with Status Quo

1.1 Savings in road travel time and vehicle operating expenses

The estimated present value of the savings in travel time and vehicle operating expenses as a result of grade separations for each of the crossings are shown in Table IV.9. These savings are calculated in the same manner as before (see section B.1.1 above). We treat the reconstruction as if they were new grade separations.

1.2 Net benefit of generated travel

For the reconstructed grade separations, generated travel would be negligible. For the new grade separations, net benefit of generated travel could be significant. If all level crossings were grade separated, the net benefit of generated travel for individual crossings would be relatively small, due to the inelastic nature of urban travel. However, if grade separations were built for only some of the level crossings, then considerable traffic may be diverted to these grade separated crossings. Unfortunately, we do not have any data on the amount of diverted traffic due to grade separation. In any case, even if we assume that the net benefit of generated travel is as high as one-third of the savings in travel time and vehicle expenses estimated, the results do not change to any significant extent.

TABLE IV.9a

Benefits and Costs of New Grade Separations, 1972

(millions of dollars)

Grade Separation No.[a]	Total Benefits[b]			Total Costs[c]		
	Low	Middle	High	High	Middle	Low
1	.08	.17	.49	1.14	1.03	.97
2	.13	.35	1.65	5.02	4.50	3.98
3	.02	.97	.34	1.14	1.03	.92
4	.22	.59	2.68*	1.14	1.02	.92
5	.03	.06	.18	.59	.54	.48
6	.12	.39	1.70	1.99	1.99	1.99
7	.09	.27	1.30*	.40	.37	.34
8	.04	.10	.34	.41	.38	.35
9	.18	.55	2.70*	.73	.66	.60
10	.06	.13	.32	.41	.38	.35
11	.06	.13	.32	1.33	1.20	1.07
12	.20	.38	1.03	1.49	1.35	1.21
13	.13	.29	.89	1.49	1.35	1.21
14	.03	.08	.28	2.41	2.15	1.90
Total	1.39	3.56	14.22	19.67	17.65	16.29

(continued)

TABLE IV.9b

Benefits and Costs of Grade Separation Reconstruction, 1972

(millions of dollars)

Grade Separation No.	Total Benefits			Total Costs[d]
	Low	Middle	High	
15	.02	.05	.13	.26
16	.02	.05	.13	.44
17	.08	.17	.43	.50
18	.09	.22	.80	.81
19	.05	.16	.93*	.61
20	.23	.49	1.30*	.52
21	.06	.19*	1.22*	.09
22	.04	.09	.20*	.11
23	.07	.14	.40*	.36
24	.41*	.95*	3.22*	.23
Total	1.07	2.51	8.76	3.93

Notes: (a) See Figure IV.5 for the location of these crossings.
(b) Include the following benefits: savings in travel time and vehicle operating expenses and reduction in accident rates.
(c) Include the following costs: capital costs and maintenance costs.
(d) Include capital costs only.
* Indicates benefits exceed costs.

1.3 Reduction in accident rates

The construction of grade separations tends greatly to reduce accidents at road-rail crossings.[63] However, it is almost impossible to derive an accurate estimate for each specific crossing. The only thing one can say with confidence is that if most of the level crossings were grade separated, then there would be a significant reduction in the number of accidents. Thus, we have more confidence about the estimated aggregate value of reduction in accidents of the 24 grade separations than that of any individual separations. Again the same assumptions were made as before (section B.1.3) in estimating the value of accident reduction.

1.4 Reduction in air pollution at level crossings

Grade separations, by speeding up the traffic flow, would reduce vehicle emissions at the crossings. We do not estimate these reductions.

C.2 Costs of Grade Separation Compared with Status Quo

2.1 Capital costs

LUTS has estimated the capital costs of individual grade separations. These estimates seem reasonable compared with those of other studies.

2.2 Railway operating costs

As a result of grade separation, railway operating and maintenance costs may change because of savings in signal maintenance, relief from certain speed and operating restrictions and by the possibility of installing

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[63]Up to 90 per cent, according to Damas and Smith [1973]. See also U.S. Department of Transportation [1972], p. 28.

additional trackage. Due to the lack of data we are only able to derive some estimates of the change in maintenance costs.

2.3 Delay in traffic while construction is in progress

We do not estimate this item due to the lack of data. However, it is clear that construction work is a source of nuisance to motorists and pedestrians alike.

D. Benefits and Costs of Railway Relocation and Grade Separation: Evaluation and Conclusions

In this section we bring together the benefits and costs of railway relocation and grade separation. Because a range of values is assumed for some of the parameters, many sets of benefits and costs could be derived. We shall present the more significant ones.

Table IV.10 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 most 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 IV.11 we show the estimated benefits and costs of the three relocation schemes and the grade separation alternative, based on the three sets of parameter values given in Table IV.10. 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"

TABLE IV.10

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

Note: (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, Poon [1976].

TABLE IV.11a

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	2.08	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 IV.11b

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 IV.11c

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.

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. Jenkins [1972a,b] estimated that the social opportunity cost of public funds was approximately ten per cent per year for Canada. If this rate 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):

	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, 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 <u>aggregate</u> willingness to pay.

Appendix I

RAILWAY EXTERNALITIES AND RESIDENTIAL
PROPERTY PRICES

In this appendix we present a regression model of the determinants of residential property prices. Our main objective is to find out whether and to what extent a railway reduces sale prices of residential properties located in its neighbourhood. We discuss in turn: data and sample, specification of the model, and empirical results.

Data and Sample

Our sample consists mainly of single-family detached dwellings. However, a number of multiple-family dwellings (duplexes, triplexes) are included as well. The latter represent approximately 15 per cent of the total sample of 285 observations.

The principal source of data is Multiple Listing Service (MLS) sheets from the files of several real estate firms in London.[1] The following information is normally available from MLS sheets for each property sold: (i) address of the property; (ii) physical features such as style, type of siding, number of stories, age, lot size, number and size of each type of room, garage, paved driveway, basement, type of heating, etc.; (iii) asking price and down payment requirement; (iv) financial terms and mortgages; (v) assessment and taxes; (vi) actual sale price and date of sale as recorded by the real estate firms.

To obtain distances from railways, each observation was located on city land-use maps and the distance was measured in 100 foot intervals.

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[1]Published by Middlesex Real Estate Board.

Since we are mainly interested in finding the relative prices of properties located at different distances from the railways, the most suitable data would be cross-sectional rather than time series. However, the data used are both cross-sectional and time series, covering a period of six years from 1967 to 1972. The main reason for using data from six years is to enlarge our sample size.

Instead of taking a random sample of all residential property sales in the city, we selected four areas within the city for study. There are two reasons for this approach.

First, properties which are far from the tracks will not be affected by railway externalities and hence need not be included.[2] The inclusion of these transactions might create unnecessary statistical "noise." In our sample the maximum distance between track and property is about 1,400 feet.

Second, in order to isolate the effect of railway facilities on property values, other locational and environmental variables are best kept constant. By selecting a sample of given size from a limited area, we minimize the number of explanatory variables required in the regression equation.

The four areas selected are primarily residential in use. Some commercial and/or light industrial activities are present in three of the four areas. The average income of households and property values vary among the areas.

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[2]Tests of the data indicate that railway effects reach less than 1000 feet on both sides of the railway.

Specification of the Model

We hypothesize that the price of a residential property is a function of the characteristics of its structure, its lot and its neighbourhood. In addition, characteristics of the existing mortgage may affect price. Also, since our data span a period of six years, account must be taken of the change in property prices over time.

Another variable which may also be included is property tax assessment. We tried this variable without success. This may be due to the fact that London is a relatively small city under a single municipal government.[3] The tax variable will not be discussed in the rest of this appendix.

For empirical testing we specify our model in two basic forms:

(1) $$P = a_0 + a_1 x_1 + a_2 x_2 + \ldots + a_n x_n + e$$

(2) $$Ln\ P = b_0 + b_1\ L_n\ x_1 + b_2\ Ln\ x_2 + \ldots + b_n\ Ln\ x_n + e$$

where P is the sale price of an individual property, $x_1, \ldots, x_n$ are independent variables, e is the error term, Ln is the natural logarithm of numbers, and $a_0, a_1, \ldots, a_n$, $b_0, b_1, \ldots, b_n$ are coefficients to be estimated.

A priori we cannot determine which, if either, of the specifications represents the true relationship. Both forms have been used in previous studies.[4] We shall try both forms and some other specifications as well. We turn now to the specification of each of the variables in our regression model.

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[3]See Wales and Wiens [1974] and Edelstein [1974] for the rational for including the tax variable and also their empirical findings.

[4](entire footnote on next page)

(a) Dependent variable

The dependent variable is the sale price of an individual residential property. Since we want to calculate all benefits and costs in terms of 1972 dollars, we employ a house price index developed by Davies and Jackson [1975] for London to adjust all sale prices to 1972 dollar levels. Consequently, we do not include a separate time trend as one of the independent variables.[5]

(b) Structural variables

The structural variables included are: age (number of years since the house was built); number of rooms (including dining room, living room, family room, bedrooms and kitchen); number of bathrooms; recreation room (dummy = 1 if the house has a finished recreation room in the basement);

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[4]

Linear	Log	Both Linear and Log or Combination
Brigham [1965	Anderson and Crocker [1971]	Grether and Mieszkowski [1974]
Ridker and Henning [1967]	Emerson [1972]	
Wabe [1971]		
Richardson, Vipond, and Furbey [1974]		

[5]We have tried a separate time trend employing the monthly housing price index for Canada. The results do not change appreciably except that the magnitude of the coefficients estimated changed. In this case the estimated values would be some kind of 1967-1972 average dollar values which are not suitable for our purpose.

basement (full = 1, half = .5, none = 0); number of stories; fireplace (dummy = 1 if the house has one or more fireplaces); number of dwelling units (dummy = 1 if the house is single detached, dummy = 0 if duplex or triplex); garage (dummy = 1 if the house has either detached or attached garage); type of siding (dummy = 1 if stone or brick).

We expect most of the structural variables to be positively related to sale price. The age variable is likely to be negatively related to sale price, except in the case where older houses may have better landscaping (we do not include this variable) and better construction.[6]

(c) Lot-related variables

Five lot-related variables are considered: lot size (square feet); corner lot (dummy = 1 if it is a corner lot); distance from arterial road (dummy = 1 if a property is within 3 lots of an arterial road); volume of rail traffic on nearest railway (number of trains per day); and distance from railway (in units of 100 feet). All of the properties are connected to the city sanitary sewers and none of them use septic tanks. Data on other lot-related variables such as landscaping and frontage are not available.

We expect lot size and distance from railway to be positively related to sale price. Volume of rail traffic and distance from arterial road are expected to be negatively associated with sale price. The sign of the

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[6]Some realtors have suggested that the average quality of workmanship in construction in London declined after about 1967 or 1968, e.g., use of cheaper materials such as plywood instead of hardwood for floors, less wood per house, etc.

corner lot variable is ambiguous.[7]

(d) Neighbourhood variables

Each of the areas from which observations were drawn is fairly uniform with respect to neighbourhood variables such as population density, distance from employment centres, average income, and public services. Consequently no neighbourhood variable is included in the regressions for individual areas. However, when we combine observations for all areas and run one regression, area dummies are used.

(e) Mortgage variables

If a property has a large, open, low interest mortgage, it offers some financial advantages. The present discounted value of the potential saving in interest payment for the buyer is approximately

$$S = \sum_{t=c}^{N} \frac{(r_c - r_m)M_t}{(1 + h)^t}$$

where r_c = interest rate on new mortgages at time of sale (t=c);

r_m = interest rate on the existing mortgage;

M_t = outstanding mortgage at time t (in dollars);

h = buyer's annual discount rate; and

N = year in which existing mortgage will be paid off.

In our regression equation, we use $S^1 = (r_c - r_m)M_c$ as a proxy for S since we do not have data on N or h and the only value of M_t we have is M_c. We

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[7]In an area where commercial activities are allowed, a corner lot may command a positive premium. However, in a purely residential area, this probably would not be the case.

expect both S and S^1 to be positively related to sale price.

(f) Alternative specification of some variables

In specification (1) above a linear relationship is assumed for all variables. However, for the variables "age," "distance from railway," and "lot-size," it was hypothesized that the relationship with the dependent variable would likely be non-linear. Thus, in addition to specifications (1) and (2) above, non-linear (quadratic) forms of these variables were tried in the otherwise linear regression.

Empirical Results

Most of the variables have the expected signs and are significantly different from zero at the five per cent level.[8] We shall discuss the results related to the two railway variables but not those of other variables since the latter are of no interest to this study.

The distance from railway (DR) variable is significant at the five per cent level and has the expected sign in all three forms of functions tested. The estimated coefficients for the pooled sample of 285 observations are as follows:

(a) $P = \ldots + 217 \, DR + \ldots$
             (72.4)

(b) $P = \ldots + 588.7 \, DR - 35.4 \, DR^2 + \ldots$
             (239.9)   (21.1)

(c) $Ln \, P = \ldots + .052 \, ln \, DR + \ldots$
             (.014)

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[8]For detailed regression results, see Poon [1976], Appendix E.

The figures in brackets are standard errors of the individual coefficients. All these relationships show that, other things equal, residential property sale price increases with distance from the railway.

The linear and log forms do not indicate where railway adverse effects on property value would terminate. However, the quadratic form seems to indicate that discount in sale prices terminates around 800 to 900 feet from the railway track (see column (2) of Table IV.4 in Chapter IV). Unfortunately we have only a limited number of observations beyond 900 feet from the railway. Thus we cannot run separation regression equations for those observations which lie beyond 900 feet from the railway to test the significance of the railway variable. However, we did the following test. We selected the 28 observations which lay beyond 900 feet from the railway and found their estimated sale prices based on the assumption that they were 850 feet from the railway. We compared the estimated sale prices with the actual sale prices (adjusted to 1972 dollars). Our hypothesis is that if railway externalities terminate around 850 feet from the railway, the estimated sale prices should not be significantly different from the actual sale prices. We employed two tests. The first one is a simple t-test of the difference of two means. The second one is "correlated t-test," comparing each of the 28 pairs of actual and estimated sale prices. In each case we found no significant difference between the actual and estimated sale prices at the five per cent level.

When we test the distance from railway variable with subsamples, we find that this variable is significant at the five per cent level and has the expected sign in three of the four areas.[9]

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[9]It is a bit surprising to find that this variable is not significant in a relatively high income area. A closer look at this area suggests why the properties near the railway may not be adversely affected. In this area,

It is not easy to choose among the three forms (linear, quadratic and log) since each results in a fair number of significant variables and a fairly high multiple correlation coefficient. We shall employ the estimated coefficients of the quadratic form (b) in deriving the value of environmental improvement as a result of railway relocation for the following reasons:
(i) the distance from railway variable is allowed more freedom to show its true relationship with the dependent variable under a quadratic form than under either a linear or a log form. Hence if the railway variable turns out to be significant under the "freer" form there is no reason to assume its relationship with the independent variable is either linear or log.
(ii) Form (b) performs slightly better than both forms (a) and (c) in terms of the number of significant variables and explanatory power. The volume of rail traffic variable is not significant in any forms assumed.

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most of the tracks are buried in cuttings and are fenced off. This reduces the unpleasant noise and visual impact of the railway considerably. In the other areas, this is not the case.

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