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Urban Railway Relocation: An Economic Evaluation

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URBAN RAILWAY RELOCATION:
AN ECONOMIC EVALUATION

by

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ABSTRACT

The purpose of this study is to develop a framework for appraisal of urban railway relocation projects. A case study of railway relocation in London, Canada, is included. With regard to railway location and service, three policy alternatives are discussed: (1) Maintain the status quo; (2) Relocate part or all of the railways in various ways; and (3) Grade separation. Benefits and costs of these alternatives are identified and the estimation methods of each discussed. The main benefits of railway relocation are: (1) Savings in vehicle travel time and operating expenses; (2) Net benefit of generated travel; (3) Reduction in accident rates; (4) Land released for redevelopment; and (5) Improvement of areas abutting railway facilities. Benefits (1) - (3) may be realized to a different degree, by grade separation. The main costs of railway relocation are: (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. Costs (1), (2), and (5) are also incurred, to a different degree, with grade separation. Three alternative relocation schemes and a grade separation scheme in London are evaluated. The main conclusion reached is that with a discount rate of ten per cent per annum, none of the schemes appears justified economically. The study also briefly examines distributional effects of railway relocation projects. The problem of financing urban railway relocation projects is discussed as well.

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CHAPTER I

INTRODUCTION

Many urban areas[1] are debating whether to relocate the railways which pass through their centres. The cost of each of these relocation projects runs into millions of dollars.[2] 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 relocation projects. A case study of railway relocation in London, Canada, is included.

[1]See the list in Table I.1 for railway relocation projects in Canada. In the 1950's and 1960's, almost 50 communities in the United States prepared detailed plans for relocation according to U.S. Department of Transportation (42). It should be noted that although cases of railway relocation or abandonment in urban areas are known to have existed as far back as the turn of the century, there was no systematic approach. It is only recently that railroad relocation emerged as a recognizable factor in urban development. See Rotoff (38).

[2]For example, Ottawa's railway relocation program, carried out largely between 1947 and 1967, cost about $42 million (Ministry of State for Urban Affairs, Ottawa, news release, 10-10-1972).

[3]The City of Lachine and the City of Sudbury have done very elementary studies of their relocation projects. False Creek in Vancouver and the City of Ottawa have also done studies, but we have not been able to obtain copies. The most comprehensive railway relocation studies are the Winnipeg Railway Study (33) and the Sault Ste. Marie CP Rail Relocation Study (36). At a late stage in writing this thesis, we also came across U.S. Department of Transportation (42), and Rotoff (38). A review of some of these studies is contained in Appendix A.

TABLE I.1

Railway Relocation Projects in Canada

Railway Relocation Projects Completed*

Hull, Que.	Saskatoon, Sask.
Lachine, Que.	St. John, N.B.
Longueil, Que.	Ottawa, Ont.

Railway Relocation Proposals Before the Canadian Transport Commission

Brantford, Ont.	Peterborough, Ont.
Calgary, Alta.	Preston-Galt, Ont.
Chicoutimi, Que.	Quebec, Que.
Drummondville, Que.	Red Deer, Alta.
Fredericton, N.B.	Regina, Sask.
Hamilton, Ont.	Renfrew, Ont.
Kitchener, Ont.	St. Thomas, Ont.
Lac Megantic, Que.	Sault Ste. Marie, Ont.
Lindsay, Ont.	Thunder Bay, Ont.
Medicine Hat, Alta.	Tillsonburg, Ont.
Moncton, N.B.	Wetaskiwin, Alta.
New Waterford, N.S.	White Rock, B.C.
Niagara Falls, Ont.	Windsor, Ont.
North Bay, Ont.	Winnipeg, Man.
Pembroke, Ont.	Yorkton, Sask.

Source: Ministry of State for Urban Affairs, Ottawa, news release, 10-10-1972.

*Other completed railway relocation projects include: Winnipeg-Midland, Winnipeg-Harte Subdivision, Winnipeg-Fort Rouge, and Victoriaville, Quebec. See Rotoff (40).

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:[4]

(a) consolidate through services onto a smaller number of rail lines within the urban area and maintain local service (CONSOLIDATION);

(b) relocate through services from the urban area to areas 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);

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

(4) discontinue all rail services (DISCONTINUATION).

In this study we evaluate alternatives (1) - (3) but not alternative (4). The analytical technique we use to evaluate the

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

alternative policies is cost-benefit analysis.[5] We compare the social benefits with the social costs for alternatives (1) - (3) above. We consider both efficiency of resource allocation and distributional effects.

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. Chapter V discusses the distributional effects of the alternatives. Chapter VI concludes the study with a brief discussion of government policies and financing of railway relocation projects.

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[5]For some general references on cost-benefit analysis, see Das Gupta and Pearce (8), Mishan (19), Prest and Turvey (24), Layard (32), and Wolfe (30).

CHAPTER II

SOCIAL BENEFITS AND COSTS OF URBAN RAILWAY RELOCATION

A. Introduction

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. These social benefits and costs can be quite different from the private benefits and costs of railway relocation to individual groups. The private benefits and costs for some groups are discussed in Chapter V.

B. Benefits and Costs of Railway Relocation

In order to isolate the benefits and costs of railway relocation, it is useful to consider such projects separately, rather than in conjunction with other transportation or urban development projects, and to look at polar cases. The two polar cases are (a) maintaining the status quo -- alternative (1) 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.

B.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,[1] namely:

1. Savings in road travel time and vehicle operating expenses;
2. Net benefit of generated travel;
3. Reduction in accident rates;
4. Land released for redevelopment; and
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 eliminates 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

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[1] 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.

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.[2] 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 generated 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 congestion on some streets, the net benefit of generated travel should be calculated net of the additional congestion costs.[2a]

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

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

[2a] If there is no optimal pricing (i.e., equating price to marginal social cost) with urban travel, the net benefit of generated travel may be negative.

will reduce accident rates.[3] 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 "visual" pollution. Hence, removal of the railways may improve adjacent areas.[4] 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

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

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

of large areas, the net benefits 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.[5]

Apart from benefits (1) - (5),[6] 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.[7] Consequently, they are discussed in Chapter V.

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

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[5]For a discussion of the causes of slums and the benefits of slum clearance, see J. Rothenberg (170), especially ch. III.

[6]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.

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

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.

B.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 (2) acquiring properties for new railway facilities; (b) construction of new railway facilities, e.g., tracks, yards, signals, grade separations; (c) removing old tracks and installations; and (d) engineering. To obtain net capital costs, the salvage value of existing facilities should be deducted.[8]

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

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 results 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 may 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 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.

C. 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.

C.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 crossings, 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 eliminates this source of air pollution, and so benefits the surrounding area.

C.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 costs 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.

D. <u>Concluding Remarks</u>

We have identified the benefits and costs of urban railway relocation based on a greatly simplified relocation model, namely: maintaining the status quo versus complete removal of railways from the urban area. However, we believe that with suitable adaptation the simplified framework provided here can be used in evaluating any specific relocation proposal.

It is important to emphasize that the benefits and costs identified are social benefits and costs, which could be quite different from the individual benefits and costs to various groups such as the railway companies, landlords and tenants, industries and local government. Consequently, we do not include certain benefits and costs which are found in other railway relocation studies. For example, apart from benefits (1) to (5), the number of houses built and destroyed is sometimes considered as a benefit or cost of railway relocation. It seems to us that the benefit of the new houses should be considered separately, and if it must be considered together with railway relocation, it should be calculated net of construction costs and land value. As far as the houses destroyed are concerned, they are part of the capital costs of railway relocation and no separate treatment is called

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 old railway site less adverse effects at new railway site.

for. Chapter V discusses the private benefits and costs of various groups in more detail.

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.

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.

This discussion of the benefits and costs of railway relocation follows the same order as in Chapter II.

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[1] 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 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 discountinued;[2] and

(c) changes in departure times, routes, and origins and destinations by vehicles which have previously chosen alternative

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

[2]At this point we are not considering increased trucking costs of industries as a result of discontinuation of local rail service. These costs are considered later in this chapter.

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. Table III.1 summarizes the changes that would result from various alternatives. It may be noted that even though (a.i), (b.i), and (c) occur under all alternative policies, their magnitudes will vary among the policies.

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. Change (b.i) will be discussed separately in section B.1.2 below.

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

TABLE III.1

Changes in Vehicle Travel Time and Operating Expenses
Under Different Policy Alternatives

Policy Alternatives \ Changes	Delays at Level Crossings		Road Congestion		Changes in departure times, routes, origins, and destinations
	Elimination of Crossing	Change in rail traffic	Change in no. of vehicle trips	Change in truck traffic	
	(a.i)	(a.ii)	(b.i)	(b.ii)	(c)
2a. Consolidation	x	x	x		x
2b. Partial Relocation	x	x	x		x
2c. Complete Relocation	x		x	x	x
3. Grade Separation	x		x		x

x: change likely to occur.

(a) Changes in delays imposed at level crossings

First let us consider changes in delays imposed on motor vehicles at road-rail level crossings, assuming that the arrival of vehicles at the crossings is not influenced by railway relocation. To simplify the diagrams, we assume that vehicle miles of travel in the urban area are homogeneous and that they are uniformly affected by delays imposed by railways.

Let d^i (Figure III.1) and d^j (Figure III.2) be the hourly demand curves for vehicle miles of travel in the urban area during non-rush hours and rush hours respectively. MSC_0 and ASC_0 are the short-run marginal and average variable social cost curves before railway relocation.[3] ASC_0 slopes upward and MSC_0 lies above ASC_0 for levels of vehicle travel at which there is road congestion.

The equilibrium traffic flows will be q_0^i and q_0^j during non-rush hours and rush hours respectively.[4] If there is a uniform gasoline tax,[5] the marginal and average variable social cost curves are shifted by the amount of the tax. The latter is shown as $\overline{ASC}_0$ in Figure III.1 and III.2. With the gasoline tax the equilibrium traffic flows will be $\bar{q}_0^i$ (where $\bar{q}_0^i < q_0^i$) and $\bar{q}_0^j$ (where $\bar{q}_0^j < q_0^j$) during non-rush hours and rush hours respectively.

Assume that railway relocation reduces travel time and vehicle

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[3] Cost should be interpreted as "expected cost" since some but not all trips will be delayed at level crossings.

[4] Assumes no congestion tolls, but with tolls to cover marginal road maintenance and pollution costs, which are assumed constant.

[5] In excess of marginal road maintenance and pollution costs imposed by vehicles.

Figure III.1

Hourly Demand for Vehicle Miles of Travel During

Non-Rush Hours with Uniform Gasoline Tax

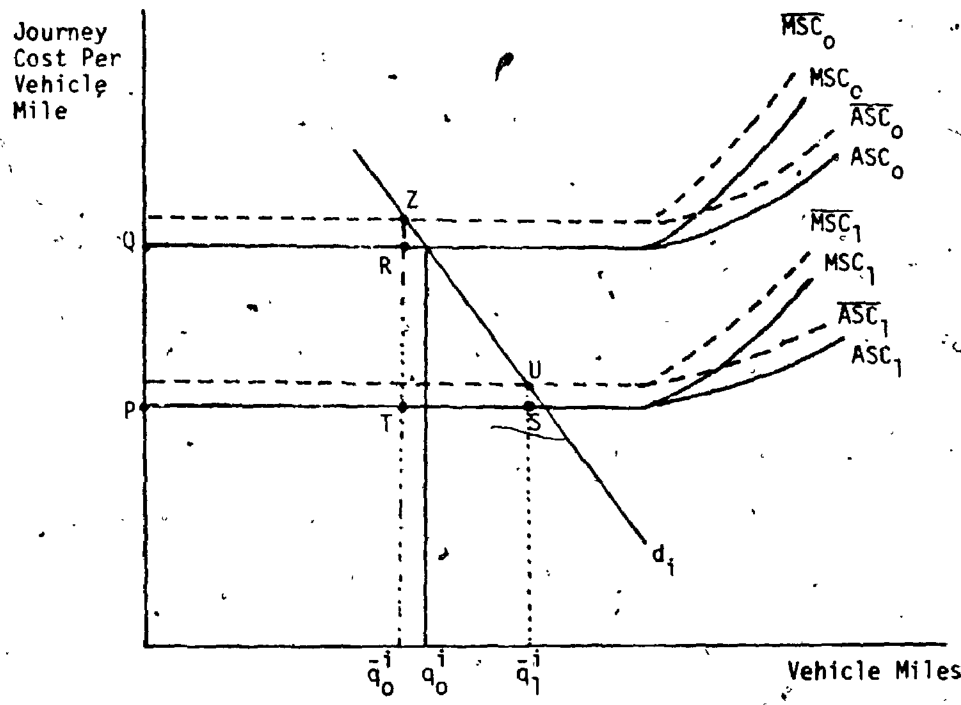
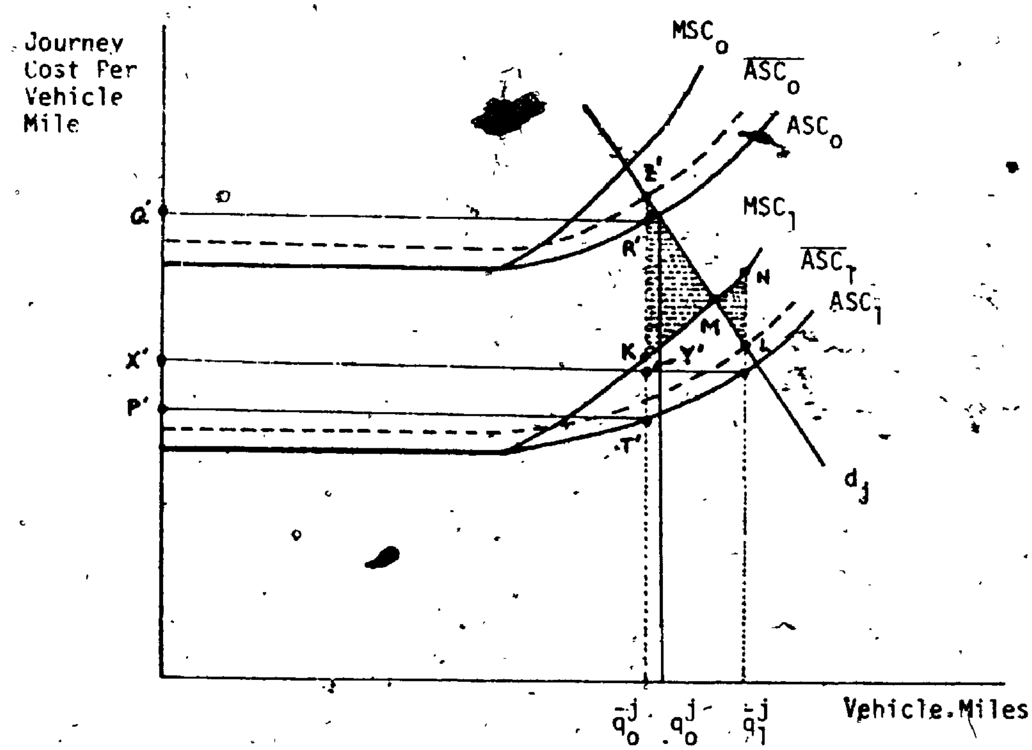


Figure III.2

Hourly Demand for Vehicle Miles of Travel During Rush Hours with Uniform Gasoline Tax*



*Note: $\overline{MSC}_0$ and $\overline{MSC}_1$ are omitted.

operating expenses. This shifts the marginal and average variable social cost curves down to MSC_1 and ASC_1 respectively in Figures III.1 and III.2. Assuming that the uniform gasoline tax remains in effect after relocation gives $\overline{ASC}_1$ as the average variable social cost curve after relocation. The equilibrium traffic volumes after relocation will be $\bar{q}_1^i$ (where $\bar{q}_1^i > \bar{q}_0^i$) and $\bar{q}_1^j$ (where $\bar{q}_1^j > \bar{q}_0^j$) during non-rush hours and rush hours respectively.

In Figure III.1 we have assumed that no congestion results from the generated traffic $(\bar{q}_1^i - \bar{q}_0^i)$. The hourly cost saving, during non-rush hours, on trips that would be taken even without railway relocation is indicated by the area PQRT. During rush hours, with a demand elasticity of less than zero as assumed by d_j, the generated traffic $(\bar{q}_1^j - \bar{q}_0^j)$ increases the congestion costs imposed on all vehicles. This reduces the hourly cost saving on the trips that would be taken even without railway relocation to an amount indicated by the area X'Q'R'Y' in Figure III.2. Assuming the own price elasticity of demand was zero would raise the rush hour savings to an amount indicated by the area P'Q'R'T'.

To take into account the increased congestion costs during rush hours (i.e., to measure X'Q'R'Y') would require information on the own-price elasticity of demand and on the elasticity of the average variable social cost curve. Data on these elasticities are not available. Hence, we will measure PQRT and P'Q'R'T'. It should be noted that this will overestimate these benefits if the demand is not perfectly inelastic.[6] The methodology for estimating these benefits

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[6] However, this overestimate would be partially offset by the fact that we do not measure the benefit of generated traffic, which we discuss in section B.2 below.

is outlined below.

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

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

$$C - 1/2F$$

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

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

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

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

hours.

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

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

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

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

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

Thus, we arrive at the following formula for the vehicle hours lost during deceleration and while at rest for vehicles which are forced to come to a stop:[7]

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

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

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

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

We must also develop a formula for the amount of time vehicles lose while they accelerate back to their normal speed. Suppose that it takes a vehicle T hours to accelerate from rest to its normal speed of S miles per hour. Assuming a constant rate of acceleration, during a period of T hours the vehicle will travel at an average speed of S/2 instead of S and hence lose a distance of TS/2, compared to the distance it would have travelled at its normal speed. It will take the vehicle a period of T/2 hours at its normal speed to make up this lost distance, and hence the vehicle loses T/2 hours of time. Since each vehicle that

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[7]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.

comes to a stop loses T/2 hours, the total time lost by the $FC/(1 - AF)$ vehicles which are stopped in one lane in one direction by a train is:

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

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

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

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

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

Then the total vehicle hours saved during day d by eliminating the deceleration and stopping processes will be:[8]

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

where $Q_{jitkd} = G_{jitkd} C_{tkd}/(1 - AG_{jitkd})$. This formula can be simplified to:[9]

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[8] 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.

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

(this footnote continued on next page)

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

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.

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

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

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

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

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

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

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

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,[10] 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:

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

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

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[10] This is shown in the empirical results of Chapter IV.

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

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

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

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. In terms of Figure III.3, an increase in truck traffic shifts $\overline{MSC}_1$ and $\overline{ASC}_1$ to the left. Assuming the volume of other traffic does not change, the increase in hourly congestion costs during the rush hours is shown by the shaded area. During non-rush hours, increased truck traffic may not increase congestion costs.

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

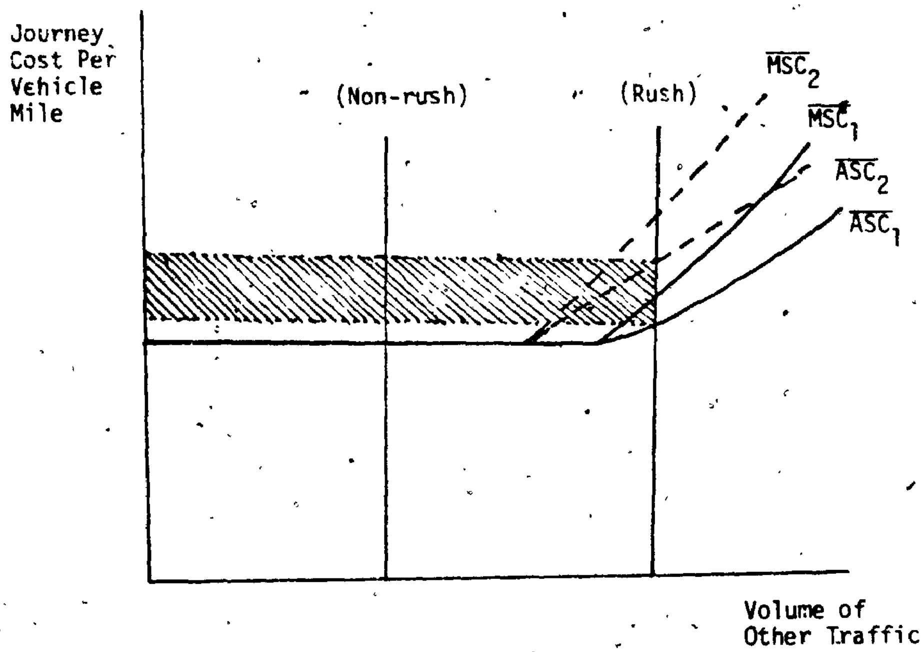
$$G_{4d} = \sum_{r=1}^{R_d} a_{rd}$$

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

$$H_4 = \sum_{d=1}^{365} H_{4d}$$

Figure III.3

Effect of Increased Truck Traffic on Urban Roads During Rush and Non-Rush Hours



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 convert vehicle-hours into man-hours.

$$J = \sum_{i=1}^{n} q_i r_i (H_1 + H_2 + H_3 + H_4 + H_5 + H_6)$$

where J = number of man-hours saved during one year;

r_i = fraction of vehicles belonging to type i;

q_i = average number of people per vehicle of type i; and

n = number of types.

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. Some of the theoretical and empirical results are discussed in Appendix B. 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.[11]

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[11]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

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

$$K = \sum_i d_i w_i X_i$$

(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.[12] For the purposes of this study, we

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in-transit time is not important to us since we are mainly concerned with in-transit time.

[12] See, for example, the following articles: Feldstein (10), Sen (27), Marglin (17), Harberger (12), Arrow (2) and Baumol (3).

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.[13] 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;

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

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[13] For example, Beesley and Foster (4) 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 (28) of the Channel tunnel, project life was assumed to be 50 years. In the study of port investment, Ross (189) suggested 50 years to be the time horizon. The U.S. Department of Transportation Guidebook (42) suggested 25 years for railway relocation projects.

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. The total hourly addition to aggregate net benefits as a result of the generated traffic is ZUST (Figure III.1) during non-rush hours and KZ'M - MNL (Figure III.2) during rush hours. These are the excesses of marginal social benefits over marginal social costs, and they can be added to benefits in category (1) above. The amount of net benefit should be aggregated over the day and the year. Net benefit over longer periods than a year should be discounted as discussed in section B.1.1 above.

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 accidents 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,[14] the more accidents will occur, other things being equal. The type of protective devices range from no protection

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[14] Perhaps speed tends to affect the severity of an accident rather than the number of accidents.

at all to grade separated crossing.[15] We expect more accidents to occur at crossings which have no protection or have "passive" protection only, other things being equal. 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.[16]

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.[17] According to Mishan, the basic rationale of the

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

[16] Several empirical studies have been done in the U.S.A. with respect to railway-highway accidents, e.g., van Belle (68), Huntington et al. in U.S. Department of Transportation (80), and National Cooperative Highway Research Program Report (76).

[17] For a critique of some of the methods, see Mishan (75).

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."[18] The introduction of a specific investment project will make some community member 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.

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[18] Ibid. (fn 32), p. 225.

Most empirical studies[19] have followed a different approach. The essence of this conventional approach is to measure the <u>ex post</u> costs associated with accidents. For example, the following cost items are often included:[20] (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, 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 straight forward 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.[21] If this person died in an accident in the current or Tth year, the loss to the economy would be

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[19]Except Jones-Lee's study (73) which attempted the willingness to pay approach.

[20]For more detailed discussion of these cost elements, see Winfrey (183) and Abramson (67).

[21]For examples, see Ridker (190), Winfrey (183), Dawson (72), Joksh (15).

$$A = \sum_{t=T}^{\infty} E_t P_T^t (1+r)^{-(t-T)}$$

E_t is the expected gross labour earnings or marginal product of the person during the t^{th} year. P_T^t is the probability in the current year of the person being alive during the t^{th} year, and r is the annual social rate of discount.

For a permanent but partial disablement the loss to the economy would be:

$$A_1 = b \sum_{t=T}^{\infty} E_t P_T^t (1+r)^{-(t-T)}$$

where $b < 1$ measures the extent of the disability.

For a total but temporary disablement lasting N - T years, the loss to the economy is

$$A_2 = \sum_{t=T}^{N} E_t P_T^t (1+r)^{-(t-T)}$$

The goal of economic policy implicit in the gross product approach is maximization of gross national product. If this goal is not accepted, the measure is not appropriate.[22]

There is no reason to expect that the *ex post* costs estimated

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[22]An alternative approach to calculating the economic value of a person's life is the "net product" approach. If a person died in an accident the economic net loss to society is the following:

$$A_3 = \sum_{t=T}^{\infty} (E_t - C_t) P_T^t (1+r)^{-(t-T)}$$

where C_t is the expected consumption of the person during the t^{th} year. According to this approach the death of old people or children may confer net benefits on society.

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.[23]

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[24] is made available for other uses. We must determine the social benefit from

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[23]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.

[24]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.

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.[25] 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;

(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.4, 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.[26] The equilibrium price of land is P_o. Now suppose that

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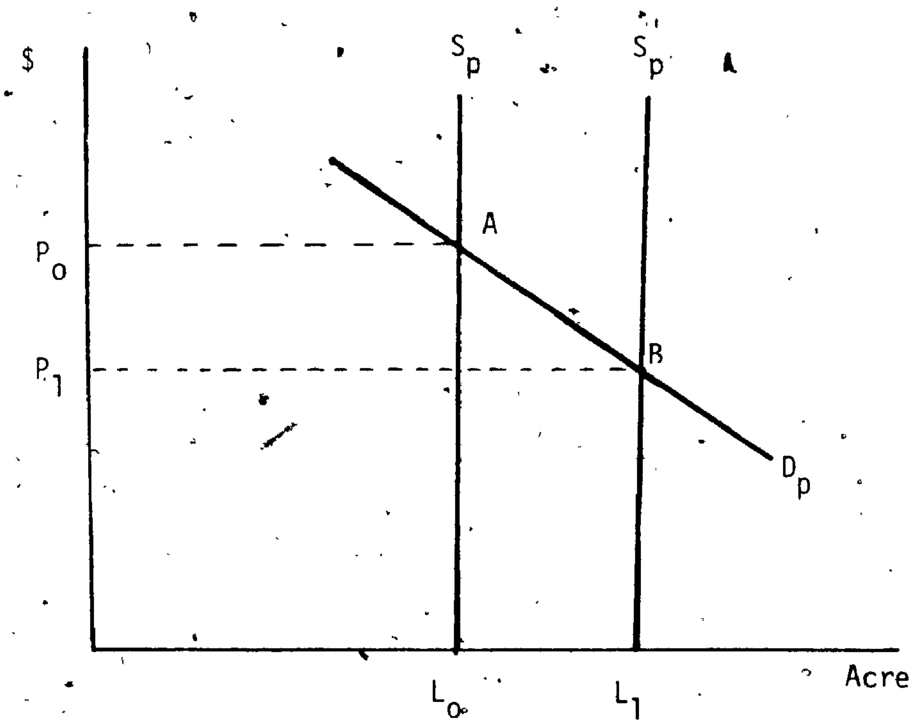
[25] For example, this is the approach used by LUTS (34). The Winnipeg Railway study (33) follows a more sophisticated approach, allowing for different types of land and differences in the time when the land is expected to be released.

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

Figure III.4

Change in Supply of Urban Land

Following Railway Relocation



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_0, which is equal to

$$(L_1 - L_0)(P_0 + P_1)/2$$

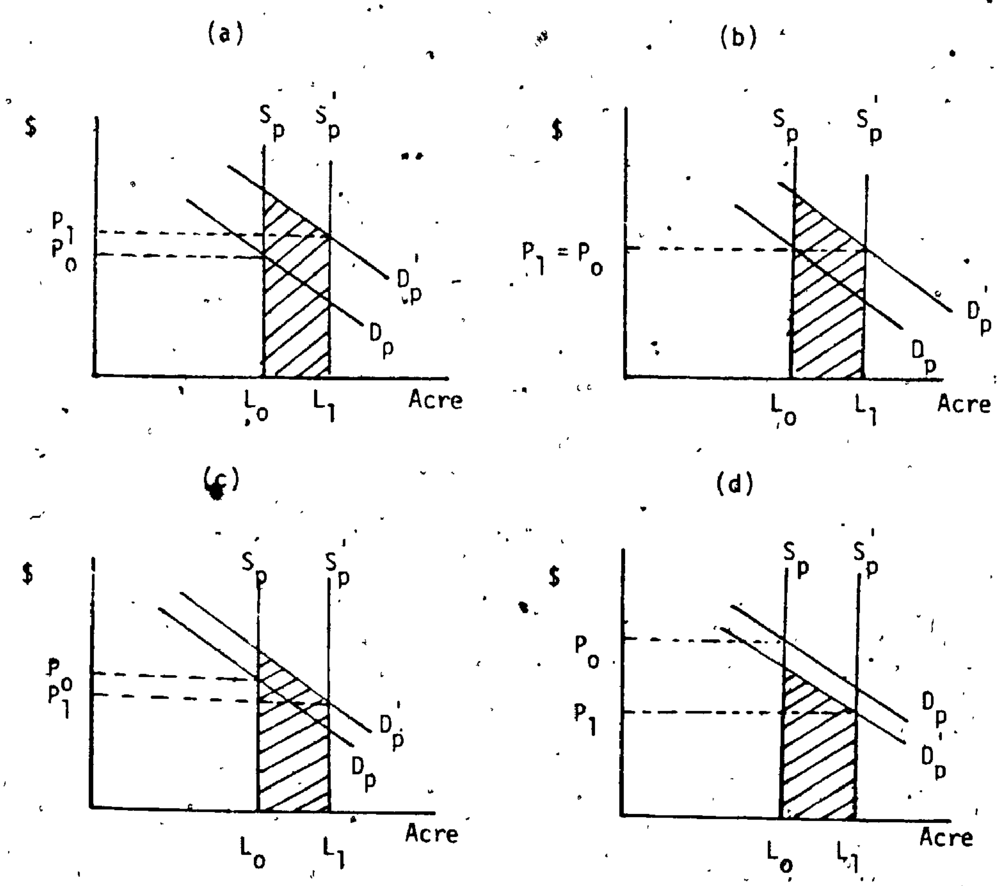
Thus the pre-relocation equilibrium price (P_0) overstates and the post-relocation equilibrium price (P_1) understates the benefit from the release of land.

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 inter-urban 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 the three groups of users will shift as a result of railway relocation. In Figures III.5(a-d), various possibilities are depicted. The shaded area in each diagram indicates the social benefit of the land released. In Figures III.5(a) and III.5(b), both P_0 and P_1 understate the benefit. In Figure III.5(c), P_1 understates and P_0 may overstate the benefit. In Figure III.5(d), P_0 overstates and P_1 understates the benefit. Thus, true social benefit would be underestimated by P_1 and may be either

Figure III.5

Change in Demand for Urban Land

Following Railway Relocation



overestimated or underestimated by P_o. 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.

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. In almost every North American city, zoning regulations prevail and may influence land prices and uses.[27] With zoning regulations, the value of the marginal product and price of land may not be the same in all uses, especially in the short run. The value of the released land will depend on the category into which it is zoned.

If released land is zoned for or allocated to public use, the valuation problem becomes even more difficult. There is no observable price for public land. The conventional approach is to value land allocated for public use by its opportunity cost in the private market. One implicit assumption underlying this approach is that the government uses land to the point at which the marginal social benefit

[27] For studies on zoning and land values, see Yeates (122), Crecine, Davis, Jackson (86), and Reuter (116).

of public land equals the price of land in the private market. This assumption is highly questionable, and the opportunity cost approach may either under or overstate the value of the land in public use.

If the released land were used to build highways, parks, or public housing, the benefit of the released land will be one of the following: (i) If the highway, park, or public housing project would not be built without the released land, the benefit becomes the "net" benefit of the highway, park, or public housing project.[28] (ii) If the highway, park, or public housing project would otherwise be built in another location, the benefit would be the costs (e.g., land, demolition, assembly, transportation) saved by making use of the released land.

Another possible source of error in using market price as a measure of social value has been suggested by Solow.[29] He shows that if congestion tolls are not charged on crowded roads, land rents will reflect the private costs of transportation, not the full social costs, and market land values will then be faulty guides to land use.

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

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[28] Suppose the gross benefit of the project is B and there are only three inputs to the project, namely: labour, capital, and land. In this case the value of land is the residual benefit of the project after the deduction of capital and labour costs.

[29] Solow (174).

released by railway relocation, in practice one probably must rely on market prices prevailing prior to railway relocation.

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.

Another problem concerning the value of the released land is the possible difference between the private discount rate and the social discount rate. Nobody has determined what the social discount rate is. However, the consensus appears to be that the social discount rate should be equal to or less than the private discount rate. From this point of view, the market value of land released may underestimate its social value.

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.

There has been no study which systematically measures railway noise, air, and "visual" pollution. However, there are several studies concerned with the noise impact of railways.[30] Figure III.6 illustrates the noise levels created by a passing train at various distances from the track. According to Figure III.6, a passing train may give rise to a noise level of 80 dBA at points one train-length from the track.[31] To give an idea of what an 80 dBA noise level means to the human ear, Table III.2 gives some examples of average noise levels from various sources.

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

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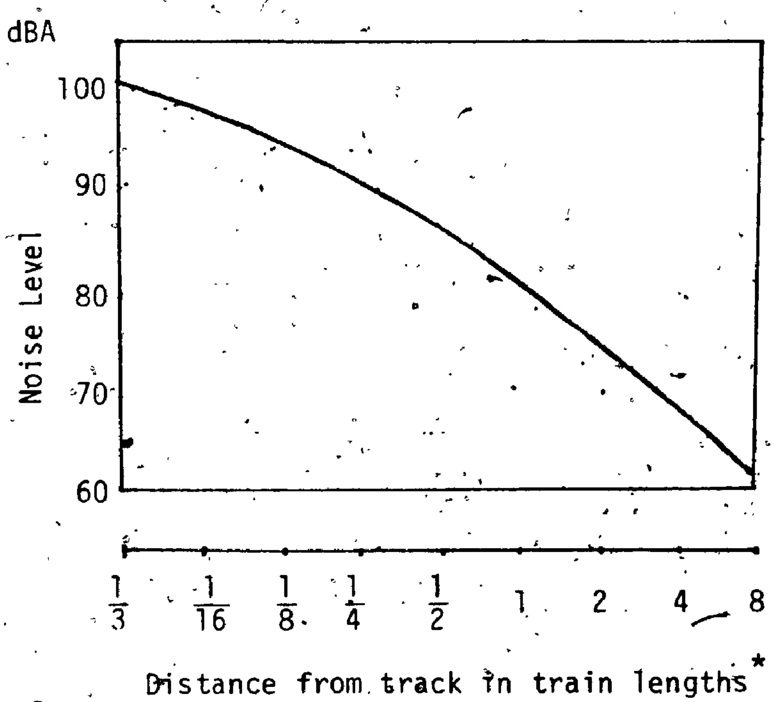
[30] See Peters (165) and the studies cited therein.

[31] Sound energy is generally measured in decibles (dB) a unit that corresponds to 10 times the common logarithm of the ratio of energy between two sounds. dBA is an A-scaled measure of sound pressure level. It has been demonstrated that the subjective reaction of humans to noise is reasonably closely correlated with readings on the A-scale (in dBA) of a sound level meter.

Figure III.6

Noise Level and Distance From Railway Track



Source: S. Peters (165).

*Train types tested include British Railway freight trains, diesel hauled intercity trains and short, relatively slow diesel multiple units.

TABLE III.2

Noise Level and Relative Loudness of Typical Noises in Outdoor Environments

(dBA)	Subjective Impression	Community	
130			32 times as loud
		Military jet aircraft takeoff with afterburner from aircraft carrier at 50 ft. (130 dBA).	
120	Uncomfortably loud		16 times as loud
		Turbofan aircraft at takeoff power under flight path at 200 ft. (118 dBA).	
110			8 times as loud
		Same jet flyover at 1,000 ft (103 dBA). Boing 707, DC-8 at 6,080 ft. before landing (106 dBA). Bell J-2A helicopter at 100 ft. (100 dBA).	
100	Very loud		4 times as loud
		Boing 737, DC-9 at 6,080 ft. before landing (97 dBA). Motorcycle at 25 ft. (90 dBA)	
90			2 times as loud
		Car wash at 20 ft. (9 dBA). Prop. plane flyover at 1,000 ft. (88 dBA). Diesel truck, 40 mph. at 50 ft. (84 dBA).	
80	Moderately loud		Reference loudness
		High urban ambient sound (80 dBA). Passenger car, 65 mph. at 25 ft. (77 dBA). Freeway at 50 ft. from pavement edge 10 a.m. (76 ± 6 dBA).	
60			1/4 as loud
		Air-conditioning condensing unit at 15 ft. (55 dBA). Large transformers at 100 ft. (50 to 60 dBA).	
50	Quiet		1/8 as loud
		Bird calls (44 dBA). Lower-limit urban daytime ambient noise (40 dBA).	
40			1/16 as loud
		Scale interrupted	
10	Just audible		
0	Threshold of hearing		

Source: Leo L. Beranek (127), p. 576, Table 18.5.

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. In Table III.3, we list a number of studies which have attempted to determine the effect of externality-generating projects on property values in their surrounding areas.

Some attempts have been made to use estimated changes over time or differences among locations in property values to measure spillover benefits or costs of public projects. For example, Ridker and Henning (115) estimated that if the sulfation level (a measure of air pollution) was to drop by .25 $mg/100\ cm^2/day$, the total increase in property values for St. Louis might be as much as $83 million.[32] They argue that "if

[32] This is likely to be an overestimate of the change in property

TABLE III.3

Externalities and Property Values

Study	Source of Externalities	Effect on Land and/or Property Values in the Surrounding Areas
Mohring (107)	highways	positive
Nourse (110)	public housing	none
Knetsch (104)	reservoir	positive
Nourse (111)	air pollution	negative
Kitchen and Hendon (105)	park	positive
Ridker and Henning (115)	air pollution	negative
Rothenberg (170)	urban renewal	positive
Anderson and Crocker (81)	air pollution	negative
Crowley (87)	airport	none

our model of the housing market is reasonably correct, households should be willing to pay at least this amount for the specified reduction in pollution." The same kind of reasoning appears in Rothenberg (170).

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 railway relocation will measure the willingness to pay for removal of the externalities by the <u>marginal</u> 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

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values since this measure assumes that demand will increase in the newly cleared areas to equal demand elsewhere without the balancing effect of demand reductions elsewhere. See Edel (92).

[33] This point is mentioned by Edel (92) and is the central issue in Freeman (97) and Lind (16).

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.7 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 (97). Freeman was concerned with property values and air pollution. His model can be used to illustrate the relationship between property values and railway externalities.

Assume that the market for residential properties is in equilibrium and that

$$V = V(Q, \ldots),$$

where V is the market value of a property, which is a function of distance from the railway (Q). Figure III.8a shows one possible form of this partial relationship. Q* is the distance from the railway at which the externality becomes zero.

Figure III.7

Demand for and Supply of

Railway Polluted Land

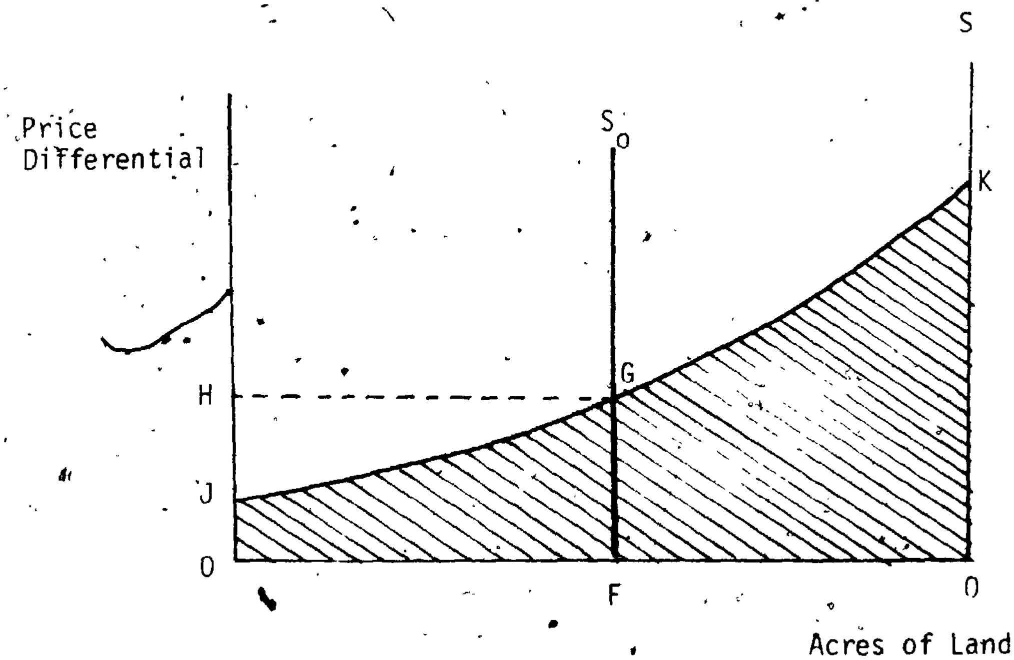

Figure III.8

The Relationship Between the Property Valuation Function and Willingness to Pay for Distance from Railway

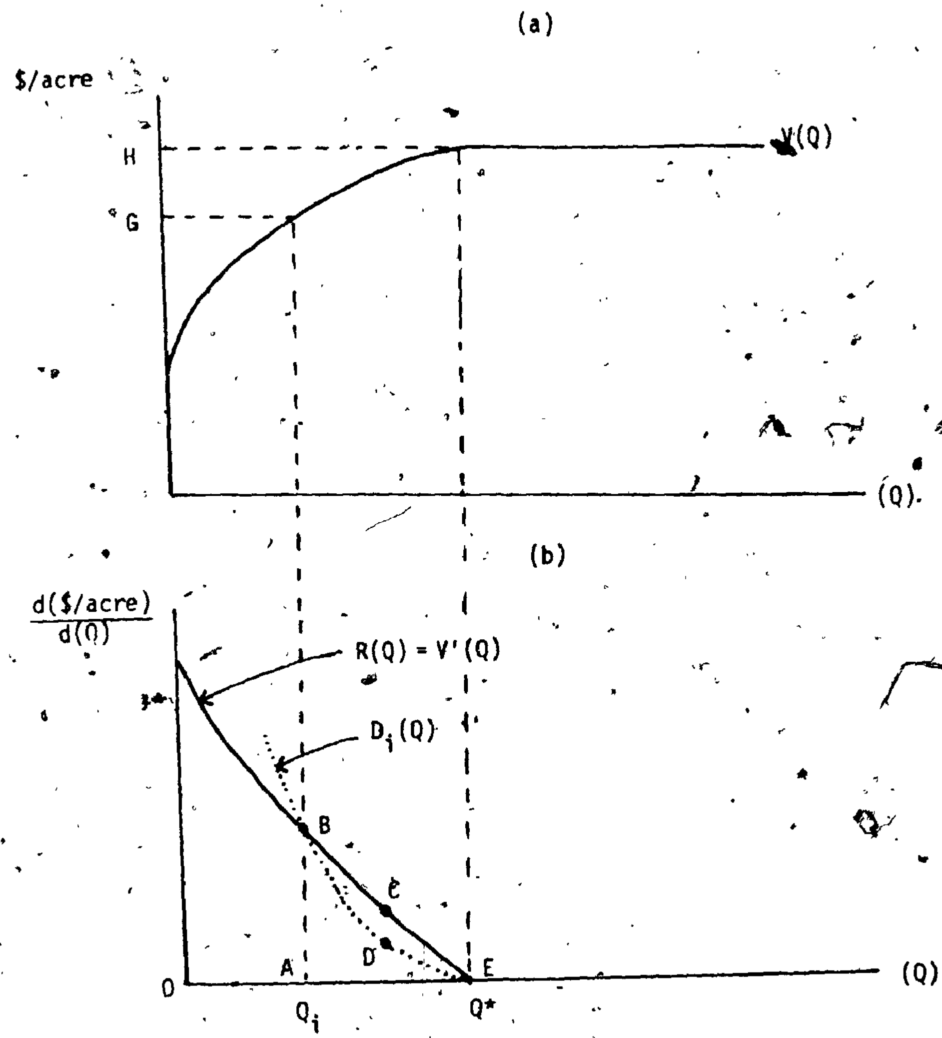

Figure III.8b shows the marginal purchase price function, $R(Q) \equiv V'(Q)$. $D_i(Q)$ is the demand curve for distance from the railway for an individual household i. The first order conditions for household utility maximum require that the household live at Q_i where:[34]

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

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.8, 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 would be ABCE $\equiv$ 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.

We have discussed the relationship between differences in

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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.

property values and spillover effects in a partial equilibrium framework.[36] A study by Lind using an optimal assignment land market model arrives at essentially the same kind of conclusion.[37] Furthermore, this study demonstrates under certain assumptions that "the benefits associated with a particular project can be measured in terms of the changes in the profits or surplus on those activities which locate on the parcels of land directly affected by the project."[38]

There are two complementary approaches that can be used to estimate the differences in property values. One is the "controlled areas" approach.[39] 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.

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[36] Another problem in connection with the use of property values is the danger of double counting. We have treated savings in vehicle travel time and improvement of areas abutting railway facilities separately. Depressed property prices near railway facilities may reflect both inaccessibility and environment externalities arising from railways.

[37] Lind (16).

[38] Ibid., p. 201.

[39] For examples, see Nourse (110, 111) and Crowley (87).

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. Table III.4 summarizes some of the studies which have used this method for residential properties.

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

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

where P is the price of a residential property and $X_1, \ldots, X_n$ are locational housing characteristics, environmental, and other variables which affect housing prices. We shall discuss the specification and estimation of this equation in detail in Appendix E. One of independent variables, say X_i, will be distance from the railway. Our main hypothesis will be that because of railway externalities:

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

The hypothesized relationship between price and distance from the railway, other things being equal, is illustrated by the surface ABEHIJLF in Figure III.9.

1.6 Reduction in air pollution at level crossings

A number of gases, vapors, and types of particles have been identified as air pollutants. It happens that vehicular transportation tends to generate some of the most important pollutants:[40] (1) carbon

[40]See National Cooperative Highway Research Program (163).

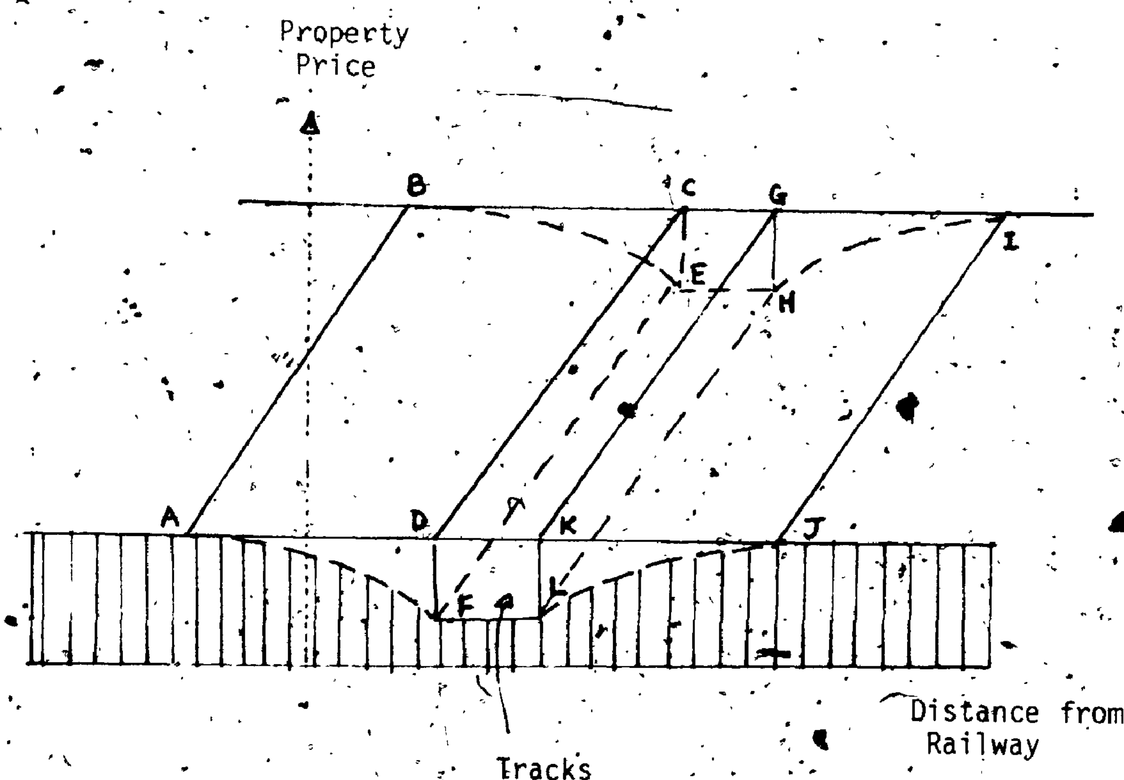
TABLE III.4

Determinants of Land or Property Value

Study	Dependent Variable	Significant Variables in "Best" Fit Equation		
		Locational	House-Related	Environmental
Brigham (85)	Land value per square feet	Distance to CBD, topography dummy	Not applicable	Neighbourhood quality index, building value
Ridker and Henning (115)	Mean property value	Travel time to CBD accessibility to main highways, state dummy	Number of rooms	Air pollution, % of recently built homes, housing density, school quality, SEG index, population density, % of non-white, average income
Kain and Quigley (103)	House price (log) or monthly rent	Non significant	Dwelling unit quality, age, no. of rooms, plot area, 1st floor area	Basic residential quality non-residential usage, median schooling of residents in area
Anderson and Crocker (81)	(log) mean house price	(log) distance to CBD	None	Sulphur pollution index, % of housing 20 years old, % non-white
Wabe (66)	Average house price	Rail travel time and cost to CBD	Age, central heating, floor area	Social class and population density in area, proximity to green belt
Emerson (94)	House price	Distance to school within 2 lots of freeway	Sq. ft. in house, sq. ft. in lot, garage space, baths, ranges, fireplaces, age	Open green space, non-white population, dilapidation, freedom from aircraft nuisance
Grether and Mieszkowski (101)	House price	None	Sq. ft. of living space; value of appliances, stone or brick, size, garage, fireplace, family room, age, baths, lot size	Pupil/teacher, no. of neighbours within 500 ft.
Richardson, Vipond, and Furbey (114)	House price	Distance from CBD	House type, age, change in use	Zoning, industry, % population under 15, % of population over 65, open space amenities, car ownership

Figure III.9

Prices of Areas Abutting Railways



monoxide (CO); (2) hydrocarbons (HC); (3) oxides of nitrogen (NO_x); (4) smoke and particular matter; (5) lead; and (6) photochemical smog. It has been found that emissions per vehicle mile are increased by decreasing speeds and increasing the number of speed changes.

Consequently, the deceleration-acceleration cycle that is characteristic of the traffic at most level crossings adds pollution to the air. The removal of the level crossing eliminates this source of air pollution.

Where the level crossing is removed because of railway relocation the benefit of the reduction in air pollution is captured in the value of the improvement to areas abutting railway facilities. Where the level crossing is replaced by a grade separation the benefit of the reduction in air pollution must be measured directly.

Given sufficient data it is not difficult to measure the above reduction in air pollution. We may proceed as follows: (1) Estimate the number of vehicles (V_1^k) slowing down and accelerating at level crossing k per day. (2) Estimate added emissions of HC, CO, NO_x, etc. from decelerating and accelerating. (3) Multiply V_1^k by the estimated added emissions to get the daily reduction in air pollution at crossing k. (4) Carry out the same calculation for all relevant crossings and add the daily reductions to get annual reductions.

With respect to motor vehicle air pollution we should take into account the fact that future modifications in automobile design will probably reduce air pollution and hence future air pollution should be discounted from a technological point of view.[41]

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[41]For a suggested discount curve, see National Cooperative Highway

Valuation of the reduction in air pollution is no different from the valuation of reduction of railway externalities. What we need is some damage functions relating automobile emissions to human health, etc. A dollar value may then be assigned to the damages.[42] At present, such an approach cannot be followed due to the lack of knowledge in this area.

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.[43] However, it is up to the economist to make sure that all the correct opportunity costs are included and that nothing is left out or double counted.

2.1 Capital costs

The main items of capital costs are:[44]

Research Program (163), p. 41. For a detailed study of alternative strategies to combat future automobile pollution, see Dewees (138).

[42] For a concise discussion of the losses caused by automobile pollution, see Dewees, ibid., pp. 23-37.

[43] For detailed discussions of railroad construction costs, see American Railway Engineering Manual (124) and U.S. Department of Transportation (42).

[44] The exposition of the list of capital costs follow that of U.S. Department of Transportation (42).

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

(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 within 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, which can be measured conceptually in the following manner.

Let us assume that (a) railway traffic and hence the use of railroad facilities does not change as a result of relocation, (b) the average service life expectancy of all new railway facilities is m years, (c) the existing railroad facilities have an average remaining life expectancy of m/2 years, and (d) the planning period under consideration is N years. Then the present discounted value of replacement costs under the status quo will be:

$$C_{sq} = \frac{C^1_{sq}}{(1+r)^{m/2}} + \frac{C^2_{sq}}{(1+r)^{m+m/2}} + \ldots + \frac{C^k_{sq}}{(1+r)^{km+m/2}} - \frac{V_{sq}}{(1+r)^N}$$

The present discounted value of replacement costs with relocation is:

$$C_{rr} = \frac{C^1_{rr}}{(1+r)^m} + \frac{C^2_{rr}}{(1+r)^{2m}} + \ldots + \frac{C^g_{rr}}{(1+r)^{gm}} - \frac{V_{rr}}{(1+r)^N}$$

where C_{sq} = present value of replacement costs under status quo;

C_{rr} = present value of replacement costs with relocation;

C_{sq}^{i} = replacement costs occur at the beginning of period i under status quo where $i = 1,2,\ldots,k$;

C_{rr}^{j} = replacement costs occur at the beginning of period j with relocation where $j = 1,2,\ldots,g$;

r = discount rate per year;

V_{sq} = salvage value of railroad facilities under status quo at the end of the planning period;

V_{rr} = salvage value of railroad facilities with relocation at the end of the planning period.

It may be noted that $N = km + m/2 + s = gm + t$, where s and t are respectively the remaining life expectancy of railway facilities (which are replaced at years $km + m/2$ and gm from now) at the end of the planning period under the status quo and relocation alternatives. The savings in replacement costs will be

$$C = C_{sq} - C_{rr}$$

This amount should be deducted from the sum of capital costs (1) to (10).

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[45] have all combined to render refined railroad cost analysis extremely difficult if not impossible. According to one author, there are at least six approaches to the finding of railroad costs. They differ (a) in the basic statistics they include; (b) in the source from which the statistics are secured, and (c) in the methods used in arriving at final conclusions from the data employed.[46] We do not intend to discuss the different approaches. The list of operating costs to be presented below represents one such approach[47] which seems appropriate for our purpose.

We may distinguish three general categories of operating costs, 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

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[45]See Canadian Transport Commission (132).

[46]Poole (167).

[47]Followed by the U.S. Department of Transportation, op. cit.

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. It is essential to understand as to how these changes may affect the various costs discussed above.[48]

Table III.5 shows the degree of responsiveness of each cost category to various plant or operating changes which might result from a railroad relocation project. One change which is not explicit in Table III.5 but which should not be ignored is the potential reduction in railway operating and maintenance costs due to modernization, i.e., newer and more modern capital stock following railway relocation. It must be realized that the analysis of "causes" and "effects" presented in Table III.5 is more a conceptual exercise to identify the key elements affecting railroad cost changes than a practical guide as to

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[48] For more detailed discussion of the operating costs, see ibid., chapter IX, and Poole, op. cit.

TABLE III.5

Categories of Railway Operating Costs
and Selected Causes of Variation

Cause of Variation	Cost Categories Likely to be Affected
Change in route length	Through train crew wages Mileage portion of car rental and ownership costs, including cabooses Maintenance of way Smaller part of fuel expense Part of locomotive expense
Change in running time	Local and switch crew wages Time portion of car rental Most other cost categories are slightly affected, but can be ignored unless change is large
Change in gradient, rise and fall, curvature, speed restriction zones, etc., affecting work done by locomotives	Greater part of fuel expense Greater part of locomotive expense
Change in "fixed" plant	"Fixed" plant maintenance and operating costs

Source: U.S. Department of Transportation (42), Table 3.

how these changes may be estimated. In our case study of railway relocation in London, we shall examine how some of these costs have been estimated.

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.[49] The change in transportation costs for passengers over the time 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

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

to trucking (or other modes altogether).[50] 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.

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,[51] 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

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

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[50] 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.

[51] 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.

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

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

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;

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 railways: (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:[1]

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).

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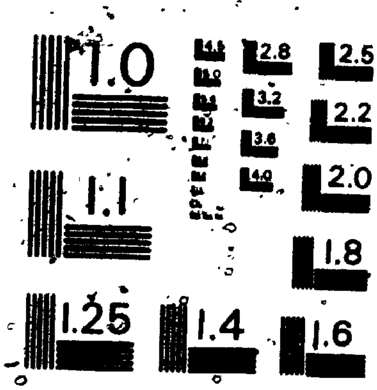
[1]The information concerning the existing railway network is based on DeLeuw Cather (34).

2 OF/DE 3



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS - 1963 - A

ARC - 374

These lines are illustrated in Figure IV.1. The first line has a double track and runs east and west. The CNR main freight yard terminal is located approximately two miles to the east of the city's central business district (CBD). The passenger terminal together with a train operational building are on the edge of the CBD.

The second line, which has a single track, enters the city in the north-east, joining the first line to the west of the main yard.

The third line, which is also a single track line, joins the first line near the CBD.

The fourth line, which runs from east to west, is approximately 3/4 of a mile north of the first line. The yard terminal is also located within a built up area of the city.

In addition to the main lines, CNR operates 100 and CPR operates 36 private sidings and public team tracks within the city.

Table IV.1 shows some railway facilities owned by the two railway companies in the City of London.

Data on typical daily rail traffic are presented in Table IV.2.

The locations of the industries with rail service in London are shown in Figure IV.2. These industries generate about 60 revenue cars per day or approximately 2 per cent of the total train traffic passing through the area.[2]

In the recent London Urban Transportation Study (LUTS) by DeLeuw Cather (34), some consideration was given to railway relocation schemes.

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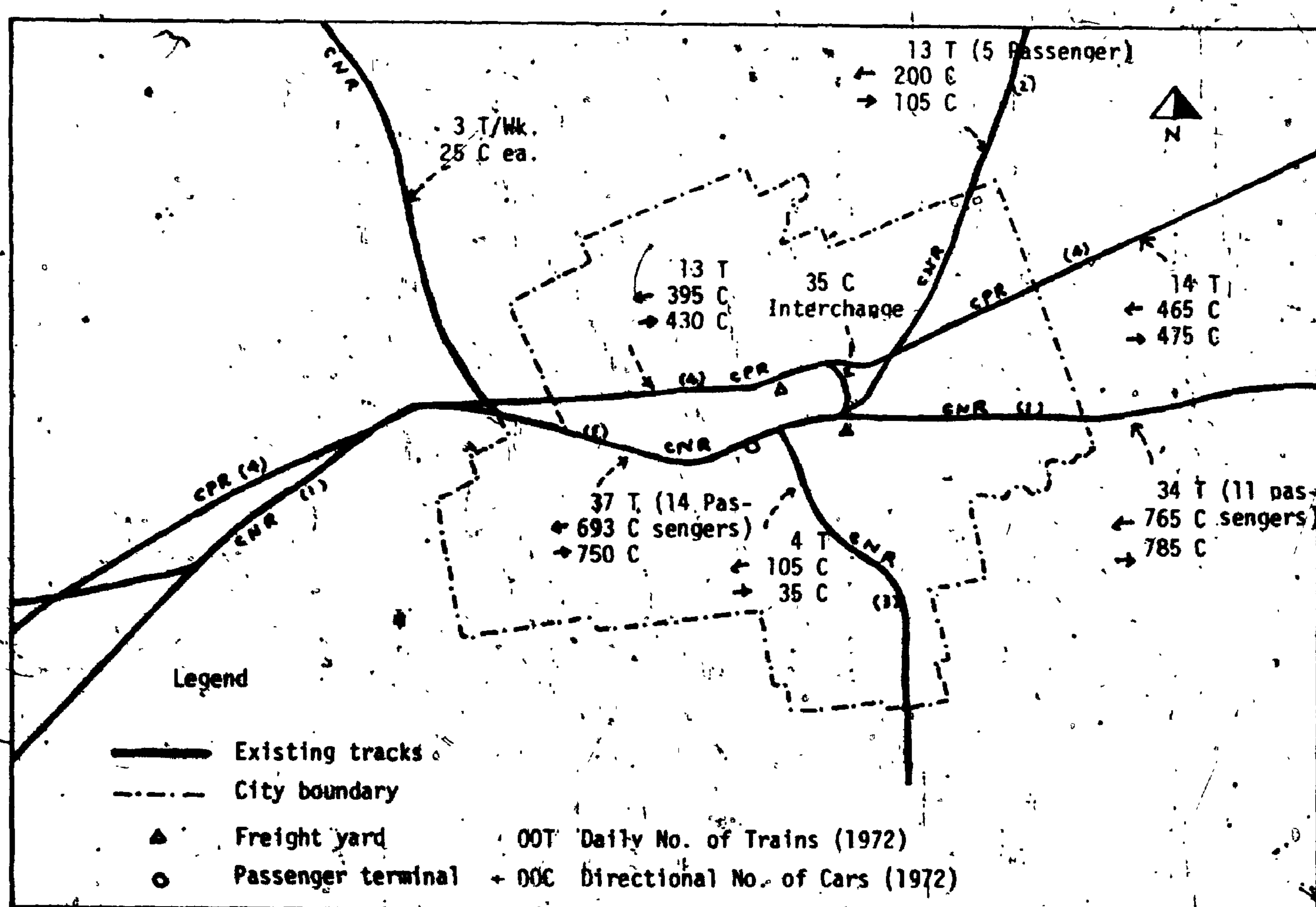
[2]DeLeuw Cather, ibid., p. 145.

Figure IV.1

Existing Track Layout and Typical Daily Rail Traffic



Source: DeLeuw Cather (34).

TABLE IV.1

Railway Facilities in the City of London

	CNR	CPR
Main track route, miles	20.0	8.8
Yard and siding tracks, miles	50.0	20.0
Shed or storage space, sq. ft.	14,150	10,200
Office space, sq. ft.	81,800	13,700
Freight shed space, sq. ft.	28,200	22,200
Shop space, sq. ft.	21,100	14,300

Source: DeLeuw Cather (34).

TABLE IV.2

Typical Daily Railway Traffic

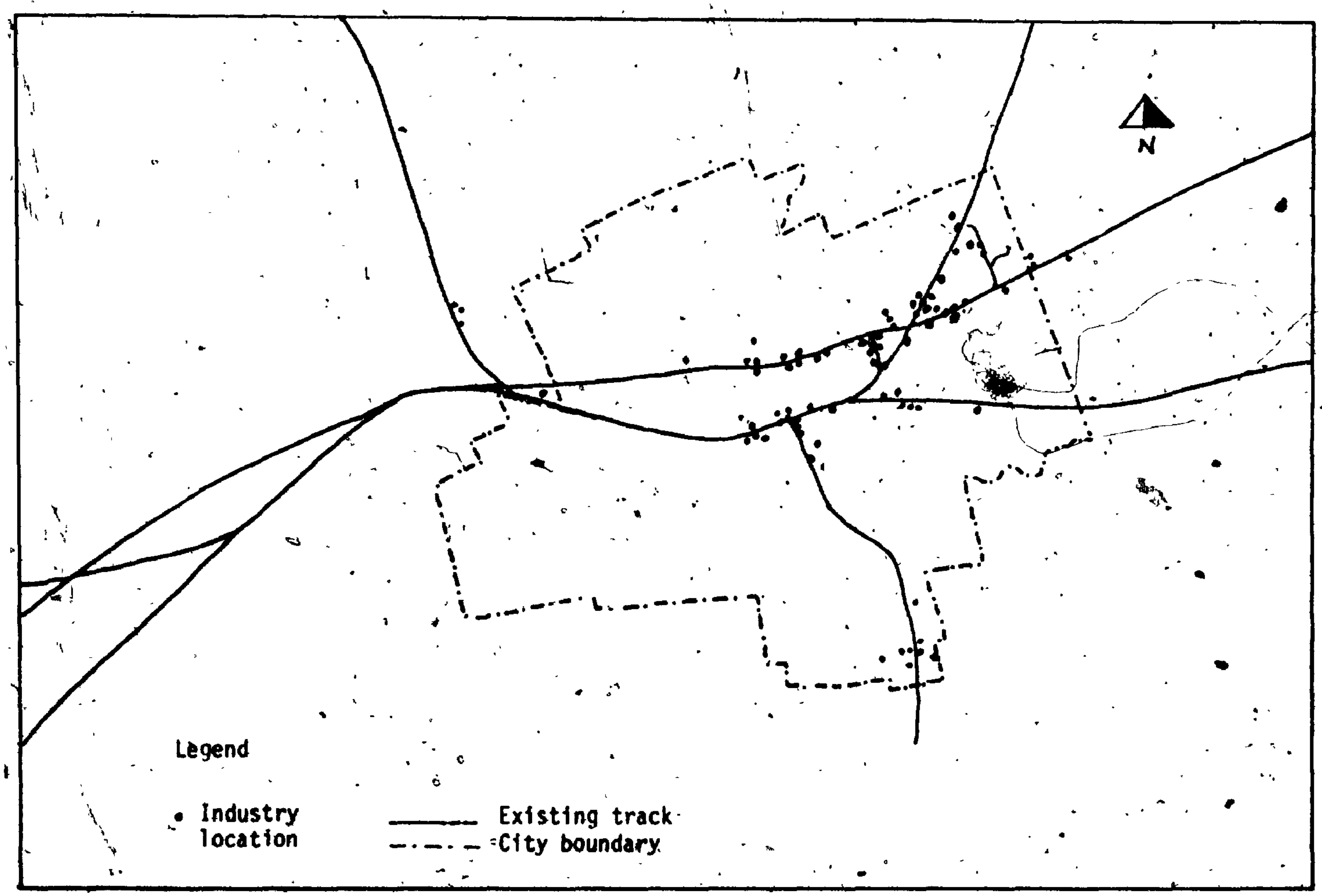
Subdivisions	Railway Company	Passenger Trains	Average No. of Cars per Passenger Train[a]	Freight Trains	Average No. of Cars per Freight Train[b]
(1) Galt	CPR	0	-	14	67.0 (2.6)
(2) Windsor	CPR	0	-	13	63.5 (2.5)
(3) Dundas	CNR	11	8	23	67.3 (2.3)
(4) Strathroy	CNR	14	8	23	63.0 (2.6)
(5) Thorndale	CNR	5	8	8	38.0 (1.6)
(6) Talbot	CNR	0	-	4	36.0 (2.5)
(7) Interchange	CNR,CPR	-	35 cars daily	-	
(8) Exeter[c]	CNR	0	-	3/wk.	25.0 (1.5)

Source: DeLeuw Cather (34), Working Papers.

[a]Based on Statistics Canada (175), Table 9.
[b]Figures in brackets are average number of engines.
[c]Located outside the city boundary of London.

Figure IV.2

Industries with Rail Sidings



Source: DeLeuw Cather (34).

After preliminary investigation,[3] two schemes were recommended for further study, the CNR scheme (Figure IV.3) and the Southern scheme (Figure IV.4). These two schemes resemble alternatives (2.a) CONSOLIDATION, and (2.b) PARTIAL RELOCATION, respectively in Chapter I. The main thrust of theCNR 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.5), 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. 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.

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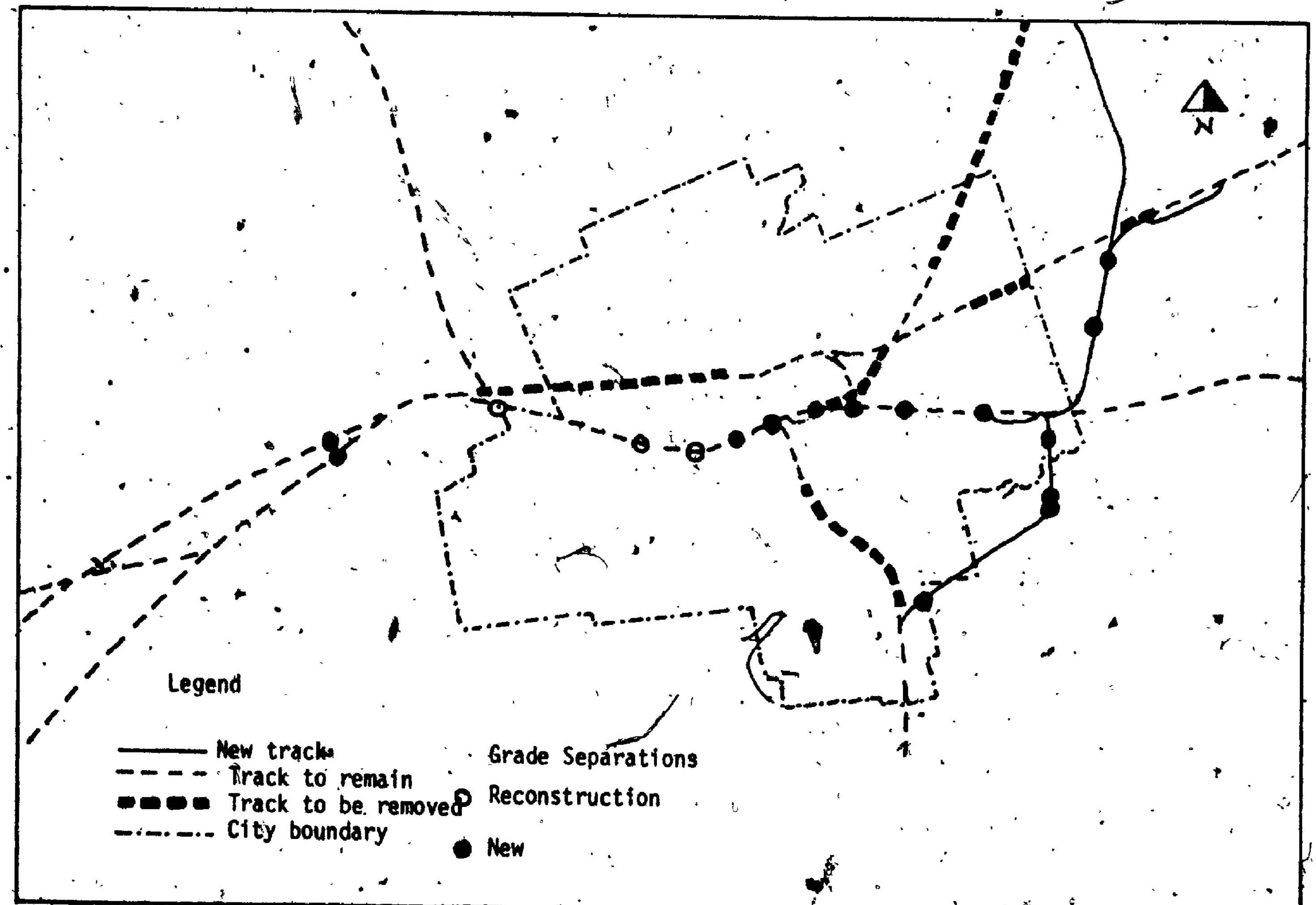
[3]The consultants who prepared the LUTS report suggested 16 schemes and the Railway Committee of the city government decided to retain two schemes for future study. It appears that the major criteria used in their choice were compatibility of land use and maintenance of railway service to local industries.

Figure IV.3

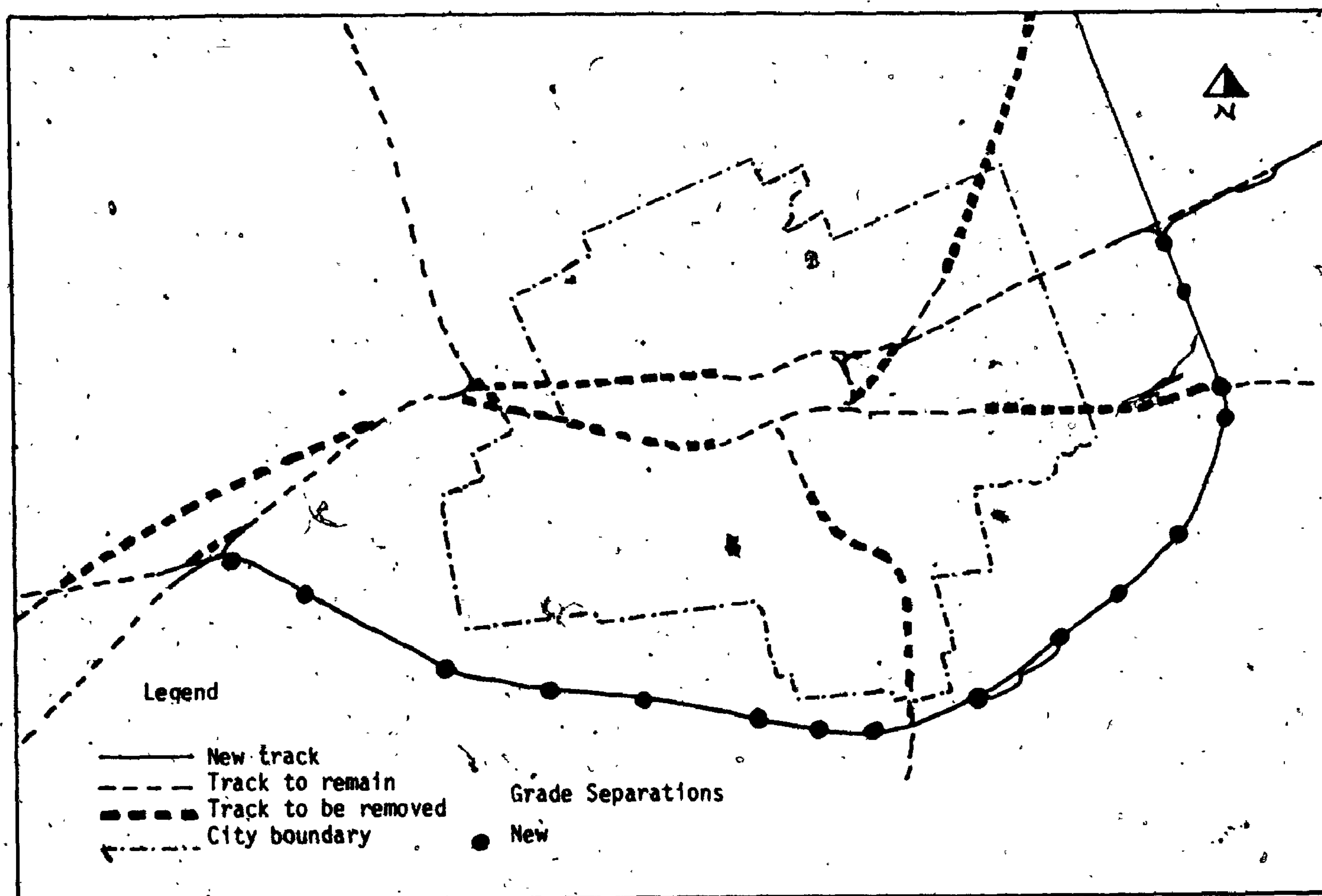
Railway Relocation: The CNR Scheme



Source: DeLeuw Cather (34).

Figure IV.4

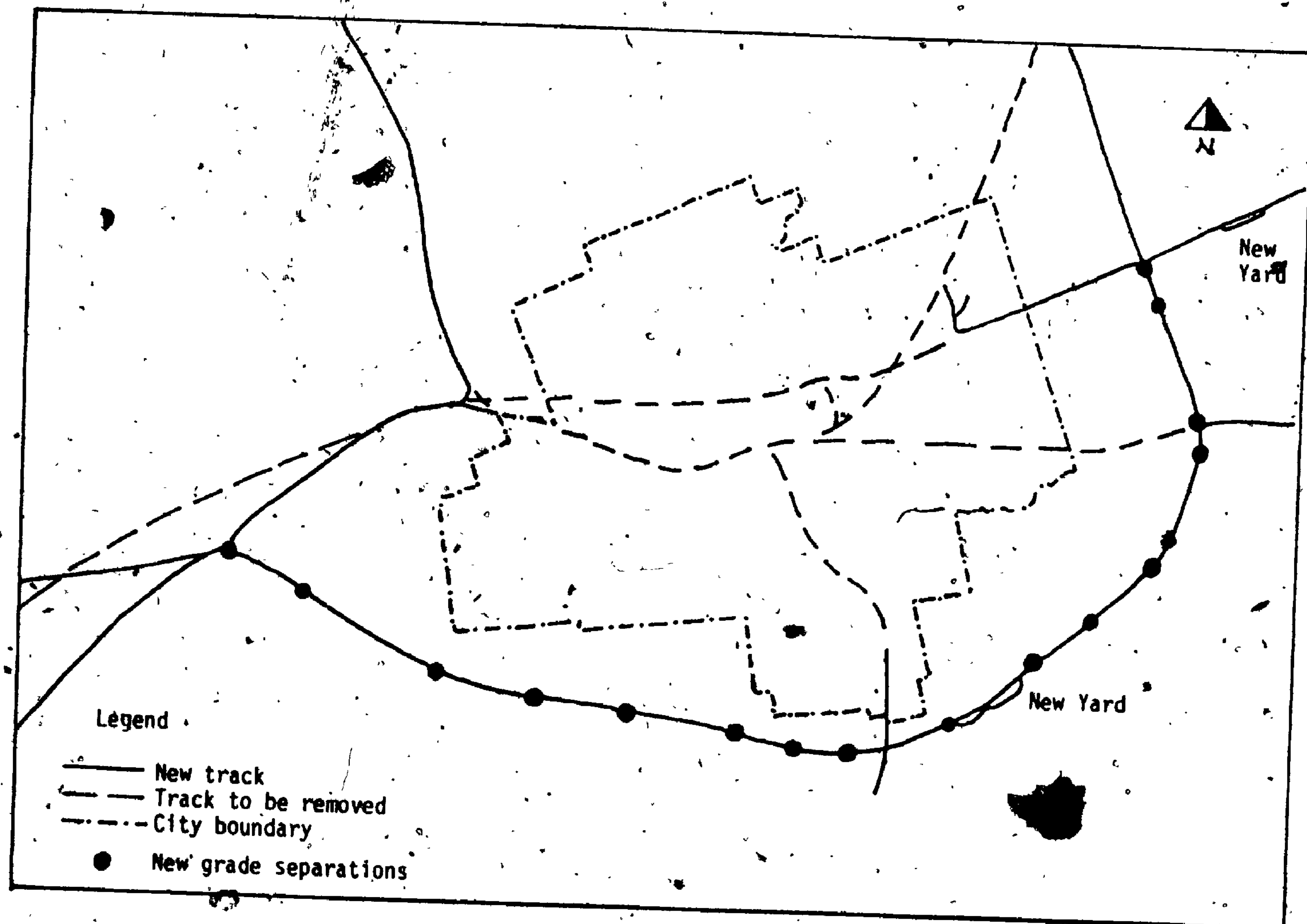
Railway Relocation: The Southern Scheme



Source: DeLeuw Cather (34).

Figure IV.5

Railway Relocation: The Complete Removal Scheme



Source: DeLeuw Cather (34).

Due to the lack of data, we will not be able to estimate some of the benefits and costs. Also, in some cases, a good 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. Here we shall discuss some of the key parameters to be used in the analysis. Others will be discussed as we go along. A summary table of all the key parameters is given in the last section of this chapter (Table IV.28).

(i) Project life. Railway service is likely to be with us for a long time to come. London is located along the busiest transportation corridor in Ontario and as long as trains are used to move goods and people, rail service in London will continue. Future developments in railway technology may reduce some of the adverse environmental impacts of this mode of transport. It is difficult to see, however, how the conflicts between vehicles and trains can be reduced so long as the two modes continue to use the same level crossings. From this point of view, the project life could be assumed to be long since railway relocation would reduce motor-rail conflicts which would continue to exist for a long time.

The project life question may be viewed from another point. Railway facilities and structures have a limited service life. For example, for main line track with heavy duty continuous welded rail carrying a high volume of traffic, service life expectancy would be 20 years. For sidings and yard tracks, a life expectancy of 40 years can be expected. Grade separations and buildings may have an even longer life expectancy. Since railway facilities and structures are expected to be replaced at the end of their life expectancy, the project life of railway relocation may be assumed to correspond with a railway replacement cycle.[4]

The range of project life values (30 to 100 years) which we assume for the purpose of sensitivity analysis is intended to cover both points of view.

(ii) Trend in rail traffic. Even though rail service is likely to be with us for a long time to come, it is probably safe to assume that future growth in rail traffic will be negligible. Over the past decade the volume of rail freight traffic has remained unchanged and that of passenger traffic has declined.[5] We assume that the growth in rail traffic is zero in the future.

(iii) Trend in motor traffic. We expect motor traffic to grow over time, though not as fast as in the past. From 1960 to 1963, motor traffic in London grew at 4 per cent per year.[6] In this study we use growth rate of 1, 2, and 3 per cent per annum.[7]

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[4]For more discussion of railway replacement cycles, see Damas and Smith (33).

[5]See Statistics Canada (176).

[6]Margison and Associates Limited (153, 154).

[7]It is expected that car ownership would increase at a faster rate than population and the number of people per car would decline, ibid. Since we use man hours instead of car hours, the savings in travel time may therefore be overestimated. Also, decentralization may reduce conflicts at level crossings.

(iv) Discount rate. The choice of discount rate has given rise to a large body of literature which yields no definite conclusion as to what is the proper rate to use in social benefit-cost studies. Jenkins (149a,b) estimated that the social opportunity cost of public funds was 9.5 per cent for Canada during the period 1965 to 1969. This discount rate was constructed as a weighted average of the rates of return from investment in the private sectors which would give up funds to finance a public project plus a weighted average of the rates of time preference for consumption in the sectors which would forego consumption to release resources for a public project. In this study, we use a range between four and ten per cent per year, which brackets the rates used in most cost-benefit studies as well as the rate estimated by Jenkins.[7a]

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.3) the existing CPR lines within the city would be

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[7a]It may be noted that the rate estimated by Jenkins is a nominal rate. We regard this rate as a high estimate of the real rate of discount.

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.

Under the Southern and Complete Removal schemes, 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.

In Appendix C we show in detail how H_1, H_2, H_3, G_1, G_2 and G_3 are measured. The estimated annual savings in travel time and vehicle operating expenses for the three relocation schemes are summarized in Tables IV.3 and IV.4.

As indicated in Chapters 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. In Appendix B we discuss some of the theoretical and empirical findings with respect to the value of time. It seems that the value of travel time depends on a large number of factors such as the socio-economic characteristics of the traveller (age, sex, income), purpose of trip (working, recreation, school), and form of time saved (in-vehicle, walking, waiting), as well as the size of time savings. However, 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. Findings with respect to other variables are scarce and the results cannot be applied with confidence.

TABLE IV.3

Annual Savings in Travel Time (Man-Hours)

Travel Time (Man-Hours)	CNR	Southern	Complete
Passenger Car and Transit Users	79,958	80,196	109,448
Commercial Vehicle Users	12,280	12,525	16,739

TABLE IV.4

Annual Savings in Travel Time and Vehicle Operating Expenses

	Value of Travel Time (per man-hour)	CNR	Southern	Complete
Travel Time ($)				
Passenger Car and Transit Users	$ .70	55,971	56,137	76,614
	1.25	99,947	100,245	138,810
	1.80	143,924	144,353	197,006
Commercial Vehicle Users	$ 5.00	61,400	62,625	83,695
Vehicle Operating Expenses ($)		93,495	79,609	170,404

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[8] 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.[9]

To the extent that the value of travel time is related to the real wage rate and that the latter increases over time, the value of travel time should increase as well. However, no study has attempted to determine the trend of the value of time. In Appendix B, we make some estimates of the savings in travel time under the three relocation schemes based on the assumption that the trend of the value of travel time is equal to that of the real wage rate in Canada.

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[8] Include both hourly rated and salaried workers.

[9] 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 (178).

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

Tables IV.3 to IV.5 show the estimated values of travel time and vehicle operating expenses saved per year for the three relocation schemes. Two points need to be noted in Table IV.4. First, the saving in vehicle operating expenses is high compared with saving in travel time. This is mainly because (a) the number of cars slowed down due to presence of tracks far exceeds the number of cars actually stopped or slowed down due to trains at railway crossings, and (b) the extra time cost (given the values of time assumed above) is less than the extra vehicle operating expenses incurred in speed changes at railway crossings. Second, even though the saving in travel time is greater for the Southern scheme than for the CNR scheme, the savings in vehicle operating expenses is smaller for the former than for the latter. This divergence is due to the fact that the CNR scheme would result in fewer motor vehicles being slowed down at the railway crossings than the Southern scheme.

The estimated savings presented in Tables IV.3 to IV.5 are for a single year. Since these are recurrent benefits it is necessary to find their present discounted values. The estimated savings in travel time and vehicle operating expenses over time under various assumptions are presented in Table IV.6.

It can be seen in Table IV.6 that the range 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.

TABLE IV.5

Annual Savings in Travel Time and Vehicle Operating Expenses ($) with Different Values of Travel Time Assumed

	Relocation Schemes		
	CNR	Southern	Complete
A	211,000	198,000	331,000
B	255,000	242,000	391,000
C	299,000	287,000	451,000

Notes: The value of travel time (per man hour) assumed for passenger car and transit users are $.70, $1.25, and $1.80 respectively under A, B, C. The value of travel time for commercial users is assumed to be $5.00 in each case.

TABLE IV.6

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. Values of travel time assumed under A, B, and C are the same as those given in Table IV.4 above. For the set of low, middle, and high parameters used, see Table IV.28 below.

(e) Assumptions which may bias the results

In the process of calculating the savings in travel time and vehicle operating expenses, some assumptions have had to be made mainly because of the lack of data. These assumptions could bias our results one way or the other. Let us first note the assumptions which would bias the estimates upwards.

(1) Perfectly inelastic demand for urban travel.

We have indicated above that this assumption would lead to overestimation. The extent of overestimation may be as high as 10 per cent of the savings estimated.[10]

(2) Conversion of vehicle hours into man hours.

In converting vehicle hours into man hours we make no allowance for the fact that some of the people are children. If we consider only persons 15 years or older, then the average number of people would be lowered to 1.1 for the private car and 12 for the public bus. This would reduce our estimates of savings in travel cost by 10 to 13 per cent.

(3) Subsequent land use at eliminated level crossings.

For the eliminated level crossings, we assumed that no traffic light or stop sign would be erected. If some of the railway

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[10] The guessed figure is based on the following reasoning: As can be seen in Figures III.1 and III.2, the perfectly inelastic assumption results in overestimation only during the rush hours. In London, rush hour traffic amounts to 20% of the daily total (Margison and Associates (153)). Suppose the increase in travel cost during the rush hours is 50% (which is unlikely), then we could have overestimated the savings in travel time and vehicle operating expenses by 10%, i.e., 50% x 20%.

rights-of-way were used for transportation purposes, we would have overestimated the savings.

(4) Increase in congestion due to increased truck traffic.

Under the Complete scheme, truck traffic in the urban area could increase, and this would result in more congestion. We have not allowed for such an increase in our calculation and hence our estimates may be biased upward.

Now let us turn to assumptions which probably lead to a downward bias of the estimates.

(1) Exclusion of H_5, H_6, G_6.

Due to the lack of data we are unable to estimate these. For illustrative purposes, let us suppose that there are 500 people in London who spend 5 extra minutes daily to follow longer routes or depart early to avoid being late if they are caught by trains at level crossings. We calculated that the extra travel cost incurred could be 5 per cent of the savings estimated.

(2) No allowance for pedestrians and cyclists.

This would bias our results but probably not to any significant extent.

(3) As we have indicated in Chapter III (footnote 7), the formulas for calculating H_1 and H_2 ignore any delays imposed on vehicles which slow down but do not stop as a result of the closing of the crossing. Also, the formulas do not take into account delays caused when backed-up traffic blocks nearby side streets, driveways, etc. However, this bias is probably very small except during rush hours.

Balancing the above factors it seems to us that we are more likely to have an upward rather than a downward bias in our estimates of savings in travel time and vehicle operating expenses.

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. Our guess is that it would be less than 5 per cent of the savings in travel time and vehicle operating expenses.[11]

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

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[11] Let us assume the following:

	Reduction in travel cost as a result of railway relocation	Elasticity of demand for urban travel
(a)	25%	.3
(b)	50%	.5

Then the net benefit of generated travel would be:

(a) 25% x (25%)(.3)/2 = 1%

(b) 50% x (50%)(.5)/2 = 6%

Case (b) is likely to be the upper limit.

in Ontario (Table IV.7). The number of railway-highway crossing accidents in London during the 1969-1974 period is shown in Table IV.8. In Table IV.9 we show the level crossings in London at which more than three accidents have occurred from 1969 to the beginning of 1975. Most of these crossings have active protections in the form of flashing lights and bell.

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.

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 (Table V.7) and Canada (Table IV.10). 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

TABLE IV.7

Road-rail Crossing Accidents in Ontario (1958-1972)

Year	Types of Accidents		
	Fatal	Non-fatal Injury	Property Damage Only (PDO)
1972[a]	47	291	523
1971[a]	38	251	380
1970	32	154	194
1969	43	136	234
1968	34	139	236
1967	53	142	222
1966	41	147	263
1965	44	131	217
1964	38	138	196
1963	53	150	225
1962	49	132	219
1961	42	130	178
1960	49	129	239
1959	50	144	249
1958	58	140	256
Average	45	157	255

Source: Motor Vehicle Traffic Accidents, Statistics Canada, Catalogue 53-206, various years.

Notes: (a) There is no reason given for the large increase in non-fatal injury and PDO accidents in 1971-72.

TABLE IV.8

Road-rail Crossing Accidents in London (1969-1974)

Year	No.	Types of Accidents		
		Fatal[a]	Non-fatal Injury[a]	Property Damage Only (PDO)
1974	19	3	5	15
1973	17	1	6	14
1972	17	3	7	9
1971	10	0	8	5
1970	4	0	2	2
1969	15	3	7	7
Average	13.67	1.67	6.00	8.67

Source: Canadian Transport Commission, unpublished data.

Notes: (a) These columns refer to the number of people killed or injured.

TABLE IV.9

Number of Accidents at Selected Level Crossings in London

(1969 - Feb. 1975)

Crossing[a]	Protection[b]	No. of Accidents
(39) Clarke Side Road	F.L. & B.	4
(42) First Street	F.L. & B.	4
(6) Egerton Street	F.L. & B.[c]	7
(25) Horton Street	R.C.S.	7
(29) South Street	R.C.S.	5
(13) Clarke Side Road	F.L. & B.	4
(18) Dundas Street	F.L. & B.	7
(19) Highbury Avenue	F.L. & B.	9

Source: Canadian Transport Commission, unpublished data.

Notes: (a) Numbers in brackets are crossing numbers used in Table C.1 in Appendix C.

(b) F.L. & B. = Flashing Lights & Bell
R.C.S. = Reflectorized crossing signs

(c) Before 1971 the protection at this crossing was manned gates.

TABLE IV.10

Persons Killed and Injured in Accidents at Road-Rail Crossings, Canada

Year	Pedestrians				Riding in Motor Vehicles*				Other Vehicles		Total No. of Persons in Urban Areas	
	Urban		Rural		Urban		Rural					
	K	I	K	I	K	I	K	I	K	I	K	I
1972	10	6	1	3	38	201	78	202	1	7	48	207
1971	5	5	2	1	38	229	68	45	1	11	43	234
1970	5	4	2	-	36	203	56	126	3	4	41	207
1969	5	7	2	1	66	265	34	91	3	2	71	272
1968	9	3	1	-	69	302	35	999	4	2	78	305
1967	8	8	1	-	76	298	75	100	1	3	84	306
1966	15	12	-	-	119	355	49	103	2	3	134	367
1965	4	8	2	1	86	340	53	86	3	4	90	348
1964	5	8	2	2	59	259	78	160	1	2	64	267
1963	6	5	2	-	40	221	92	216	6	4	46	226
1962	6	-	5	1	44	175	99	175	-	2	50	175
1961	5	4	4	3	49	181	79	168	1	2	54	185
1960	11	9	3	-	62	208	46	110	42	80	73	217
1959	9	5	2	1	54	201	83	162	26	79	63	206
1958	6	4	1	3	36	112	123	153	-	2	42	116
1957	4	8	5	4	44	140	124	231	1	-	48	148
1956	7	7	5	3	53	201	123	237	2	11	60	208
1955	9	7	1	-	47	170	99	190	-	-	56	177
1954	7	7	2	3	34	192	106	259	1	13	41	199
1953	3	8	3	-	48	157	101	259	2	16	51	165
1952	9	6	3	2	48	156	121	262	3	8	57	162
1951	5	4	6	5	62	200	124	241	1	30	67	204
1950	9	8	5	4	41	232	76	189	8	19	50	240
1949	4	8	4	3	44	206	83	231	5	4	48	214

Source: Railway Transport Part I, Statistics Canada, Catalogue 52-207, various years.

Notes: K = Killed

I = Injured

proportional to the annual vehicle hours saved.[12]

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) Valuation of accident reduction

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.[13] 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 *per se*. Quite a number of studies have been done, however, to determine the costs of motor vehicle accidents.[14] 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.

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[12]Only H_1 and H_2 are included in the calculation; H_3 is probably not relevant. The annual vehicle hours saved for the three relocation schemes are shown in Table C.3 in Appendix C.

[13]A study by Michael Jones-Lee (73) attempted to determine the value of life following this approach. However, only hypothetical data were used and the results cannot be applied here.

[14]See Abramson (67) and the studies cited therein.

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.11 shows some of the results of these studies. The North American studies made no attempt to estimate the dollar value of pain and suffering associated with vehicle accidents. The United Kingdom study included an arbitrary amount of money to take care of pain and suffering. The figures in the table do not include this amount, however.

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.11. It must be emphasized again that these are <u>ex post</u> 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;

TABLE IV.11

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. (67)
J. A. Cassils (71)
R. Winfrey (183)
R. F. F. Dawson (72)

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.12.

From Table IV.12, it can be seen that the highest estimate is approximately 100 times the lowest estimate in each case. This is mainly due to the fact that a low discount rate is combined with a high growth rate of future railway crossing accidents in one case and a high discount rate combined with a zero growth rate of accidents in the other. Given the values of other parameters, estimates based on "high" cost per accident is approximately 21 times that based on "low" cost per accident. The difference between the "low" and "middle" estimates are much smaller than those between the "middle" and "high" estimates.

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.3, IV.4, and IV.5 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

TABLE IV.12

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.28 below. Cost per accident is assumed to be as follows:

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

give an accurate indication of the true social value of the released land. In addition, in practice we usually do not even have reliable land price data. This is because there have not been many transactions in vacant land except at the periphery of the city. As a result, an average land price often has to be used.

According to estimates made in LUTS by DeLeuw Cather (34), the amount of railway land released for other uses by the CNR and Southern schemes would be 395 and 455 acres respectively. The value of the released land was estimated to be $5.5 million and $5.8 million respectively for the two schemes.[15]

It seems to us that LUTS has underestimated the value of the released land because the estimated values include the value of freight shed and yard areas only. No value is assigned to most of the railway rights-of-way released. In Appendix D we discuss these estimates in more detail. Also we attempt to establish the upper bound for the value of the released land by assigning a dollar value to all the released rights-of-way. As a result, we arrive at the following estimated values ($ million) of land released under the three schemes:

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

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[15] DeLeuw Cather ([illegible]), pp. 152, 158.

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.[16] 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.

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[16] The number of people per property could be higher than that in residential areas, however.

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. (See the discussion in subsection (c) below and Appendix E.)

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.[17]

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

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

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.

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. A detailed discussion of the data and sample as well as our regression model is contained in Appendix E. 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.13). However, the volume of railway traffic seems to have no significant effect on residential property sale prices.

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 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.

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)[18] could mean that some of our conclusions would not hold for high-rise apartments.[19]

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.[20]

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

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[18] 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.

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

[20] Both of the railway variables are not significant in one area. See Appendix E.

(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:

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

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

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

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

where

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

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

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

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

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

Equation (b) in Table E.3a

Based on the above relationship, column (2) of Table IV.3 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.13 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. The number of properties at each distance is shown in Table IV.14. To find SB for each of the relocation schemes, we multiply column (3) of Table IV.13 by columns (2), (4), and (6) respectively of Table IV.14. 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

TABLE IV.13

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.

(b) Based on figures in column (2).

TABLE IV.14

Number of Developed and Undeveloped Residential Properties at Various Distances from Railways on Which Service Would Terminate as a Result of Railway Relocation

Distance from Railway (feet)	CNR		Southern		Complete	
	Developed	Undeveloped	Developed	Undeveloped	Developed	Undeveloped
(1)	(2)	(3)	(4)	(5)	(6)	(7)
50	135	190	187	280	333	280
150	225	190	329	280	472	280
250	248	190	343	280	525	280
350	312	190	396	280	813	280
450	296	190	418	280	726	280
550	312	190	367	280	804	280
650	317	190	393	280	307	280
750	280	190	331	280	778	280
850	266	190	325	280	748	280

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 (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.

In the northwest corner of the city there are approximately 400 acres residential land within 900 feet of railway tracks. Assuming 25 per cent of the land will be used for roads, etc., 300 acres can be used to build houses.[21] The average lot size of existing properties in this area is 9,000 square feet. However, there is a tendency for new lots to be closer to 6,000 square feet. Assuming the future properties in this area have an average lot size of 6,000 square feet, approximately 2,200 properties may be affected by the railways. We do not know when

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[21]Taking the city as a whole, approximately one third of the land is devoted to residential use (LUTS, Working papers). However, for areas which are designated as residential, it seems reasonable to assume that 75 per cent of the land would be used as lots. Examination of several new subdivisions indicates the above assumption is reasonable.

these properties would be developed.[22] Our calculation will be based on the assumption that they would be developed at a uniform rate over the next 20 years.[23] Furthermore, we suppose that the properties will be evenly located within 900 feet on both sides of the tracks. Given these assumptions, the discounted value ($ million) of the reduction in railway externalities on properties which have not been developed for the three railway relocation schemes will be:[24]

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.15.

In Table IV.16 we summarize the factors that may bias the above estimates in one direction or another. We may also mention that we have assumed adverse environmental effects at the new railway sites are nil.

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[22] In the 1971 Official Plan of London, some of the land in this area would be developed in stage I (before 1981) and others in stage II (after 1981). However, conversation with persons in the Planning Department of the City of London raises uncertainty regarding the timing of development of this area.

[23] If the total number of undeveloped properties is N, then N/20 properties are assumed to be developed per year for the next 20 years.

[24] These estimates include undeveloped properties in other parts of the city as well.

TABLE IV.15

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

TABLE IV.16

Factors that Bias the Estimated Values of Reduction in Railway Externalities

Upward Bias	Downward Bias
1. The use of land or property price tends to overstate people's willingness to pay.	1. Exclusion of benefits in high-rise apartments, institutions, offices and commercial stores.
2. Possible increase in adverse environmental effects due to increased rail traffic is not considered.	2. Possible adverse effects on farmland at the new location are not considered.
3. Some house related variables (e.g., quality) which are not included in the regression equation might be correlated with the distance from railway.	
4. The assumption that subsequent use of released railway properties would be compatible with existing land use in their neighbourhood.	
5. Future railway technology development may reduce railway externalities.	

It seems more likely that our estimates of benefits would be over rather than under biased.

B.2 Costs of Railway Relocation Compared with Status Quo

2.1 Capital costs

Table IV.17 presents some capital cost estimates of the Southern and the CNR relocation schemes made by LUTS. 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.

Our second consideration is whether the unit prices used to arrive at the capital costs are reasonable. Table IV.18 provides a comparison of some of the unit 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 most cases the unit prices used by LUTS are closer to the low end of the range. Since the unit prices of the U.S. study are 1973 prices and those of LUTS are 1972 prices,[25] allowing for inflation would bring most of the unit prices of LUTS to the medium estimates of the U.S. study.

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[25]Actually the prices of the U.S. study are in January 1974 prices and those of LUTS, January-February 1973 prices. Also note that the U.S. estimates are in U.S. dollars and the LUTS estimates in Canadian dollars.

TABLE IV.17

Capital Costs of Relocation

($ million)

Cost Item	CNR	Southern	Complete[a]
New Work			
Main tracks	4.50	10.90	
Signals	1.60	2.50	
Railway bridges	.60	4.20	
Yards & sidings	4.00	4.35	
Buildings	3.93	4.30	
Grade separations	12.00	7.20	
Property	.50	.92	
Engineering & contingencies	2.46	4.74	
Removing old tracks, fittings and structures less credit for possible salvage	.24	.15	
Total capital costs	29.84	39.25	> 39.25

Source: DeLeuw Cather (34), Table 9.4.

Notes: (a) As can be seen in Figures IV.4 and IV.5, the Complete scheme is almost identical to the Southern scheme except that more tracks within the City would be removed. Hence the capital cost of the Complete scheme should be greater than that of the Southern scheme.

TABLE IV.18

Comparison of Unit Price of Capital Items

Item	Unit	Unit Prices (dollars)			
		LUTS	U.S. Dept. of Transport		
			Low	Medium	High
Grading: cut to fill	cu. yd.	1.50	1.50	3.00	7.00
Track (single)	trk. ft.	22.00	21.00	24.00	30.00
Turnouts	each	3,200.00 - 9,500.00	5,000.00	6,000.00	8,000.00
Engine house	each	215,000.00	200,000.00	1,500,000.00	10,000,000.00
Station and office buildings	sq. ft.	30.00	-	35.00	-
Roadway buildings	sq. ft.	14.00 - 25.00	25.00	-	30.00
Passenger station	each	315,000.00	10,000.00	100,000.00	5,000,000.00
Bridges	linear ft.	3,000.00	400.00	1,500.00	2,800.00
Telegraph lines	linear mi.	25,000.00	10,000.00	25,000.00	100,000.00
Fences	linear ft.	.30	.90	3.50	5.00
Centralized traffic control	linear mi.	43,000.00	25,000.00	30,000.00	40,000.00
Removing track	trk. ft.	1.00	.85	1.25	1.75
Salvage value	trk. mi.	12,000.00	15,000.00	25,000.00	35,000.00
Grade separation	each	330,000.00 - 3,570,000.00	200,000.00	1,000,000.00	7,500,000.00
Engineering & contingencies	% of total	20%	18%	19%	20%

Sources: DeLeuw Cather (34), Working Papers.
U.S. Department of Transportation (42), Table 1.

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 the following cost estimates for the three relocation schemes.[26] It is likely that actual cost would fall between the medium and high values rather than the low and medium values in each case since a number of unit prices used to derive the low estimates appear to be too low. The capital cost of the complete scheme would be greater than that of the Southern scheme because more tracks have to be removed under the former.

	CNR	Southern	Complete
Low	19.56	30.36	> 30.36
Medium	28.43	42.97	> 42.97
High	45.15	68.78	> 68.78

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.

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[26]The high unit prices 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.

As one might expect, LUTS has not made adjustments for possible savings in replacement costs. We have indicated in Chapter III how these savings may be conceptually measured. 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. These assumptions together with our calculations are shown in Appendix F.

In Table IV.19 we present some results of our sensitivity analysis based on various assumptions. From these results, we reach the following conclusions. Given the service life expectancy of railway facilities and the project life assumed, the savings in replacement costs are small if the existing railway facilities are new and/or if the discount rate is high. Conversely, if the existing facilities are old and/or the discount rate is low, there can be considerable savings in replacement cost.

If the estimated replacement cost savings were deducted then the capital costs of the relocation schemes would be the following:[27]

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[27] The low, medium, high values selected from Table IV.19 are as follows:

	CNR	Southern	Complete
Low	1.92	4.03	4.03
Medium	2.89	6.18	6.18
High	4.78	9.88	9.88

TABLE IV.19

Savings in Future Railway Replacement Costs

(millions of dollars)

Discount Rate %	Age of Existing Facilities[a]	Time Horizon					
		CNR			Southern		
		30 Yrs.	50 Yrs.	100 Yrs.	30 Yrs.	50 Yrs.	100 Yrs.
4	A	.35	2.86	2.16	.71	5.71	4.51
	B	3.97	4.78	4.33	10.63	9.88	9.26
	C	7.73	7.90	7.02	17.29	16.63	15.34
7	A	.38	1.33	1.36	.78	3.48	2.84
	B	2.69	2.89	2.98	5.99	6.18	6.42
	C	5.86	5.76	5.87	12.90	12.50	12.80
10	A	.31	.68	.68	.64	1.47	1.47
	B	1.76	1.92	1.90	3.90	4.03	4.10
	C	4.44	4.40	4.31	7.25	9.67	9.55

Notes: (a) Let x,y,z be the respective age (yrs) of existing main tracks, yards and sidings, and buildings, grade separations, signals, etc., then A: (x = 5, y = 10, z = 15); B: (x = 10, y = 20, z = 25); C: (x = 15, y = 30, z = 35).

	CNR	Southern	Complete
Low	17.64	26.33	> 26.33
Medium	25.54	36.48	> 36.48
High	40.37	58.90	> 58.90

Since not all of the capital costs would be incurred within the first year of a relocation project, we should discount those costs which would occur after the first year and find their present discounted value. Figure IV.6 illustrates the per cent of project completion versus per cent of expenditure. Based on the hypothetical expenditure path shown in Figure IV.6 we calculate the present discounted costs of the relocation projects under different assumptions with respect to the period of construction. These are shown below.[28] The discount rate used is 7 per cent.

	CNR		Southern			Complete	
	3 yrs	5 yrs	3 yrs	5 yrs		3 yrs	5 yrs
Low	18.64	17.61	28.93	27.33	>	28.93	27.37
Medium	27.09	25.59	40.95	38.69	>	40.95	38.69
High	43.03	40.65	65.54	61.92	>	65.54	61.92

2.2 Railway operating costs

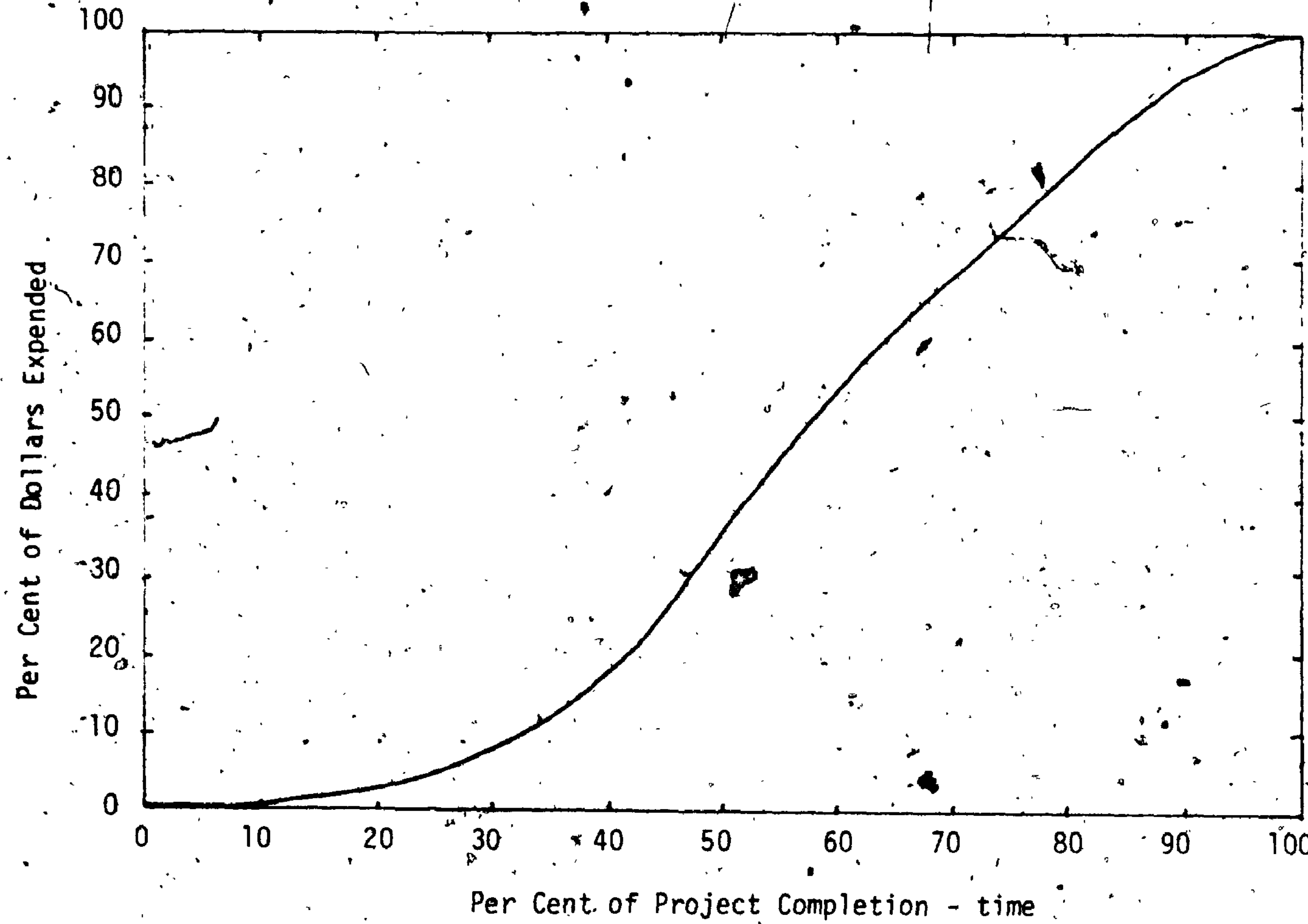
In Table IV.20 we present the estimates of changes in railroad operating costs under the various relocation schemes, made by LUTS.

As in the case of capital costs, we have to take LUTS' measurements of physical units (e.g., track miles, number of switch assignments)

[28] These time periods refer to actual construction time and do not include the planning period that goes before actual construction.

Figure IV.6

Per Cent of Project Expenditure Versus Per Cent of Project Completion



Source: U.S. Department of Transportation (42), Figure 7.

TABLE IV.20

Change in Annual Operating Costs
($1000)

	CNR	Southern	"Complete"
Railway Changes			
To through rail traffic	35	420	
Switching and yard operations	-200	-60	
Track maintenance	-25	20	
Other Changes			
Maintenance of grade separations and at grade crossing	145	90	
Industrial handling	5	5	
Total Change	-60	475	≥ 475

Source: DeLeuw Cather (34), Table 9.5.

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 (see Table IV.21). 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.

As can be seen in Table IV.22, the costs considered by LUTS include the following: ton-mile, time, main track maintenance, switching, gate house operation and maintenance of crossings. Other changes in operating costs have been ignored. For example, LUTS assumes that the geometrics of new railway lines are equal or better than the existing lines and yet no allowance is made for the change in gradient and curvature in its estimates. Change in terminal costs other than switching is not considered. Better design and more modern facilities and structures would probably improve terminal operating efficiency and hence reduce costs. Other changes in operating cost due to change in schedules, freight car rental and ownership, etc., are also not considered. With respect to track maintenance costs, nothing is allowed for the change in maintenance cost for yard and siding tracks, and furthermore no account is given for the difference in maintaining old and new tracks or facilities. Such features as new welded rail, concrete ties, compacted earthwork, prestressed concrete bridges, etc., necessarily require a new basis for estimation. Many of the elements of maintenance will not occur for 20 or 30 years because of improved design.

Under the CNR scheme, CP trains will be using the CN corridor. One would expect some savings in track maintenance and other railway

TABLE VI.21

Railway Operating Costs: Cost Per Unit of Service

Item	Unit	LUTS	U.S. Dept. of Transportation		
			Low	Medium	High
Maintenance of yard & branch tracks	mile (annual)	$ 1,800	$ 1,000	$ 2,000	$ 4,500
Maintenance of main line track	mile (annual)	3,000	3,500	7,000	17,500
Linehaul expenses	Train - ml.	3.20 - 6.20	3.30[a]	3.80[a]	4.40[a]
Manual signal or interlocking	Per position manned 24 hrs/day (annual)	36,000	30,000	40,000	60,000

Sources: DeLeuw Cather (34), Working Papers.
U.S. Department of Transportation (42), Table 5.

Notes: (a) Include the following expenses only: train and engine crew wages, dispatching expenses and locomotive cost assigned to miles.

TABLE IV.22

Change in Annual Railway Operating Costs Under the CNR Scheme, Estimated by LUTS

Subdivision	Change in track mile	Freight, tons/day	Change in ton-miles cost[a]	Change in time cost due to speed change[b]	Change in main track maintenance cost[c]
Thorndale (CN)	.8	20,200	11,800	23,400	-5,200
Galt & Windsor (CP)	1.8	47,150	62,000	?	-20,000
Talbot (CN)	-.4	8,500	-2,500	-12,700	2,800
Dundas & Strathroy (CN)			0	0	0
Exeter (CN)			0	0	0
Change in gate house operation[d] = -236,520					
Change in switching costs = 14,300					
Change in maintenance cost					
grade separations[e] = 190,000					
grade crossings[f] = -45,000					

Source: DeLeuw Cather (34), Working Papers.

Notes: (a) ton-mile cost assumed = \$.002; (b) assume cost/train car = \$10/day and cost/engine = \$6.5/hr; (c) maintenance cost varies from \$1800/track mile to \$3000/track mile; (d) operator wage = \$9.50/hr.; (e) annual maintenance cost = 2% of capital cost; (f) annual maintenance cost = \$1500/crossing.

operating costs as a result of consolidation. However, this is not considered by LUTS. If it were not for the reduction of six gate house operators, the consolidation of the two lines would increase the total operating costs in LUTS. Under the Southern scheme, all through trains will by-pass the congested part of the city and considerable increase in speed will result. It appears that LUTS has not included a sufficient allowance for this increase in train speed.

Since most of the above mentioned changes tend to reduce railway operating costs, their exclusion by LUTS would mean that the reduction in operating costs under the CNR scheme is underestimated and the increase in operating costs under the Southern scheme is overestimated.

We attempt to derive some cost estimates following the methodology developed by the U.S. study. A breakdown of these costs is given in Table IV.23. It is interesting to compare these results with those of LUTS. With the U.S. approach, the CNR scheme would result in more savings and the Southern scheme would result in a smaller increase in operating costs. However, we are not in a position to claim that the estimates made here are superior to those of LUTS since the former are also based on very limited railway operating data. In addition, both sets of estimates are based on a "disaggregated differential" approach. By this we mean that total operating cost changes are assumed to be the sum of operating cost changes in each subdivision or section of the railway. However, it may be more appropriate to estimate the changes in operating costs on a total network basis, since all the parts are closely interrelated. What should be compared is the operating costs of the old network with those of the new network as a whole and not merely the marginal changes associated with the increase or decrease of a few

TABLE IV.23

Change in Annual Railway Operating Costs
Under the CNR and Southern Schemes

Operating Costs	CNR	Southern
Train delay or running time cost	$ -70,000	$ -58,000
Route length or distance cost:		
Train operating	136,000	647,000
Track maintenance	31,000	78,000
Yard track	12,000	12,000
Switching[a]	12,000	175,000
Grade crossing maintenance cost	126,000	51,000
Speed reduction cost	-113,000	-419,750
Gate house operation cost[a]	-234,000	-234,000
Industrial handling[a]	5,000	5,000
Net change	-95,000	257,000

Notes: (a) Estimated by DeLeuw Cather (34).

miles of track, etc. In short, the ideal would be a detailed railway cost simulation model. Unfortunately, such a model is not available to us.

Due to the lack of sufficient railway operation data, the change in annual railway operating costs ($) given below must be regarded as highly tentative:[29]

	CNR	Southern	Complete
High	- 60,000	475,000	≥ 475,000
Medium	- 95,000	257,000	≥ 257,000
Low	- 130,000	40,000	≥ 40,000

Table IV.24 gives the discounted value of these annual 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

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[29]The "low" estimate of the CNR scheme is calculated as follows:

$$(x + 60{,}000)/2 = 95{,}000$$
$$x = 130{,}000$$

The "low" estimate of the Southern scheme is calculated as follows:

$$(y + 475{,}000)/2 = 257{,}000$$
$$y = 39{,}000$$

The Complete scheme resembles the Southern scheme, and the change in annual operating costs is assumed to be equal or greater than that of the Southern scheme.

TABLE IV.24

Present Discounted Value of Changes in Railway Operating Costs

(millions of dollars)

Disc. Rate (%) \ Scheme / P. Life (Yr)	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

to the complex 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 shceme, 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.[30] (c) The average speed of vehicles is 20 miles per hour in the urban area. Given these assumptions we may proceed to calculate the

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[30]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.

increase in travel time and vehicle operating expenses in the following manner.

In 1972, approximately 250,000 passengers embarked or disembarked at the terminal.[31] Based on assumptions (a), (b), and (c) above we estimated that the annual increase in travel time would be 37,500 man hours.[32] The annual increase in travel time cost would be $26,250, $46,875, and $67,500 depending on the dollar value of travel time assumed.

To estimate the increase in vehicle operating expenses we assume that 80 per cent of the passengers go to the terminal by private cars and the rest by public bus. In addition we assume that the number of people per vehicle is 1.5 and 20 for the private car and public bus respectively. With these assumptions the increase in vehicle miles per annum is estimated as follows:[33]

Private Car	Bus
400,000	7,500

The operating costs per vehicle mile have been estimated to be roughly

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[31] DeLeuw Cather (34).

[32] For a return trip, the sum is calculated as follows:
2 x 125,000 x 3/25 = 30,000.

[33] In the following calculation, we have ignored the fact that some of the existing passenger traffic may choose to travel by a different mode, as a result of station relocation. Also, it is possible that more than 20 per cent of the passengers going to the train terminal use public transit. Unfortunately data on these aspects are not available.

Number of passenger car miles increased:
(125,000 x .8 ÷ 1.5) x 3 x 2 = 400,000

Number of bus miles increased:
(125,000 x .2 ÷ 20) x 3 x 2 = 7,500.

$.10 and $1.00 for the private vehicle and public bus respectively.[34] Thus the annual increase in vehicle operating costs is $47,500.

In Table IV.25 we show the present discounted value of the increase in railway passenger travel costs as a result of relocation of the passenger terminal.

It may be noted that our estimates above consider the increase of travel costs for the railway passengers only. We have not allowed for the increase in travel costs of relatives and friends who accompany the railway passenger to the terminal. Thus our estimates are likely to be on the low side.

(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

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[34] See Dewees (138), pp. 87-90 for automobile operation costs. The operating cost for public bus is based on transit operating statistics of the City of London.

TABLE IV.25

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.

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. Hence we shall resort to some estimates made by other studies. The North Bay study (35) estimated that the total cost of relocating and paying damages to 10 firms was $1.2 million. In the Sault Ste. Marie study (36), the total cost was estimated to be $2 million for relocating and paying damages to 10 firms. Thus the average cost of relocation and paying damages ranges between $100,000 and $200,000 per firm. 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.26 presents some estimates of relocation costs of industries under different assumptions with regard to the number of firms relocated and the average 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.

TABLE IV.26

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

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. However, we may make some assumptions to derive some numbers for illustrative purpose. In 1972, the total number of cars registered in London was 96,000. Suppose one-twentieth or 4,800 of the cars were delayed by an average of 10 minutes daily, then the total number of vehicle hours delayed per year would be .28 million. If similar assumptions were made with respect to the number of people per car, vehicle operation expenses and the value of time as we did in section B.1.1 above, the annual travel time and vehicle operation expenses incurred would be \$0.6 million.[35] Suppose it takes three years to complete the

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[35] Number of vehicle hours delayed per year
= 4,800 x 1/6 x 313 + 4,800 x 1/6 x 52 x .8 = 282,880

Man hours delayed per year
= 282,880 x 1.5 = 424,320

Value of travel time assumes to be \$1.25 per man hour.
Thus value of travel time lost per year is \$530,400.

Vehicle operating expenses of idling and slowing down:
Gas: \$(.35)(.48)(282,880) = \$47,523
Other operating costs:
\$(4800 x 313 + 4800 x 52 x .8)(.0011) = \$1,872

Hence the annual increase in travel time and vehicle operating operating expenses is
\$(530,400 + 47,523 + 1,872) = \$580,000

project, then the cost of time delay to vehicles would be around $1.6 million. In addition to vehicle delay costs, train traffic might also be delayed by construction and the public would have to live with additional air, noise and visual pollution during the construction period.

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 the 1966 Traffic Report (154), 19 new and 9 reconstructed grade separations would be warranted within the City of London by 1985.[36] The locations of the existing and proposed grade separations are shown in Figure IV.7. In what follows we 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.27. These savings are calculated in the same manner as before (see section B.1.1 above). We treat the reconstructions as if they were new grade separations.

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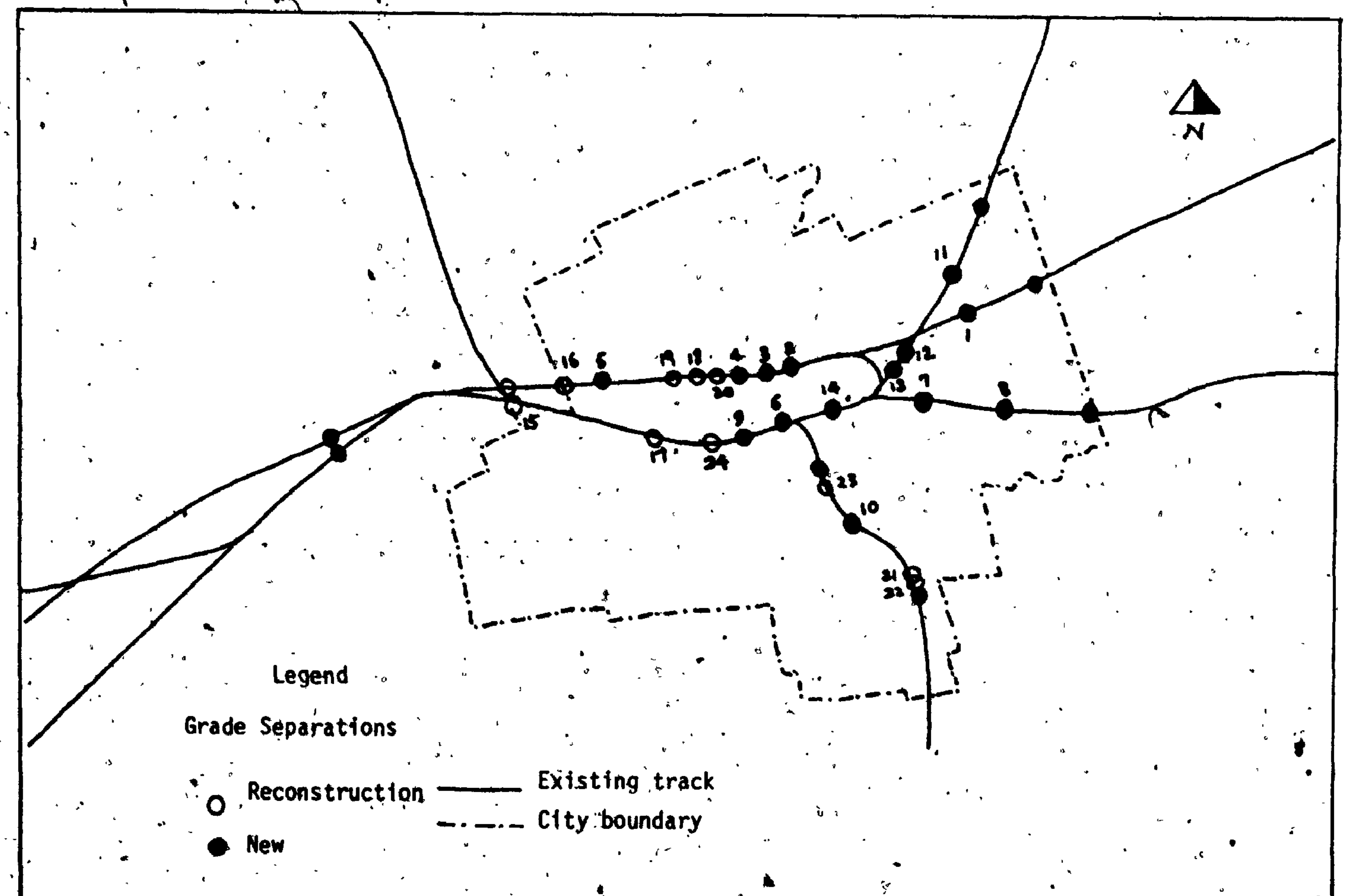
[36] It is not clear why these grade separations are warranted.

Figure IV.7

Grade Separations: New and Reconstructions



Source: DeLeuw Cather (34).

TABLE IV.27a

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	17.95	16.29

(continued)

TABLE IV.27b

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*	.63
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.7 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.

1.2 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.

1.3 Reduction in accident rates

The construction of grade separations tends greatly to reduce accidents at road-rail crossings.[37] 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

[37] Up to 90 per cent, according to Damas and Smith (33). See also U.S. Department of Transportation (80), p. 28.

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.[38] Appendix G illustrates in detail the various items of capital costs of grade separation construction.

It should be noted that the capital costs of grade separation of crossings No. 15 to No. 24 are reconstruction costs. If they were new grade separations, the capital costs would be at least one-third more.[39]

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[38]See for example the range of costs suggested by the U.S. Department of Transportation (42) study in Table IV.18 above. The range used in Damas and Smith (33) is as follows:

	$ Million
All roads	.4 - .7
Arterial	1.3 - 1.5
Collector	.8 - 1.0

[39]No land or property acquisition costs would be necessary in the case of reconstruction. The case illustrated in Appendix G shows that land and property costs amount to almost half of the total costs. For crossings at the outskirts of the city, land cost would be lower.

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 additional trackage. Due to the lack of data we are only able to derive some estimates of the change in maintenance costs.[40] It may be argued that these estimates represent the maximum increase in railway operating costs since the inclusion of other operating costs would offset some of the increase 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

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[40] The annual maintenance cost of a grade separation is assumed to be 2% of its capital cost. This figure is used by LUTS. See also U.S. Department of Transportation (80), p. 28. The annual maintenance cost of grade crossings assumed follows those suggested by U.S. Department of Transportation (42). They are as follows:

Crossbuck signs	$ 410
Wigwags	$1,150
Flashing lights	$1,500
Gates	$2,500

assumed for some of the parameters, many sets of benefits and costs could be derived. We shall present the more significant ones.

Table IV.28 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." As mentioned before, the "middle" values are the ones we consider to be the mostly likely. The set of "low" parameter values is unfavourable to the projects in the sense that it combines low estimates of benefits with a high estimate of capital costs. The set of "high" parameter values is favourable to the projects in the sense that it combines high estimates of benefits with a low estimate of capital costs.

In Table IV.29 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.28. It can be seen that under both the "low" and "middle" sets of parameters, none of the projects is justified on the basis of aggregate net benefits. With the set of "high" parameter values, all three relocation schemes show positive returns. The net benefit is largest in the case of the CNR scheme. The grade separation alternative, however, remains a marginal project even under this set of favourable assumptions.

These results are most sensitive to the discount rate and unit capital costs used. We mentioned earlier that Jenkins (149a,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,

TABLE IV.28

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	[illegible]00	350	600
(3) Project life (years)			
(a) Railway relocation	30	50	100
(b) Grade separation	30	50	50
(4) Discount rate, % per annum	10	7	4
(5) Trend in rail traffic, % per annum	0	0	0
(6) Trend in motor traffic, % per annum	1	2	3
(7) Trend in railway accidents, % per annum	0	1	2
(8) Trend in value of travel time, % per annum[a]	0	0	0
(9) Unit costs of capital	High	Middle	Low

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

TABLE IV.29a

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

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

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

TABLE IV.29b

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.29c

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	+	[illegible]	+	+
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.

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.

The London Urban Transportation Study, which recommended the CNR relocation scheme, was completed in 1974. However, the provincial government chose not to support London in applying for financial assistance from the Canadian Transport Commission for a detailed railway relocation study, and apparently the City of London has shelved plans for railway relocation for the time being. Nevertheless, the methodology used and conclusions reached in this study would be useful in any future evaluation of railway relocation in London.

CHAPTER V

DISTRIBUTION OF BENEFITS AND COSTS

To this point we have dealt only with the aggregate social benefits and aggregate social costs of urban railway relocation. In this chapter we will briefly discuss the distribution of these benefits and costs. We will discuss two distributional issues. First, we will review the distribution of benefits and costs by income group. Then, we will examine the private benefits and costs of railway relocation for the following groups: (1) railway companies, (2) local government, and (3) industries with rail service.

A. Income Distributional Effects of Urban Railway Relocation

In this section we will examine how the social benefits and costs of railway relocation are distributed among various income groups. Before beginning, we should define some of the terms that will be used. Benefits are distributed regressively (progressively) if the ratio of benefits to income increases (decreases) with income. Costs are distributed regressively (progressively) if the ratio of costs to income decreases (increases) with income.

A.1 Distribution of Benefits

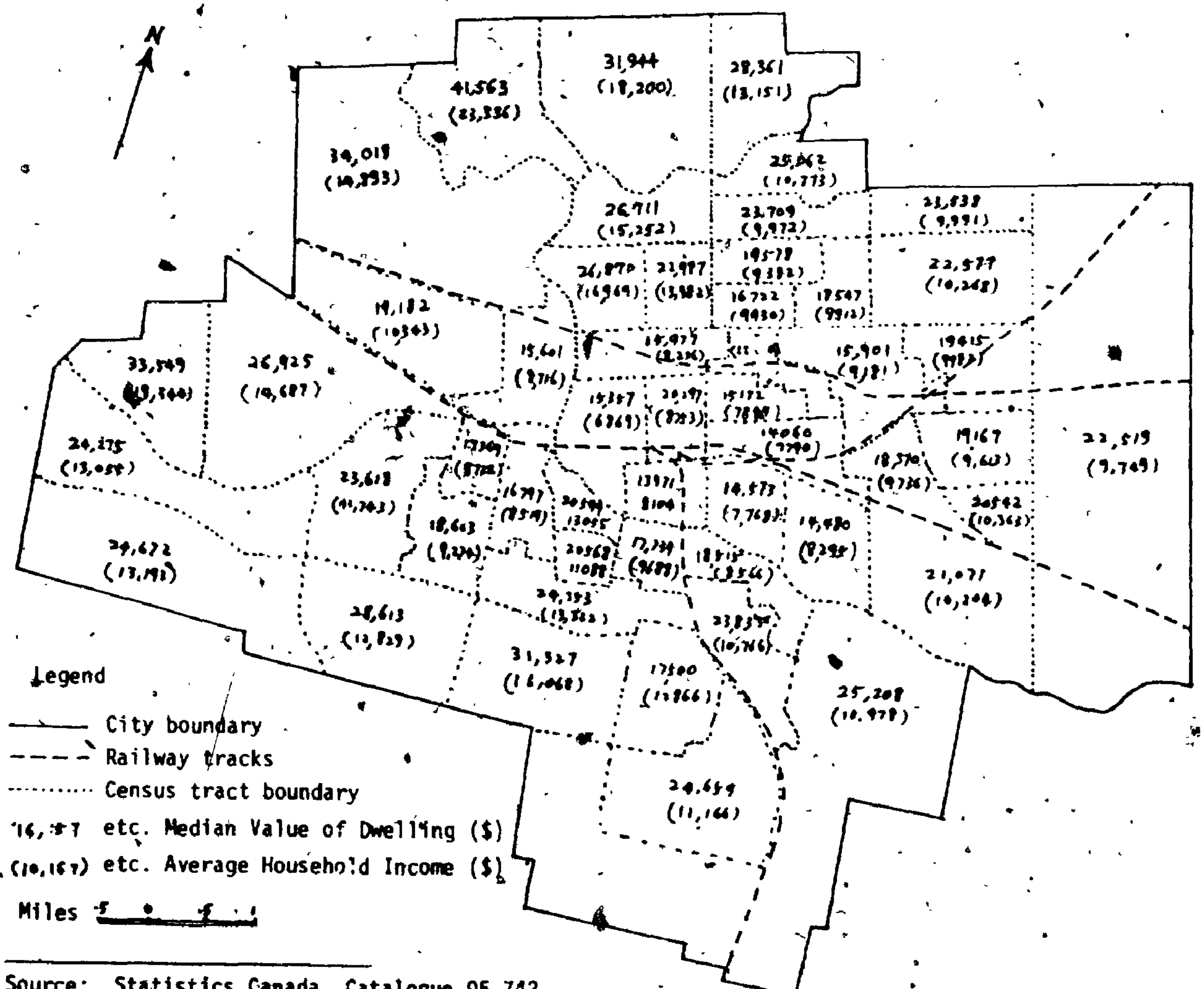
Among the six categories of aggregate consumption benefits identified, the last two categories -- improvement of areas abutting railway facilities and reduction in air pollution at level crossings -- are mainly restricted to people who live or own property near the existing railways. The first three categories of benefits -- reduction in travel time and vehicle operating expenses, net benefit of generated travel, and reduction in accident rates -- would be enjoyed by motorists and users of public transit. Since costs of railway relocation can be calculated net of the value of released railway land, this category of benefits need not concern us here.

In Figure V.1, we present the average family income and the median value of dwellings by census tract for the City of London. It can be seen that the average family income and the median value of dwellings are relatively low for most of the areas (especially the central areas) adjacent to the existing railways and yards. Since the benefits of urban railway relocation are probably greater for people residing near the railways, it seems probable that the benefits of railway relocation would be distributed progressively.

The conclusion that the low income residents of areas near the existing railways probably receive most of the benefits of relocation must be qualified. The relocation scheme will remove the externalities due to the railway. This will tend to raise the property values in the areas affected. The relocation scheme will also involve development of the released lands, possibly for high value residential or commercial uses. To the extent that the low income residents of areas near the existing railways are tenants rather than property owners, they will not share in the benefits. The benefits will accrue to the property owners rather than the tenants. Indeed, the low income tenants may be forced to pay higher rents or to relocate because of the increase in property values.

Figure V.1

Average Household Income and Median Dwelling Values, By Census Tracts, 1971



Legend

——— City boundary

– – – Railway tracks

········ Census tract boundary

16,517 etc. Median Value of Dwelling ($)

(10,167) etc. Average Household Income ($)

Miles

Source: Statistics Canada, Catalogue 95-742.

A.2 Distribution of Costs

In the previous chapters, we identified five categories of costs. We shall first look at the income distributional effects of capital costs and railway operating costs. According to the existing legislation (see Chapter VI for details of The Railway Relocation and Crossing Act), the federal government would be responsible for up to 50 per cent of the "net cost of railway facilities." This is defined as costs of new railway facilities (excluding land costs) plus or minus the capitalized value of the change in railway operating costs and plus or minus the change in the value of the railway's land (see Table VI.2 in Chapter VI). The other 50 per cent would probably be shared equally between the provincial and the municipal governments. The railway companies, as specified in the Railway Relocation Act, should neither be better nor worse off financially. Hence, the net cost of the railway relocation scheme will be paid by the federal, provincial, and municipal governments. According to Maslove (156), federal, provincial, and municipal taxes are distributed progressively, proportionally, and regressively, respectively. Maslove makes the traditional assumptions about the incidence of the municipal property tax, with the result that he concludes that it is regressive. However, the new view of the municipal property tax is that it is a tax on capital and hence proportional or progressive.[1] Hence, approximately 25 per cent of the financial costs would be distributed regressively or progressively

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[1] See, for example, Canadian Public Policy, Vol. 2, Supplement, 1976 for discussion of this, and for more detail see H. J. Aaron, Who Pays the Property Tax: A New View, Brookings Institution, Washington, D.C., 1975.

depending on which view one may have on the income distributional effects of the property tax.

With respect to the third category of costs -- relocation and transportation costs of railway users -- one may assume that the industries affected would be compensated so that they are financially neither worse nor better off as a result of the railway relocation. It is reasonable to assume that the compensation payments to the affected industries would be shared in the same manner as the railway costs. The arguments presented in the previous paragraphs then apply to the compensation payments as well. For the other category of railway users, namely passengers, the costs probably would not be distributed progressively since railway passengers and mainly middle or low income people.

The fourth category of costs -- transportation and relocation of non-users -- is probably distributed regressively since most of the people affected, i.e., employees of railway companies and industries, are from middle or low income groups.

The last category of costs -- delay in traffic while construction is in progress -- would fall mainly on residents who live near the old and new railway sites. If most of these people belong to the middle and low income groups, then this category of costs would not be progressive.

To conclude, a very high portion of railway relocation costs, i.e., the capital costs and railway operating costs, would be distributed progressively while the rest of the costs are likely to be regressive in nature.

A.3 Distribution of Net Benefits

Based on the conclusions reached for the gross benefits and costs, net benefits would probably be distributed progressively.

B. Benefits and Costs of Some Specific Groups

B.1 Railway Companies

In Table V.1 we list the benefits and costs which a railway company would consider if it were to carry out a relocation project on its own initiative. This list of benefits and costs is somewhat different from the list of social benefits and costs presented in the previous chapters. An explanation of some of the items follows.

(a) Value of released land

In discussing the value of land released in the previous chapters, we have ignored the rather complicated ownership problem, which is not important in an aggregate social context. However, when we try to assess the value of released land to railway companies, the ownership problem becomes crucial. This is because the removal of railway facilities may have an effect upon the clarity of title of such land. Some railroads hold title to land on a reversionary basis, i.e., use of land for other than railroad purposes implies a possible reversion of title to individuals or government jurisdictions.[2]

The railways may also be able to develop some of property without relocating by constructing buildings over the tracks. Such developments would not affect the railway's title to the land. The

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[2] For a brief discussion of railway land, see Rotoff (38).

TABLE V.1

Benefits and Costs of Railway Relocation to Railway Companies*
($ million)

Benefits and Costs (\$)	Relocation Scheme		
	CNR	Southern	Complete
1. Capital costs less savings in replacement costs	-25.54	-36.79	≤ -36.79
2. Change in railway operating and maintenance costs	1.31	-3.54	≤ -3.54
3. Value of land released	6.72	8.03	8.76
4. Change in shipping revenue	0	0	0
5. Change in taxes (income and property)	?	?	?
6. Change in road-rail crossing accident costs	1.46	1.56	1.82
7. Public goodwill, better business image	+	+	+
8. Inconvenience caused by relocation	-	-	-
9. Compensation to industries that lose rail service	0	0	4.0
Net Benefits**	-16.05	-30.74	≤ -33.75

*The estimates are based on the set of middle parameter values. See Table IV.29b.

**Apart from items 5, 7, 8.

value of the released land to the railway companies is its opportunity cost for such uses.

(b) Tax savings and expenses

From the social point of view, taxes may be regarded as transfer payments and hence they are excluded from the calculation of benefits and costs. To individual companies, tax expenses are just as real as any other category of costs. Changes in property taxes as a result of change of the use of properties and changes in income taxes due to change in operating expenses and revenues would affect a railway company's benefit-cost position. In addition, relocation projects will often involve retirement of property that is not fully depreciated, capitalized investments in depreciable property, or capital loss or gain on certain retired assets. All of these would have tax implications which can only be fully assessed by experts in railroad accounting and taxes.

(c) Reduction in accident rates

It would not be society's willingness to pay nor the *ex post* economic costs associated with road-rail accidents that would enter a railwaycompany's calculation of benefits and costs. Rather, it would be the reduction in insurance costs and costs over and above those covered by insurance (such as delay of rail traffic, temporary loss of equipment, etc.) that the railway company would care about. Hence the value of a reduction in accident rates could be lower for railway companies than that for society.

It is not possible for us to determine the private benefits and costs of railway relocation to the railway companies due to the lack of data. However, based on the social benefits and costs estimated, we can get a crude indication of these private benefits and costs. These are illustrated in Table V.1. The capital costs and the change in operating costs would be the same as those estimated in Chapter IV. The values of released land and reduction in accidents would probably be smaller. In each case, unless the tax savings are considerable, the costs would exceed the benefits. Hence it would not be in the interests of the railways to relocate on their own initiative.

The nature of the benefits and costs of railway relocation are such that it is generally not beneficial to the railways to relocate on their own initiative. They would incur the net capital and operating costs. They would need to compensate the industries that would lose their rail service. These are generally the major cost items. The benefits to the railway would be the value of the released land, to the extent that this is increased by relocation and that the title remains with the company. The railway would also benefit from any resulting reduction in accidents. These generally represent only a small portion of the benefits of relocation. As a consequence it is unlikely that the benefits to the railway would exceed its costs.

The Railway Relocation and Crossing Act of 1974 (see Chapter VI) was passed to allow municipal governments to take the initiative in railway relocation proposals. Prior to 1974 the initiative lay solely with the railway companies, and as we have seen it was unlikely that they would find it beneficial to relocate.

B.2 Local Government

In Table V.2 we present the benefits and costs of railway relocation to a local government. Again these benefits and costs are somewhat different from the social benefits and costs discussed in the previous chapters.

The local governments will be concerned with the benefits of railway relocation to their constituents. These benefits include the time and cost savings to vehicle traffic, the net benefit of generated traffic, the reduction in accidents and the reduction in externalities in areas near the existing railways. The local governments may also benefit in a number of other ways. Some of the released land may revert to the local governments because of the conditions under which it was granted to the railways. The development of the released lands will raise the tax revenues of the local governments. The relocation may also reduce the expenditures that would be required for future grade separations. There may also be in-street maintenance costs at level crossings. The local governments may also be concerned about the changes in the number of industries and jobs located within their boundaries. Indeed in LUTS one of the major constraints employed in choosing among alternative relocation proposals was to minimize the impact on existing industries.

Under the existing legislation the local governments would share in the net cost to the railways of the relocation scheme. The local government share is not fixed in the legislation, but we argued above that 25 per cent is a reasonable estimate. The local governments would also share in the compensation payments to industries that lose

TABLE V.2

Benefits and Costs of Railway Relocation
to a Local Government (City of London)
($ million)

	CNR	Southern
Benefits		
1. Social benefits[a]	8.38	9.11
2. Value of released land reverting to the City of London	≥ 0	≥ 0
3. Increase in taxes[b]	13.80	16.55
4. Savings in future grade separation costs[c]	5.0	5.0
5. Savings in maintenance costs for streets, signals	?	?
6. Reduction in unemployment[d]	+	+
7. Reduction in crime	0	0
Total Benefits	27.18+	30.66+
Costs		
1. Capital costs and railway operating costs	6.38	9.20
2. Compensation paid to industries which lose rail service and/or relocate	0	0
3. Other social costs[e]	+	+
4. Loss of taxes due to relocation of industries and individuals	0	0
Total Costs	6.38+	9.20+

Notes: *The estimates are based on the set of middle parameter values. See Table IV.29b.

[a]Include all the social benefits identified in the previous chapters except the value of released land for redevelopment.

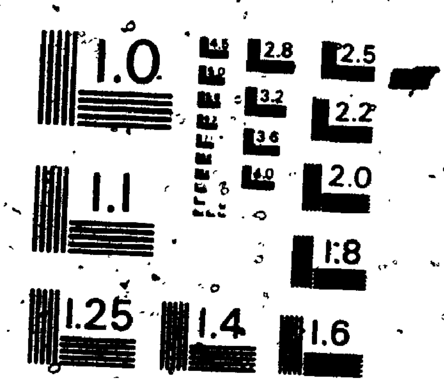
[b]Annual increase estimated by LUTS to be $1.0 million and $1.2 million for the CNR and Southern scheme respectively. The sum presented is the discounted present value assuming a time horizon of 50 years and a discount rate of 7%.

[c]Estimated to be $6.8 million by LUTS. However the sum should be discounted.

[d]There would be an increase in the number of jobs because of the construction work and the development of the released railway land.

[e]These include: increase travel costs for railway passengers and employees of industries which relocate, delay in traffic while construction is in progress.

3 OF/DE 3



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS - 1963 - A

ARC - 374

their rail service.

As can be seen from Table V.2 the distribution of benefits and costs is such that there is often a substantial net benefit for the local government even though there is no net social benefit. This situation arises largely because of the cost sharing arrangements in the existing legislation. There is a danger, therefore, that local governments may pursue relocation schemes that are socially inefficient because they provide a net benefit locally.

B.3 Industries

Among the industries affected by railway relocation, some may decide to relocate while others would remain at their original locations. The benefits and costs to these industries are listed in Table V.3. We shall not estimate these benefits and costs due to the lack of data.

TABLE V.3

Benefits and Costs of Railway Relocation to Affected Industries

Costs	Benefits
(Industries which do not relocate)	
1. Transportation cost may increase due to switch to an alternative mode etc.	
2. Costs of adjustment in production, storage and distribution.	
3. Inconvenience caused by readjustment.	
(Industries which relocate)	
1. Property acquisition and construction costs of new facilities etc.	1. Proceeds from the sale of old site and facilities etc.
2. Moving costs.	2. Improve in opereration efficiency due to more modern facilities and equipments.
3. Increase in transportation costs	3. Decrease in transportation costs.
4. Revenue losses due to change of location.	4. Revenue gains owing to new location.
5. Inconvenience caused by readjustment.	

CHAPTER VI

FINANCING OF URBAN RAILWAY RELOCATION PROJECTS

Railway relocation projects have been undertaken in several Canadian municipalities (see Table I.1). Prior to 1974 it was necessary to have the cooperation and agreement of the railways involved in order to carry out a relocation project. A municipality wishing to undertake a relocation project had to negotiate a settlement agreeable to the railways involved.

In 1974, the federal government passed the Railway Relocation and Crossing Act "to facilitate the relocation of railway lines or rerouting of railway traffic in urban areas and to provide financial assistance for work done for the protection, safety and convenience of the public at railway crossings." Under the provisions of the Act a municipality may take the initiative in railway relocation projects. It can evaluate a proposed relocation, and should it decide to proceed, can present the project to the Canadian Transport Commission (CTC). If the CTC decides that the project should proceed, it can order the railways to relocate in accordance with the proposal. In this case the Act specifies that the railways be made neither better nor worse off by the relocation. Hence, the voluntary agreement of the railway companies is no longer required to carry out a relocation project. As yet no relocation projects have been carried out under the provisions of the Act.

The next section outlines the principal provisions of the Act and the following section contains comments on some features of the legislation that may inhibit the realization of socially beneficial relocation projects.

A. The Railway Relocation and Crossing Act

The Act is divided into three parts. Part I deals with railway relocation projects. Part II provides special grants for the construction of grade separations. Part III deals with the financing of grade separation construction from the Railway Grade Crossing Fund. The financing shcemes specified in the various parts of the Act are summarized in Table VI.1. Part III simply updates the previously existing legislation with respect to the financing of grade separation construction from the Railway Grade Crossing Fund. Part II provides for the payment of special grants for the construction of grade separations where the costs are greater than can be financed from the Railway Grade Crossing Fund. These two parts of the Act are not of much interest to us, so we will focus on Part I which deals with railway relocation projects.

The procedure for railway relocation outlined in the Act is straightforward. As a first step, the governments of the province and of all the municipalities affected by the proposed relocation must prepare an urban development plan and a transportation plan. The Act provides that the federal government may pay up to fifty per cent of the cost of these studies. The remainder of the cost is shared in some manner by the provincial and municipal governments.

The Act specifies that the transportation plan must outline for some specified time "the layout of any streets, highways, bridges, railway lines, railway crossings at level or at grade separation, bus

TABLE VI.1

1974 Railway Relocation and Crossing Act - Financing Schemes

Part	Activity	Federal Share of Costs
I	(1) Studies (urban development or transportation plan)	- Up to 50% of total costs
	(2) Railway relocation/rerouting	- Up to 50% of "net costs of railway facilities"*
II	(1) Grade separation (new)	Special grant:
	(a) Total costs exceed $1.25 million but not more than $5 million	- $1 million plus an amount not greater than 60% of the costs in excess of $1.25 million
	(b) Total costs exceed $5 million	- $3.25 million plus an amount not greater than 40% of the costs in excess of $5 million
	(2) Grade separations (reconstruction)	
	(a) Total costs exceed $1.25 million but not more than $5 million	- $625,000 plus an amount not greater than 37.5% of the costs in excess of $1.25 million
	(b) Total costs exceed $5 million	- $2.031 million plus an amount not greater than 25% of the costs in excess of $5 million
III	(1) Grade separation (new)	From Railway Grade Crossing Fund:
		- Up to 80% of total costs or $1 million, whichever is less, plus 80% of the cost of any relocation of a public utility plant
	(2) Grade separation (reconstruction)	- Up to 50% of total costs or $625,000, whichever is less, plus 50% of the cost of any relocation of a public utility plant

*See definition in Table VI.2.

routes, rapid transit lines, railway stations, bus terminals, rapid transit stations and wharves and airports" in the affected area.

The Act requires that the urban development plan must specify "the development and use of land ... whereby it is proposed to control and regulate the use of such land for purposes of industry, commerce, government, recreation, transportation, hospitals, schools, churches, residences, homes for the elderly or for other purposes or classes of uses, with or without subdivisions of the various classes" in the affected area.

In terms of the railway relocation project, the transportation plan outlines which sections of the existing railway network are to be removed. It also specifies the locations of any new railway lines. Finally, it indicates which portions of the rail network will experience increases and decreases in the volume of rail traffic. The urban development plan specifies how the released land is to be used. It also specifies the land uses in the areas surrounding new rail lines and measures to alleviate the possible adverse consequences of increases in the volume of rail traffic.

Once the provincial government and the municipal governments affected agree upon the urban development and transportation plans they are ready to proceed with the second step. The Act specifies that all of the municipalities "materially affected" in whole or in part by the relocation project must agree to the proposed urban development and transportation plans.

The second step in the relocation procedure is that the municipalities file an application with the CTC. This must include the agreed transportation and urban development plan for the affected communities. It must also include a financial plan. The financial plan must show, among other things, "how the costs and benefits of the transportation plan included in the accepted plan are to be shared by the province, the municipalities concerned, the railways affected by the accepted plan and any other interests that may be affected thereby." The Act makes no provision for financial assistance towards the cost of preparing the financial plan. However, it appears that the content of the transportation and urban development plans could be specified in such a manner that all of the data required to prepare the financial plan would be available from those studies.

The Act does not specify that the social benefits of a proposed relocation project must exceed the social costs. Presumably applications for socially inefficient projects could come before the CTC. The CTC would have to decide whether or not such projects should proceed.

The Act does require that the financial plan be such that the railway companies neither gain nor lose from the relocation project. In other words, the railway companies must pay or receive sufficient compensation to make their costs and benefits equal.

The Act does not specifically mention the industries that lose their rail service. However, the Railway Act outlines the conditions under which rail service to an industry can be terminated. In essence these conditions require the railway companies to pay adequate compensation to the firms that lose their rail service. The railways would be reimbursed for these compensation payments.

The third step in the procedure is a public hearing held by the CTC. This provides an opportunity for any individual or group to express support for or opposition to the proposed relocation project.

The railway companies and firms losing their rail service might wish to raise objections to the project. Households and firms adjacent to the new location also might wish to object. The municipalities submitting the application would be expected to support the project.

Based on the material submitted and the evidence presented at the public hearing the CTC must decide whether or not the project should proceed. The CTC may accept the project as submitted, or it may specify that various changes must be made to the plans submitted.

Once a plan acceptable to the CTC is developed the project can proceed. The implementation of the project is the fourth step. To carry out this step the CTC issues the necessary orders to the railway companies. These orders outline all of the actions required of the railway companies in order to carry out the project -- the construction of new facilities, the removal of existing facilities, etc.

The CTC may also recommend to the Minister of Transport that a "relocation grant" be paid to meet part of the cost of implementing the accepted plan. The relocation grant may be up to fifty per cent of the net costs of the railway relocation project. The Act defines how the net costs of the project are to be calculated. The calculation is summarized in Table VI.2. It is interesting to note that the Act specifies that the difference in railway operating and maintenance costs is to be capitalized over a 15-year period and that the discount rate is to be established jointly by the CTC and the federal Department of Finance.

TABLE VI.2

Calculation of the Net Costs of Relocation

NET COSTS OF A RAILWAY RELOCATION	=	COSTS OF NEW RAILWAY FACILITIES	±	DIFFERENCE BETWEEN NEW & EXISTING MAINTENANCE & OPERATING COSTS OF FACILITIES	±	DECREASE OR INCREASE IN THE VALUE OF THE RELEVANT LAND
		adjusted costs		adjusted costs		
↓		↓		↓		↓
costs for which a 50% "relocation grant" is applicable under section 11(2)		exclude costs of any land or grade separations required as a result of a C.T.C order		costs calculated at current capitalized values[1] over a 15-year period at an interest rate[2] established by the C.T.C: and Dept. of Finance		land owned by railway company which value is affected by a C.T.C. order

Source: Damas and Smith presentation.

[1]Present values. [2]In accordance with Part I, Section 11(3).

B. Comments on the Railway Relocation and Crossing Act

The Railway Relocation and Crossing Act gives the Canadian Transport Commission considerable scope in terms of evaluating railway relocation proposals. No proposals prepared under the terms of the Act have yet been considered by the Commission. Therefore, it is not yet possible to judge how well the Act will work.

The Act contains several features that merit comment because they may inhibit the realization of socially desirable railway relocation projects. These features are discussed below.

The Act does not specify the criteria on which railway relocation projects are to be evaluated. There is no requirement in the legislation that aggregate social benefits exceed aggregate social costs. The only legislative requirement is that the railways do not lose or gain financially. Unless the Canadian Transport Commission adopts the criterion that social benefits exceed social costs it is possible that inefficient projects may be approved.

The initiative for undertaking a railway relocation project lies with the municipalities affected and the provincial government. It may be difficult for these governments to achieve the unanimity required by the Act because of differing priorities. Assuming that all of the governments agree that a specific railway relocation project is a priority and assuming that the project is socially beneficial, the governments may yet decide not to proceed. They may be reluctant to proceed because of the expenditures involved. In most relocation projects the costs are out-of-pocket costs incurred primarily by the railways. Under the terms of the legislation the railways must be reimbursed for the net amount of their costs. This will generally require payments from the federal, provincial and municipal governments to the railways. The benefits derived from most relocation projects accrue largely to the motorists and property owners of the area. The municipal governments may find it politically very difficult to justify the payments to the railways in return for these benefits. The payments are highly visible while the benefits accrue in small increments to a very large number of recipients who cannot be taxed in relation to the benefits they receive.

The financing scheme provided in the Act is probably not equitable. Most of the benefits of a relocation project accrue to the local motorists and property owners. However, the Act provides that the costs be shared by the federal, provincial and municipal governments. The federal share may be up to fifty per cent. Hence, the majority of the costs may be borne by residents outside of the communities where the project is located, while almost all of the benefits accrue to the residents of those communities. This has the effect of redistributing income from other parts of the country to the residents of communities that undertake railway relocation projects.

The requirement that the railways be made neither better nor worse off as a result of a relocation project may be difficult to realize. In Canada, there are no independent experts with an accurate knowledge of railway capital and operating costs. And the railway accounting systems are so complex that accurate unit cost data are almost impossible to estimate. Thus, the data used to determine whether the railways will gain or lose are likely to be biased.

The requirement that the railways neither lose nor gain may also be difficult to implement for another reason. There will be no problem if the financial plan accepted by the CTC leaves the railways neither better nor worse off and if the settlement incorporated into the plan is final. If the settlement is not final the railways could claim additional compensation should the capital or operating costs be higher than expected. And if the railways are allowed to claim additional compensation they would have little incentive to minimize their costs.

The Railways Relocation and Crossing Act does not mention industries whose rail service will be discontinued as a result of a relocation project. The responsibilities of the railway companies to provide such service are outlined in the Railway Act. Conceptually, then the railways are responsible for negotiating the discontinuation of rail service with the industries affected. Since the railways are aware of the transportation needs of these industries and since they know the alternatives, this appears to be a good provision. However, the railway companies have no incentive to minimize the compensation paid to an industry that is forced to switch to a higher cost mode of transportation or to relocate to a site where rail service will be available. These compensation payments would be costs to the railways for which they would have to be reimbursed in order not to be made worse off. As a consequence, it may prove less costly for the municipalities undertaking the project to negotiate directly with the affected industries even though they have less information on the costs of the possible alternatives.

The foregoing comments are simply potential difficulties in the realization of socially beneficial railway relocation projects. It must be stressed that they are potential difficulties. No proposals have yet been considered by the CTC. Until such proposals are considered we will not know whether these difficulties and/or others will be encountered, and how serious they will be.

APPENDIX A

A REVIEW OF RAILWAY RELOCATION STUDIES

Literature on railway relocation is scarce. To our knowledge the Winnipeg Railway Study is the most comprehensive study of railway relocation in Canada. In the United States, the Department of Transportation has recently published part of a report on this subject. In this appendix we shall briefly review the following railway relocation studies:[1]

(1) Damas and Smith (33), Winnipeg Railway Study (WRS).

(2) Dillon, M. M. (36), The City of Sault Ste. Marie C. P. Rail Relocation Study.[2]

(3) DeLeuw Cather (34), London Urban Transportation Study (LUTS).

(4) U.S. Department of Transportation (42), Guidebook for Planning to Alleviate Urban Railroad Problems.

(1) Winnipeg Railway Study.

This is a three-quarter million dollar study which purports to be a prototype or blueprint for further railway relocation schemes across Canada. It is a comprehensive study. In the technical report a number

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[1]Another study which came to our attention at a late stage is Rotoff's, "Impact of Railway Relocation in Urban Areas" (38). However, we have been able to obtain only what appears to be a summary paper and hence cannot comment on its methodology and results.

[2]Another study by M. M. Dillon is "The City of North Bay Railway Rationalization Study" (35), which employs the same approach as that in the Sault Ste. Marie study.

of excellent points and fine distinctions are made. The treatment of capital costs and change in railway operating costs is very detailed and most of the real benefits associated with railway relocation are identified.

The terms of reference of the study specified that the railway relocation study was to assume that the recommendations of the Winnipeg Area Transportation System study would be implemented. These recommendations outlined a system of freeways and expressways, a rapid transit system, and a program of grade separations. The railway relocation schemes allowed some of the released lands to be used for the recommended freeways and expressways. This reduced the estimated costs (primarily land acquisition) of implementing the recommended system. The railway relocation schemes also eliminated the need for some of the recommended grade separations. Again the result was a reduction in the cost of implementing the recommendations. Consequently the list of benefits and costs, shown in Table A.1, includes the savings in implementation of the railway grade separation program and the urban transportation program as benefits.

In addition to the costs and benefits listed in the summary table, the study mentions a number of other "social and environmental" effects. These effects are not quantified and are not explicitly included in the aggregate cost and benefit estimates.

The social effects include items such as changes in the number of jobs and housing units in the areas affected by redevelopment. These effects are primarily distributional in nature. The environmental effects include noise and visual pollution in the areas surrounding existing and new railway facilities. These effects have a

TABLE A.1

Benefits and Costs of Railway Relocation
(million dollars)

	Costs of Railway Relocation	Costs of Industrial Relocation	Savings in Railway Grade Separation Program	Savings in Urban Transportation Program	Gains in Developed Property Values
Program 1	75.7	1.8 - 2.9	18.4	44.6	7.2
Program 2	48.9	1.9 - 3.0	16.2	39.4	6.6
Program 3	71.9	2.4 - 3.8	11.4	39.8	8.7
Program 4	85.5	2.7 - 6.0	17.7	45.1	6.3

Source: Damas and Smith (33), Summary Report.

distributional aspect in that the residents of areas near facilities to be relocated gain while those in areas near the new facilities suffer. The net effect should be included in the "gains in developed property values."

(2) <u>The City of Sault Ste. Marie C. P. Rail Relocation Study</u>

This is mainly an engineering study. It gives a detailed discussion of capital costs and change in railway operating costs and it touches costs of industry relocation. Almost nothing is said about the benefits.

(3) <u>London Urban Transportation Study</u>

The railway relocation study is only a part of the total urban transportation study. Like the Sault Ste. Marie study, it is basically an engineering study. The emphasis is on capital costs and changes in railway operating and maintenance costs. It does however, touch upon some benefits of railway relocation in an *ad hoc* manner. No attempt was made to estimate these benefits except the value of released land. In Chapter IV we comment in detail on the estimated costs and the value of released land.

(4) <u>U.S. Department of Transportation Study</u>

The study consists of four volumes. Only volume 3, <u>Guidebook for Planning to Alleviate Urban Railroad Problems</u>, has been published. The purposes of this volume are "to suggest an appropriate approach to planning for community policy makers, to outline analytical processes to be used by technical specialists and to provide supporting data" for studies of railway relocation.

Among the four studies reviewed here, the U.S. study is closest to our own in its approach. The costs and benefits of railway relocation identified are similar to those in our study. However, the study follows a somewhat different approach in estimating some of the benefits.

Unlike our study, the discussion of benefits and costs in the U.S. study is carried out on a group by group basis. The main groups identified are: railway companies, highway users, railway users, residents and tenants of adjacent property, the community, the state and nation. The main weakness of the study appears to be the failure to show how the benefits and costs of the various groups of people may be combined and compared. Thus, even if we succeed in estimating every item of the benefits and costs of the various groups we are not given a guide as to how these items may be used in an evaluation. Towards the end of the volume, the study mentions the distinction between aggregative and distributional cost-benefit analysis, however, it does not show which items belong to each type of analysis.

Despite its length the U.S. study does not go into any detail in discussing the theoretical and estimation problems in evaluating railway relocation projects. The valuation of environmental externalities is almost completely ignored. The study does not contain an actual case study of evaluation of railway relocation, although illustrative materials, apparently drawn from some case studies, are used.

APPENDIX B

VALUE OF TRAVEL TIME

B.1 Empirical Estimates of Value of Travel Time

Various methods have been used in recent years to derive a value of travel time by analysis of situations where people can make choices between different "packages" of time, cost and other travel characteristics. The areas of choice where work has been attempted include:[1] (a) choice of destination to travel to, of frequency of trip making to a particular destination;[2] (b) choice of mode of travel;[3] (c) choice of route;[4] (d) choice of speed at which to drive;[5] and (e) choice of relative locations of home and work.[6]

Most works on value of time have been done in areas (b) and (c). Some empirical results of these studies are summarized in Table B.1. It appears that for work trips travel time is valued at 20 to 50 per cent

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[1]For a discussion of the methodology of these studies, see Harrison and Quarmby (49).

[2]For example, N. W. Mansfield, "Trip Generation Functions and Research into the Value of Time," as cited in Harrison and Quarmby, ibid.

[3]For example, Beesley (43), Gronau (47), Moses and Williamson, (58), and Quarmby (62).

[4]For example, T. C. Thomas, "The Value of Time, for Passenger Cars: An Experimental Study of Commuters' Values," as cited in Harrison and Quarmby, op. cit.

[5]Mohring (56).

[6]Mohring (197) and Wabe (66).

TABLE B.1

Value of Time from Choice of Route

Study	Date	Modes	Place	Value of Time (% of wage rates)		
				Travel	Wait	Walk
Claffey	1961	Auto: toll free	U.S.A.	33		
Beesley	1963	Auto-transit	London, G.B.	31-50		
Quarmby	1967	Auto-transit	Leeds, G.B.	20-25	40-70	40-70
Lave	1969	Auto-transit	Chicago	42		
Lee & Dalvi	1969			30		
Lisco	1967	Auto-transit	Chicago	25-50		3 x travel
Thomas & Thompson	1971	Auto: toll free	U.S.A.	21-40		

Source: Dewees (91), Table A.1

of wage rates, while the value of waiting or walking time saved is twice or three times that of in-vehicle time saved. According to Mohring, the following assertions can be made with reasonable assurance:

> "The amounts commuters would be willing to pay appear to be closely related to their wage rates or the hourly equivalent of their annual salaries. Specifically, workers with incomes in the $5000 a year range appear willing to pay an amount equal to 25-30 percent of their hourly wage rate to save travel time. Increases in income above that level are associated with increases in the ratio of travel time value to wage rate. Beyond $10,000 - $12,000 a year, this ratio appears to stabilize at about 50 percent. Information to determine whether these relationships also hold for travel activities other than commuting is not presently available."[7]

Most of the studies have been concerned with commuting time, but Thomas and Thompson (63) attempted to derive value of time by trip purpose, income level and the amount of time saved. A non-linear relationship is found to exist between the value of time and the size of time savings. Twenty minutes of travel time saved is valued more than twice ten minutes saved.

B.2 Trend in Value of Travel Time

Since the real wage rate may increase over time, the real value of travel time may increase as well. In this part of Appendix B, we give some estimates of the present discounted value of savings in travel time under the three proposed relocation schemes described in Chapter IV. We assume that the future trend in the value of travel time will be equal to the past trend in the real wage rate in Canada.

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[7]Mohring (57), pp. 76-77.

From 1950 to 1974, the real hourly wage rate of composite industrial workers in Canada grew at an annual rate of 2.33 per cent compounded. Given this figure, we may assume that the value of travel time will increase at 2 per cent per annum compounded. Table B.2 gives estimates of the present discounted value of savings in travel time and vehicle operating expenses assuming a 2 per cent annual growth rate in the real value of time, starting from a base in 1972 ranging from $.70 to $1.80 per man-hour.

These results may be compared with the results presented in Table IV.6. The only difference between the two tables is the different trend in the value of travel time assumed. As one may expect, the present discounted value of savings increase when the value of travel time is assumed to grow at 2 per cent per annum. Under the set of "low" and "middle" estimates, the difference between the estimates of the two tables are not large. However, there is a big difference between the two sets of "high" estimates. This is not surprising: with the "high" estimates in Table B.2, the trend in the value of travel time (2 per cent) and the trend in motor vehicle traffic (3 per cent) together exceed the discount rate (4 per cent), and hence we have a "runaway" case.

TABLE B.2

Present Discounted Value of Savings in Travel Time and Vehicle Operating Expenses in Million Dollars; Trend in Value of Travel Time Equal to 2% Per Annum

Value of Travel Time	CNR			Southern			Complete		
	L	M	H	L	M	H	L	M	H
A	2.42	4.75	25.78	2.30	4.53	25.14	3.75	7.28	37.91
B	2.97	5.88	33.24	2.84	5.66	32.62	4.53	8.88	48.45
C	3.52	7.01	40.69	3.39	6.79	40.16	5.25	10.38	58.31

Notes: Values of travel time assumed under A, B, C are the same as those given in Table IV.4. For the sets of L (Low), M (Middle), and H (High) parameter values used, see Table IV.28.

APPENDIX C

ESTIMATION OF SAVINGS IN ROAD TRAVEL TIME AND VEHICLE OPERATING EXPENSES

C.1 Purpose

In this appendix we show in detail how we estimate the following categories of savings in travel time and vehicle operating expenses: H_1, H_2, H_3, G_1, G_2 and G_3. We are unable to estimate H_4, H_5, H_6, G_4 and G_6 because of lack of data.

C.2 Source of Data

(a) Road traffic flow data

Vehicular traffic flow data are collected by the Traffic Control Department of London for various intersections in the city for the purpose of traffic control.[1] The data are for numbers of vehicles per lane per hour. The recording period is usually from 7 a.m. to 6 p.m. For some intersections, 24-hour records are available. The recording is usually done on a single weekday.

The quality of the data, in general, is good. However, there are certain shortcomings which should be noted, for example:

(i) For most of the intersections, 1970 to 1973 data are available, but for some intersections we have data only for

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[1] There is some vehicular traffic flow data in the two urban transportation studies DeLeuw Cather (34) and Margison and Associates Limited (153, 154). However, they are for selected roads or intersections only.

earlier years. Fortunately, the latter are usually minor streets with low volumes of traffic.[2]

(ii) Most of the data are confined to the 7 a.m. - 6 p.m. period. We have to rely on the 1966 Traffic Report[3] to derive estimates for the other hours of the day.

(iii) They represent a single day's record, and not average traffic flow over time, and no data are available for weekends.[4]

(iv) They are for intersections which usually do not correspond exactly to road-rail crossings. We assume that the traffic flow is the same at these intersections and the nearby road-rail crossings.

(v) No distinction is made between passenger cars, transit buses, and commercial vehicles.[5] There are no data for pedestrians or bicycles.

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[2]We did not project the growth of the traffic flow on these roads because the changes over time were not clear. On some of these roads, vehicular traffic might decline.

[3]Margison and Associates Limited (154). This report has data on daily and weekly distribution of vehicular traffic in London.

[4]We use the Margison and Associates Limited (154) study to get estimates of traffic flow for weekends.

[5]At some intersections, separate data can be found for passenger cars and trucks.

(b) Train traffic flow data

The main source of daily train traffic data was the 1974 London Urban Transportation Study. Personal interviews with CNR and CPR superintendents were another source. The following publications also provide some information: CNR (193) Express and Freight Trains Service Design Specifications; CNR (129) CN Great Lakes Region Southwestern Ontario Area Employees' Operating Time Table 55; CNR (128) Freight Equipment; and CPR (130) Eastern Region Time Table 44.

C.3 Estimation of Road Travel Time Saved

In Chapter III we derived the following formulae:

$$H_1 = \sum_d \sum_k \sum_t \sum_i \sum_j \left(\frac{G_{jitkd} \, C_{tkd}}{1 - AG_{jitkd}} \right) \left(\frac{C_{tkd} - A}{2} \right)$$

$$H_2 = \sum_d \sum_k \sum_t \sum_i \sum_j \left(\frac{G_{jitkd} \, C_{tkd}}{1 - AG_{jitdk}} \right) \left(\frac{T_{jitkd}}{2} \right)$$

where

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

C_{tkd} = ~~time~~ in hours crossing k is closed as train t passes on day d;

A = time in hours before the second road vehicle starts after the first starts as a train leaves a crossing;

T_{jitkd} = time in hours that a road vehicle takes to accelerate back to its normal speed in lane j in direction i at crossing k as train t passes on day d after being stopped at a level crossing. Due to lack of data we will assume all T_{jitkd} to be equal to the time taken to accelerate from rest to 20 mph.[6]

To calculate H_1 and H_2 we make the following assumptions:

(a) A = .00028 hour or approximately 1 second (based on actual observation);

(b) T_{jitkd} = .0014 hour or approximately 5 seconds (based on actual observation); and

(c) $G_{jitkd} = G_{jikd}$ = average hourly vehicular traffic in direction i on lane j at crossing k on day d.

Also since data on C_{tkd} are not available we have to estimate C_{tkd}. The formula which we used is the following:

$$C_{tkd} = \frac{n_{tkd}}{s_{tkd}} + z_k$$

where

n_{tkd} = length of train t in miles at crossing k on day d;

s_{tkd} = speed of train t in miles per hour at crossing k on day d;

z_k = time in hours that crossing k will be closed before a train actually arrives and after it leaves.

We do not have data on n_{tkd} or s_{tkd}, and hence each of these must

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[6]Margison, A. D., and Associates Ltd. (183) found the average speed to be 15 to 20 mph. during the evening peak hours. We adjust it upward for the daily average.

be estimated. We estimate n_{tkd} by the number of cars and engines per train and the average length of train cars and engines. Table IV.2 in Chapter IV presents the average number of cars per train on various routes. From the working papers of LUTS we also obtained information on the average number of engines per freight train. For passenger trains we assume one engine per train. The average lengths of freight cars, passenger cars, and engines are estimated to be 60, 86, and 50 feet respectively.[7] Estimated speeds of trains vary depending on specific locations; they are shown in Table C.1.[8] z_k is estimated to be 30 seconds or .0083 hour for freight trains and 20 seconds or .0069 hour for passenger trains at all crossings.[9] Thus, the formula which we use in determining the average blocking time (in hours) per train is:

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[7] Calculations based on CNR (128) show that the average length of freight cars is approximately 51 feet. However, in personal interviews with the superintendents, it was found that the freight trains that pass through London have relatively more automobile cars which have an average length of 90 feet. Hence we raise the average length of train cars to 60 feet. (The U.S. Department of Transportation (42) study suggests a figure of 50 feet.) For passenger trains the car length is usually 86 feet. The average length of engine cars is around 50 feet.

[8] These estimated speeds are based on CPR (130) and CNR (129).

[9] The Canadian Transport Commission regulation requires that red lamps start to flash and/or gates be closed at least 20 seconds before the fastest train reaches the crossing. At most of the protected level crossings, this is achieved by track circuits and other electronic devices. See U.S. Department of Transportation (80) for detailed discussion of the various devices. Since the 20-second time requirement applies to fast trains, the actual time for slower trains will be longer. This was confirmed by actual observation at some railway crossings in London.

$$C_k = \left[\frac{60\, m_k}{5280\, s_k} + \frac{50\, q_k}{5280\, s_k} \right] + .0083 \quad \text{(Freight trains)}$$

$$C_k' = \left[\frac{86 \times 8}{5280\, s_k} + \frac{50}{5280\, s_k} \right] + .0069 \quad \text{(Passenger trains)}$$

where

C_k, C_k' = average time in hours per train crossing k is blocked by freight and passenger trains respectively;

m_k = average number of cars per train at crossing k;

q_k = average number of engines per freight train at crossing k;

s_k = average speed of train in miles per hour at crossing k.

Even though we know the number of freight trains passing each crossing daily we do not have the exact time schedule.[10] However, we have information on the approximate number of trains going through London per time period during the whole day. The reason for raising this point is that vehicular traffic is heaviest during certain periods of the day and is very light in other periods. The delay of vehicular traffic caused by a train would be quite different depending on the time that the train passes through the city. We estimated that approximately 60 per cent of train traffic and 95 per cent of vehicular traffic occur during the 7 a.m. - 12 p.m. period.[11] We make separate

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[10]For some freight trains there are fixed schedules, see CPR (130) and CNR (129), but these may not be adhered to.

[11]The train traffic information is obtained from the working

calculations for this period and for the rest of the day.

We also distinguish between Sundays and other days. We estimate that Sunday traffic (both train and vehicles) is approximately 80 per cent of that on other weekdays.[12]

Thus, our modified formulas for H_1 and H_2 are:

$$H_1 = 313x + (.64)\ 52x$$

$$H_2 = 313y + (.64)\ 52y$$

and

$$x = \sum_u \sum_k \sum_i \sum_j t_k^u \left(\frac{G_{jik}^u C_k}{1 - .00028\, G_{jik}^u} \right) \left(\frac{C_k - .00028}{2} \right) +$$

$$\sum_u \sum_k \sum_i \sum_j w_k^u \left(\frac{G_{jik}^u C_k}{1 - .00028\, G_{jik}^u} \right) \left(\frac{C_k - .00028}{2} \right)$$

$$y = \sum_u \sum_k \sum_i \sum_j t_k^u \left(\frac{G_{jik}^u C_k}{1 - .00028\, G_{jik}^u} \right) \left(\frac{.0014}{2} \right) +$$

$$\sum_u \sum_k \sum_i \sum_j w_k^u \left(\frac{G_{jik}^u C_k}{1 - .00028\, G_{jik}^u} \right) \left(\frac{.0014}{2} \right)$$

where

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papers of DeLeuw Cather (34), supplemented with information provided by CPR (130) and CNR (129). The road traffic information is based on the Margison and Associates Limited (153, 154) study.

[12] *Ibid.*

t_k^u = number of freight trains per day at crossing k during period u;

w_k^u = number of passenger trains per day at crossing k during period u;

G_{jik}^u = vehicular traffic flow per hour in direction i on lane j at crossing k during period u;

u = 1 (7 a.m. - 12 p.m.); 2 (12.01 a.m. - 6.59 a.m.).

The empirical results for H_1 and H_2 are shown in Table C.1 for individual crossings and in Table C.2 for individual relocation schemes.

In Chapter III, the formula developed for estimating savings in travel time without going through the decelerating and accelerating process is:

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

where e_{kd} is the loss in time (hours) per vehicle while passing level crossing k on day d and ADT_{kd} is the number of vehicles (excluding those stopped by trains) passing crossing k on day d.

No data on e_{kd} exist, and we employ an average estimated in the following manner. Assuming the average speed of vehicles travelling in London is 20 miles per hour and motorists reduce their speed by a maximum of 40 per cent in crossing a typical level crossing,[13] then the average speed in traversing a level crossing is 16 miles per hour. Assuming the distance from the point of slowing down to the point of returning

[13] Amount of speed reduction based on U.S. Department of Transportation (42) study.

TABLE C.1

Road-Rail Level Crossings Within the City of London

Level Crossings	(a)	Train Speed (mph)	No. of Trains/Day		No. of Lanes	Road Traffic Flow Per Direction		Vehicle Hours Saved Per Year		
			Freight	Passenger		1	2	$\bar{H}_1$ [(c)]	$\bar{H}_2$ [(c)]	H_3
S/D Dundas										
1. Colborne	T,Cr	15	23	11	2	220	246	4678	128	404
2. Burwell	T	15	23	11	2	62	68	1251	31	107
3. Maitland	T	15	23	11	2	70	52	1177	28	104
4. William	T	15	23	11	2	46	70	1118	28	101
5. Rectory	T	10	23	11	2	120	112	1454	48	203
6. Egerton	T,Cr	20	23	11	2	200	310	3203	114	461
7. Trafalgar	T,Cr	20	23	11	2	230	202	2836	97	388
8. Clark Side	S,Cr	55	23	11	2	151	172	509	35	300
9. Gore	S	55	23	11	2	54	60	169	10	104
10. Crumlin	S	55	23	11	2	54	60	169	10	104
S/D Strathroy										
11. Ridout	T,Cr	15	23	14	2	454	202	6437	187	581
S/D Thorndale										
12. Huron	C,S,T	55	8	5	2	70	94	62	7	153
13. Clark Side	C,S,T	55	8	5	2	254	280	194	17	494
14. Oxford	C,S,T	55	8	5	4	282	234	197	17	475
15. Third	T	35	8	5	2	105	-	100	10	96
16. Second	T	35	8	5	2	82	-	76	7	76
17. First	T	35	8	5	2	40	52	52	3	35
18. Dundas	C,S,T	30	8	5	4	776	830	647	83	1521
19. Highbury	C,S,T	25	8	5	4	608	504	938	69	1027
20. Ashland	C,S,T	25	8	5	2	40	35	59	3	68
21. Egerton	C,T	15	8	5	2	200	310	987	41	446
S/D Talbot										
22. Bathurst	T	10	4	0	2	150	138	401	10	252
23. Maitland	T	10	4	0	2	70	95	225	7	145
24. Hamilton	T	10	4	0	4	500	497	727	38	921
25. Horton	T	10	4	0	2	460	423	1350	38	775
26. Simcoe	T	10	4	0	2	101	117	298	7	174
27. Grey	T	10	4	0	2	215	-	608	17	174
28. Hill	T	10	4	0	2	50	62	152	3	91
29. South	T	10	4	0	2	9	9	21	0	9
30. Nelson	T	10	4	0	2	5	8	17	0	9
31. Philip	T	10	4	0	2	5	8	17	0	9
32. Thompson	C,S,T	25	4	0	2	262	320	207	7	523
33. Commissioners	C,S,T	25	4	0	4	575	442	363	21	948
34. Wilton Grove		25	4	0	2	80	92	55	3	135
35. Green Valley		25	4	0	2	16	20	14	0	24
36. Adelaide	T	10	4	0	4	480	518	349	17	921
S/D Galt										
37. Crumlin	C	55	14	0	2	50	170	83	3	194
38. Industrial	C	55	14	0	2	45	50	69	3	76
39. Clark Side	T	55	14	0	2	330	322	519	31	562
40. Third	T	35	14	0	2	105	-	291	14	93
41. Second	T	35	14	0	2	82	-	282	10	68
42. First	T	30	14	0	2	40	51	152	3	77
43. Adelaide	T	15	14	0	4	400	223	3507	80	580
44. William	T	15	14	0	2	85	73	858	21	135
45. Maitland	T	15	14	0	2	47	50	2185	10	75
46. Colborne	T	15	14	0	2	47	92	734	17	105
47. Pall Mall	T	15	14	0	2	94	100	1056	24	151
48. Waterloo		15	14	0	2	240	236	2755	66	407
S/D Windsor										
49. Richmond	C,S,T	15	13	0	4	544	560	5772	73	969
50. St. George	C,S,T	15	13	0	2	86	160	1225	17	191
51. Hutton	C,S,T	50	13	0	2	130	112	197	3	203
Interchange [(b)]										
52. Francis	T	5	5	0	2	58	50	62	3	92
53. Florence	T	5	5	0	4	606	450	671	38	950
54. York	T	5	5	0	2	160	200	221	10	315
55. King	T	5	5	0	2	259	-	315	17	208
56. Dundas	T	5	5	0	4	416	542	602	31	872
57. Elias	T	5	5	0	2	50	70	73	3	95
58. Oxford	T	10	5	0	4	598	550	315	24	848

Notes: (a) C,S,T denote level crossings to be removed under the CNR, Southern and Complete schemes respectively; Cr denotes to be grade separated under the CNR scheme.

(b) The number of train cars passing the interchange line is approximately 35. We assume it to be equivalent to 5 trains with 7 cars each.

(c) We use $\bar{H}_1$ and $\bar{H}_2$ instead of H_1 and H_2 because savings due to train traffic reduction are not included here.

TABLE C.2

Savings in Daily and Annual Vehicle Hours Under Different Relocation Schemes

	CNR		Southern		Complete	
	Daily	Annual	Daily	Annual	Daily	Annual
H_1	124.2	43,008	132.5	45,882	153.4	53,119
H_2	3.5	1,212	3.7	1,281	5.2	1,800
H_3	25.7	8,899	20.3	7,015	50.5	17,487
Total	153.4	53,119	156.5	54,178	209.1	72,406

to normal speed is 150 feet, the time lost in slowing down and speeding up again is approximately 1 second. Thus e_{k0} is estimated to be 1 second or .00028 hour. Also since the traffic on Sundays is approximately 80 per cent of that of other weekdays, we distinguish between Sunday and other weekdays in our modified formula for H_3, which is as follows:

$$H_3 = 313 \sum_{k=1}^{K} .00028\ ADT_k + 52 \sum_{k=1}^{K} .00028 \times .64 \cdot ADT_k$$

For the CNR and Southern schemes, there is another source of time saving which must be considered, i.e., changes in rail traffic. Some of the level crossings will remain as a result of one or both of the schemes. However, the train traffic at some of these crossings would be changed due to the relocation of the main railway lines. Based on the estimated changes in train traffic we have calculated that the daily and annual vehicle hours saved from this source are as follows:[14]

---

[14] The change in train traffic at various crossings is summarized in the following table. These estimated changes are based on comparison of the number of daily revenue cars generated locally and the number of through train cars.

	Subdivision	Crossing Number	Train Traffic Change
Southern scheme			
Freight trains:	Dundas	(1) to (7)	reduced by 9/10
	Strathroy	(11)	reduced by 9/10
	Thorndale	(15),(16),(17)	reduced by 9/10
		(21)	reduced by 2/3
	Talbot	(22) to (31),(36)	reduced by 9/10
	Galt	(39) to (48)	reduced by 9/10
	Windsor	All level crossings eliminated	
	Interchange		none
Passenger trains:	relocated outside the city		

(footnote continued on next page)

	CNR	Southern	Complete
Daily	41.4	102.1	0
Annual	14,336.0	35,355.0	0

The figures for total annual vehicle hours saved from the various sources under each of the relocation schemes are shown in Table C.2.

We convert vehicle hours saved into man hours saved using the information in Table C.3.[15] The man hours of travel time saved per year for the three relocation schemes are:

	CNR	Southern	Complete
Passenger auto	64,028	65,304	87,278
Passenger transit	15,930	14,892	22,170
Commercial vehicle	12,280	12,525	16,739

	Subdivision	Crossing Number	Train Traffic Change
CNR scheme			
Freight trains:	Dundas	(2) to (5),(9),(10)	increase by 14 trains daily
		(1),(6),(7),(8)	none
	Strathroy		none
	Thorndale	(15),(16),(17)	reduced by 9/10
	Talbot	(22) to (31),(36)	reduced by 9/10
	Galt	(39) to (48)	reduced by 9/10
	Interchange	(52) to (58)	reduced by 9/10
Passenger trains:	No change		

[15]Transit driver man hours are separated from transit passenger hours and are included in the commercial truck category.

TABLE C.3

Mode of Travel and Average Number of People Per Vehicle

Mode of Travel	Per Cent of Vehicles	Average Number of People Per Vehicle
Passenger car	81.5	1.47
Commercial vehicle	16.6	1.32
Public transit (bus)	1.9	15.90

Source: Margison and Associates Limited (153).

C.4 Estimating the Savings in Vehicle Operating Expenses

Vehicle operating expenses include fuel and oil consumption, tire wear, maintenance, depreciation, etc. Based on the results of a Highway Research Board Study,[16] we have some information (which is presented in Table C.4) on fuel costs of idling and extra gas, tire wear, oil and maintenance cost incurred per slowdown speed change cycle.

To estimate G_1 (idling costs), we assume that 80 per cent of H_1 are passenger auto hours and the rest are commercial vehicle hours.[17] Multiplying the annual savings in passenger auto hours by .48 and that of commercial vehicle hours by .54, we obtain the annual savings in gallons of gas for not undergoing the idling process at level crossings.[18]

To estimate G_2 we again assume that 80 per cent of the vehicles stopped at level crossings are passenger cars and the rest are commercial vehicles. We multiply the number of vehicles stopped by the appropriate value in Table C.4b. Savings in other operating expenses are calculated by multiplying the number of passenger and commercial vehicles stopped by .33 and .49 respectively.

---

[16] National Cooperative Highway Research Program Report III (162).

[17] Based on the Margison and Associates (154) study. For Canada, the number of passenger autos registered is approximately four times the number of commercial vehicles registered. See Statistics Canada (177). The same ratio holds for London.

[18] H_1 consists both of idling time and decelerating time. Since the latter is a very small portion of the total (probably in the same magnitude as H_2) we do not separate it out in our calculation. In other words H_1 is assumed to be all idling time.

TABLE C.4

Vehicle Operating Expenses

(C.4a) Idling Fuel Consumption Rates with Vehicles Stationary[a,b]

Type of car	Fuel Consumed (GPH)
Composite passenger auto[c]	.48
Commercial vehicle[d]	.54
Transit (bus)	.55

(C.4b) Excess Gallons of Gasoline Consumed Per Stop-Go Speed Change Cycle

	Duration of Stopped Delay = 0
Composite auto	.0068
Commercial vehicle	.0113

(C.4c) Excess Gallons of Gasoline Consumed Per Slowdown Speed Change Cycle[b]

Composite auto	.0028
Commercial vehicle	.0064

(continued)

TABLE C.4 (continued)

(C.4d) Excess Tire, Maintenance and Oil Costs Per Speed Change Cycle (cents)

	Composite Passenger		Commercial Vehicle	
	Costs/ stop	Costs/ 10 mph slowdown	Costs/ stop	Costs/ 10 mph slowdown
Tire	.20	.06	.30[e]	.09[e]
Maintenance[f]	.12	.04[e]	.18[e]	.06[e]
Oil[g]	.009	.003[e]	.01[e]	.005[e]
	.33	.10	.49	.16

Source: National Cooperative Highway Research Program Report III (162).

Notes: [a]Results in U.S. gallons have been converted into Canadian gallons by a factor 5/6.

[b]All speed changes assumed to change from a normal speed of 20 mph.

[c]The composite passenger auto represented reflects the following vehicle distribution: large cars, 20%; standard cars, 65%; compact cars, 10%; small cars, 5%. The per cent of compact and small cars will probably increase in the future.

[d]Commercial vehicles refer to two-axle six-tire truck.

[e]Assumed figures, based on information given in Table C.4a - C.4c.

[f]Include brake shoes and lining costs.

[g]Price per quart assumed to be $1.00.

To estimate G_3 we employ the following formulae:

Gas:

$\$(.0028)(.35)[.82\ (g_k - s_k)]$	passenger auto
$\$(.0064)(.35)[.18\ (g_k - s_k)]$	commercial vehicle

Other operating expenses:

$\$(.001)[.82\ (g_k - s_k)]$	passenger auto
$\$(.0016)[.18\ (g_k - s_k)]$	commercial vehicle

where g_k is the annual number of cars passing crossing k and s_k is the annual number of cars stopped by train at crossing k.

The estimated annual savings in vehicle operating expenses for the three schemes are shown in Table C.5. The price of gasoline is assumed to be \$.35 per gallon and that of oil is \$1.00 per quart.[19]

It may be noted that G_3 was found to be several times as large as G_1 or G_2. This is because the number of cars slowed down far exceeds the number of cars actually stopped by trains at the crossings. However, the extra operating costs incurred for slowing down and speeding up again are close to those incurred in stopping a vehicle.

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[19] The retail price of gas in 1972 was around \$.54. Since the sales tax on gasoline in much higher than most other commodities, we assume a price which is net of part of the taxes. The sales taxes (provincial and federal) were approximately \$.19 per gallon in 1972.

TABLE C.5

Savings in Daily and Annual Vehicle Operating Expenses

(dollars)

	CNR		Southern		Complete	
	Daily	Annual	Daily	Annual	Daily	Annual
G_1, Gas	21.3	7,375	22.8	7,885	26.3	9,107
G_2, Gas	15.0	5,194	16.2	5,609	18.8	6,510
Other Expenses	20.2	6,994	21.7	7,514	25.2	8,726
G_3, Gas	111.0	38,437	88.2	30,542	220.0	76,181
Other Expenses	102.5	35,320	81.0	28,048	201.8	69,879
	270.0	93,495	229.9	79,609	492.1	170,403

APPENDIX D

ESTIMATING THE VALUE OF LAND RELEASED FOR REDEVELOPMENT

According to estimates made by DeLeuw Cather (34), the number of acres of railway property released by the CNR and Southern schemes would be 395 and 455 respectively. However, their estimated values, $5.5 and $5.8 million, are based on the value of released yards and freight shed areas only. No value is assigned to railway rights-of-way. In Table D.1 we show the areas included and the unit land prices used in the DeLeuw Cather study. It is clear that only 190 acres of land in the core of the urban area are considered and a unit price of $30,000 per acre is assumed for most of the land.

In Figure D.1 we present some land sale prices (per square foot) in London during the period 1969 to 1973. Most of these would represent residential land prices. Compared with these prices, the unit price used by DeLeuw Cather ($.69 per square foot for most of the land) seems low. However, the price assumed by DeLeuw Cather may still be reasonable because the release of all railway land could depress the market price somewhat.

The neglect of released railway rights-of-way by the DeLeuw Cather study would probably mean they have underestimated the benefits. These rights-of-way are probably less valuable than the yard areas because of their location and narrow shape, but they are far from useless. In order to establish the upper limit of the value of the released land, we shall go to the other extreme and assign a dollar value to all released

TABLE D.1

Value of Released Railway Land ($) [a]

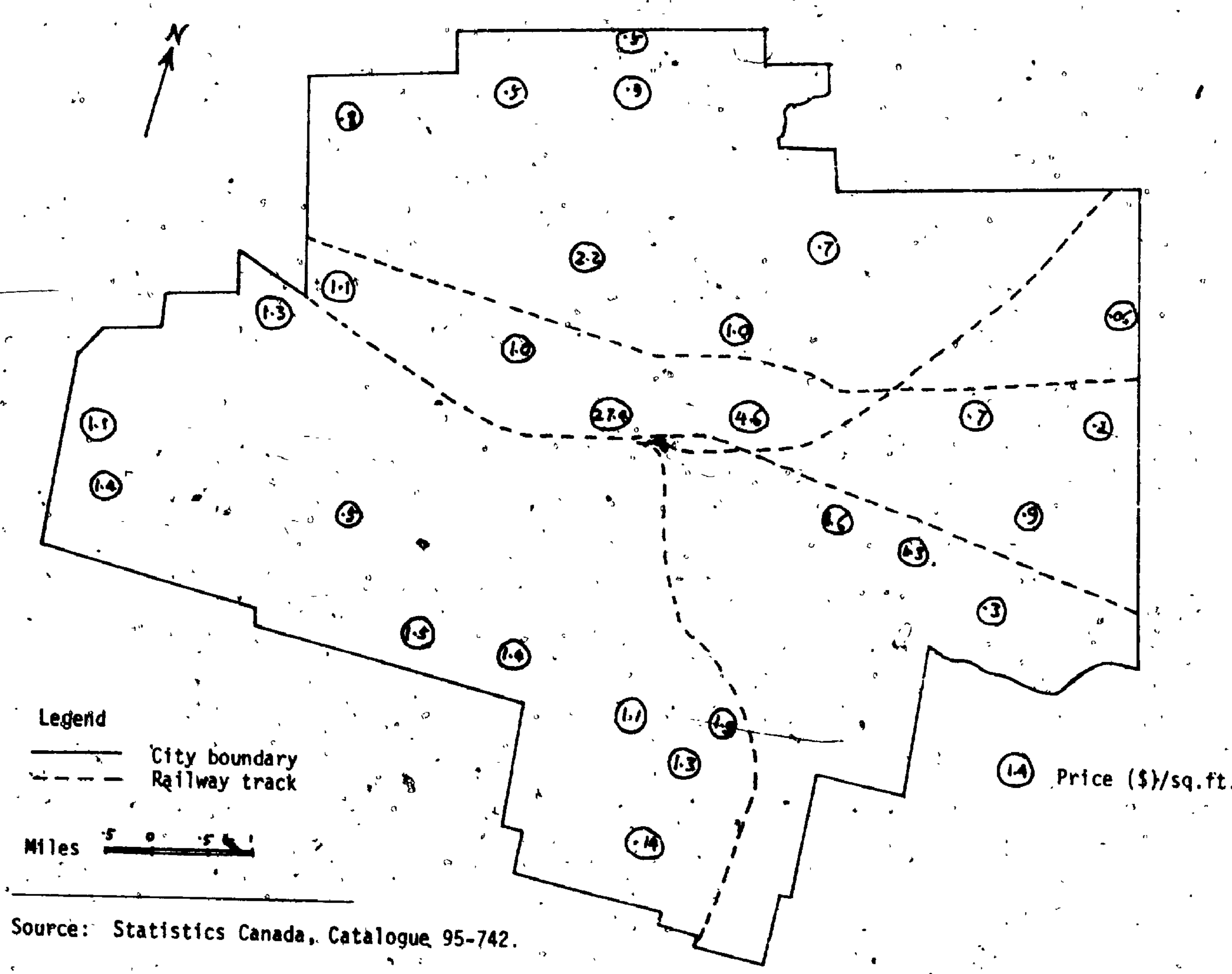
Location	CNR		Southern	
	No. of Acres	Value	No. of Acres	Value
1. CNR freight shed area	10	2,000,000	12	2,400,000
2. CNR at Egerton Street	28	850,000	28	850,000
3. CNR at Bathurst and Little	30	900,000	30	900,000
4. CNR yard	65	1,950,000	85	2,550,000
5. CPR yard	35	1,000,000	35	1,000,000
6. CNR; Thorndale subdivision	23	700,000	0	0

Source: DeLeuw Cather (34), Working Papers.

Notes: [a] The total value of land released under the CNR and Southern schemes are $7.4 million and $7.7 million respectively. However, in the final report, $1.9 million is deducted from each for a reason unknown to us.

Figure D.1

Selected Land Sale Prices in London, 1969-1972



Source: Statistics Canada, Catalogue 95-742.

rights-of-way. The value of each piece of the released rights-of-way would be assumed to equal the value of nearby land. In Table D.2, we show the area of the rights-of-way to be released and the assumed unit land prices. In the absence of grade separations, railways share rights-of-way with road transport. We assume that only 80 per cent of the rights-of-way released would actually be available for other uses.

The estimated values of the released rights-of-way (in addition to that estimated by DeLeuw Cather) for the three relocation schemes are:

CNR	Southern	Complete
2.43	4.46	5.93

The above estimated values may be added to those of DeLeuw Cather to establish the upper bound of the value of the released land. They are:

CNR	Southern	Complete
7.93	10.26	11.73

We average the two extreme values to get the middle value, namely:

CNR	Southern	Complete
6.72	8.03	8.76

TABLE D.2

Value of Released Railway Rights-of-Way

Location[a]	$/sq.ft.	CNR		Southern		Complete	
		Area (1000 sq.ft.)	Value ($1000)	Area (1000 sq.ft.)	Value ($1000)	Area (1000 sq.ft.)	Value ($1000)
N 48	.9	213	192	213	192	213	192
M 48	.8	200	160	200	160	200	160
O 49	.9	440	396	440	396	440	396
P 49	.9	240	216	240	216	460	414
P 45	.5	-	-	40	20	300	150
P 46	.8	-	-	-	-	1,124	900
O 42 to O 45	.25	-	-	1,420	355	1,420	355
Q 43	.2	168	33	-	-	-	-
Q 44	.2	240	48	-	-	-	-
Q 45	.5	72	36	-	-	384	192
Q 46	.8	-	-	-	-	468	374
Q 50	1.2	80	96	80	96	80	96
Q 51	1.2	-	-	360	432	400	480
Q 52	1.0	-	-	330	330	330	330
Q 53	1.2	-	-	630	756	630	756
R 44	.2	360	72	360	72	360	72
R 45	.5	84	42	84	42	84	42
R 51	1.0	360	360	360	360	360	360
R 52	1.2	620	744	620	744	620	744
R 53	1.2	460	552	460	552	460	552
R 54	1.0	-	-	600	600	600	600
R 55	.5	-	-	336	168	336	168
S 43	.1	900	90	900	90	900	90
		4,437	3,037	7,673	5,581	10,169	7,413

Notes: [a]Refers to the number of land use maps for the City of London.

APPENDIX E

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 extend 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.

E.1 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.

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[1]Published by Middlesex Real Estate Board.

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

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 (see Figure E.1). 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. In Table E.1 we show the frequency distribution of our observations according to distance from railway track.

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.

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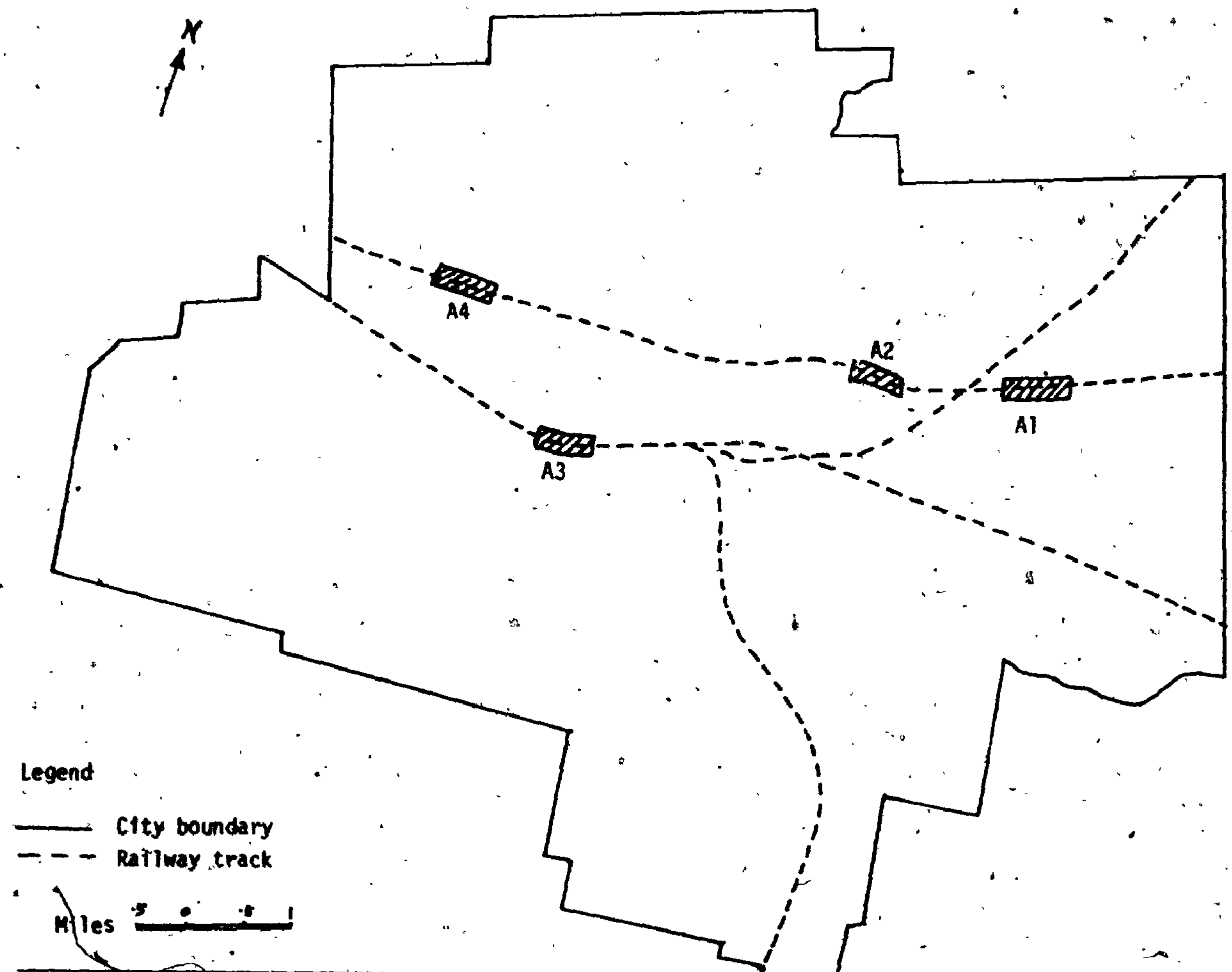
[2]Tests of the data indicate that railway effects reach less than 1000 feet on both sides of the railway.

Figure E.1

Sample Areas



Source: Statistics Canada, Catalogue 95-742.

TABLE E.1

Distance from Railway

Mid-Point of Distance Interval (ft.)	No. of Observations
50	37
150	39
250	46
350	35
450	25
550	22
650	16
750	30
850	7
950	17
1050	5
1150	4
1250	1
1350	1
	285

Table E.2 presents some of the characteristics of the four chosen areas. All areas are primarily residential in use. Some commercial and/or light industrial activities are present in areas (1), (2) and (3). Area (4) has the highest average income and average property value. Areas (1) and (4) are relatively new in comparison with areas (2) and (3).

E.2 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) $$P = a_0 + a_1x_1 + a_2x_2 + \ldots + a_nx_n + e$$

(2) $$\text{Ln } P = b_0 + b_1 \text{ Ln } x_1 + b_2 \text{ Ln } x_2 + \ldots + b_n \text{ Ln } x_n + e .$$

where P is the sale price of an individual property, $x_1,\ldots,x_n$ are

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[3]See Wales and Wiens (120) and Edelstein (93) for the rational for including the tax variable and also their empirical findings.

TABLE E.2

Characteristics of Sample Areas

	A1	A2	A3	A4	A1 + A2 + A3 + A4	City
Census Data[(a)]						
Average total income per family ($)	9,892	7,844	8,519	14,687	--	10,917
Population density per sq. mi.[(b)]	3,517	15,410	11,678	3,677	--	3,603
Median value of properties ($)	19,415	15,172	16,797	26,826	--	21,502
Sample Data						
Sample size	47	90	103	45	285	--
Average sale price of properties	16,290	14,230	16,650	32,260	18,245	--
Average number of rooms/property	6.2	6.7	7.1	7.9	6.9	--
Average age (years)	18.7	28.4**	48.1**	2.6	36.1**	--
Average lot size (sq. ft.)	6,823	4,505	5,076	9,341	5,831	--
Average distance from CBD (1000 ft.)	20	8	4	19	--	--
Number of trains/day[(c)]	14	14+	37	13	--	--

Notes: (a) 1971 Census. (b) Gross density. (c) DeLeuw Cather (34).

**Based on the assumption that "older" houses are 50 years old.

+Plus some daily interchange of freight cars.

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.

(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 (89) 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]

---

[4]

Linear	Log	Both Linear and Log or Combination
Brigham (85)	Anderson and Crocker (81)	Grether and Mieszkowski (101)
Ridker and Henning (115)	Emerson (94)	
Wabe (66)		
Richardson, Vipond, and Furbey (114)		

[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

(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); 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

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the estimated values would be some kind of 1967 - 1972 average dollar values which are not suitable for our purpose.

[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.

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 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

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

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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.

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 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.

E.3 Empirical Results

The regression results are presented in Table E.3. Most of the variables have the expected signs and are significantly different from zero at the five per cent level. 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) $P = \ldots + 217\ DR + \ldots$
$\qquad\qquad(72.4)$

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

(h) $\ln P = \ldots + .052\ \ln DR + \ldots$
$\qquad\qquad(.014)$

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.6 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

TABLE E.3a

Determinants of Residential Property Price, Regression Results
(Pooled Sample; Linear and Quadratic)

Independent Variable+	(a)	(b)	(c)	(d)	(e)	(f)	(g)
Age of house	-134.27* (6.28)	-500.94 (3.64)*	-135.24 (6.40)*	-139.71 (6.55)*	-487.78 (3.52)*	-470.75 (3.36)*	-121.14 (1.15)
Garage	576.28 (1.57)	643.66 (1.87)*	603.89 (1.64)	590.16 (1.61)	701.67 (1.92)*	939.14 (2.37)*	410.09 (1.50)
Bathrooms	1459.28 (3.04)*	1538.87 (3.24)*	1388.35 (2.87)*	1408.86 (2.92)*	1583.85 (3.30)*	1565.71 (3.03)*	1174.51 (3.28)*
Lot-size	.38 (3.92)*	.39 (4.06)*	.38 (4.22)*	.39 (4.00)*	.23 (2.09)*	.37 (3.73)*	.40 (5.60)*
No. of rooms	852.08 (5.19)*	827.12 (5.08)*	827.62 (5.01)*	801.80 (2.79)*	814.64 (4.95)*	1002.07 (5.60)*	594.60 (4.86)*
Siding material	1498.87 (2.75)*	1318.42 (2.43)*	1493.03 (2.74)*	1516.19 (2.79)*	1364.46 (2.51)*	1334.97 (2.34)*	1176.92 (2.89)*
No. of stories	1245.69 (2.18)*	1266.82 (2.24)*	1305.09 (2.27)*	1281.05 (2.24)*	1321.23 (2.33)*	1280.35 (2.09)*	952.98 (2.24)*
Basement	1766.91 (1.91)*	1957.43 (2.14)*	1717.28 (1.85)*	1782.18 (1.93)*	1840.01 (2.00)*	1300.18 (1.32)	1722.90 (2.50)*
Heating	538.73 (1.18)	456.22 (1.01)	589.86 (1.28)	538.80 (1.17)	521.20 (1.14)	677.46 (1.41)	410.56 (1.21)
Fireplace	688.64 (1.15)	735.12 (1.26)	684.56 (1.18)	572.37 (.98)	798.69 (1.37)	793.40 (1.29)	1076.67 (2.49)*

(continued)

TABLE E.3a (continued)

Independent Variable+	(a)	(b)	(c)	(d)	(e)	(f)	(g)
Recreation room	-280.54 (.35)	-120.75 (.15)	-351.30 (.44)	-263.34 (.33)	-115.70 (.45)	35.85 (.04)	189.59 (.32)
Corner lot	1077.92 (3.00)*	2041.77 (2.99)*	2095.55 (3.03)*	2063.41 (2.99)*	2036.58 (2.97)*	2173.11 (3.00)*	1784.46 (3.44)*
Distance from arterial road	-592.44 (.81)	-499.39 (.69)	-587.34 (.81)	-555.81 (.77)	-538.83 (.75)	-777.23 (1.03)	-641.86 (1.19)
Duplex, triplex	1264.99 (2.05)*	1135.98 (1.86)*	1184.35 (1.92)*	1125.84 (1.82)*	1117.31 (1.81)*	--	533.16 (1.16)
Areas dummy A2	532.19 (1.00)	598.63 (1.14)	-3310.58 (1.03)	-3222.22 (1.00)	572.86 (1.09)	966.36 (1.68)*	1060.94 (2.65)*
A3	-717.15 (.87)	-616.33 (.75)	380.61 (.31)	330.85 (.27)	-647.54 (.81)	-480.92 (.56)	-44.05 (.07)
A4	7464.52 (5.30)*	4116.08 (2.24)*	9652.51 (4.22)*	9467.11 (4.14)*	4334.41 (2.35)*	3810.61 (2.06)*	8145.52 (5.78)*
Train volume	--	--	352.60 (1.21)	350.24 (1.20)	--	--	--
Distance from railway	217.04 (2.99)*	588.72 (2.45)*	268.82 (3.08)*	556.83 (2.30)*	--	599.93 (2.26)*	136.08 (2.52)*
Distance from railway squared	--	-35.43 (1.68)*	--	-32.72 (1.62)	--	-35.88 (1.61)	--
Mortgage variable	-.00 (.30)	.00 (.06)	-.01 (.43)	-.00 (.24)	-.00 (.00)	.00 (.10)	-.00 (.01)
Age of house squared	--	5.77 (2.67)*	--	--	5.57 (2.55)*	5.23 (2.33)*	.67 (.40)

(continued)

TABLE E.3a (continued)

Independent Variable+	(a)	(b)	(c)	(d)	(e)	(f)	(g)
LSDR	--	--	--	--	.062 (1.67)	--	--
LSDRR	--	--	--	--	-.00 (1.00)	--	--
Time trend	--	--	--	--	--	--	.28 (4.10)*
Constant	6739	10030	269	105	11276	9964	107
N	285	285	285	285	285	242	285
R^2	.84	.85	.84	.85	.85	.87	.88

TABLE E.3b

Determinants of Residential Property Price, Regression Results
(Pooled Sample; Log)

Independent Variable+	(h)	(i)	(j)	(k)	(l)
Age of house	-.13 (5.60)*	-.13 (5.65)*	-.13 (5.25)*	-.13 (5.65)*	-.09 (4.00)*
Garage space	.00 (.10)	.00 (.10)	.01 (.45)	.00 (.00)	.00 (.12)
Bathrooms	.13 (2.75)*	.12 (2.66)*	.13 (2.67)*	.13 (2.53)*	.11 (2.37)*
Lot size	.15 (4.15)*	.15 (4.04)*	--	.16 (4.07)*	.16 (4.53)*
No. of rooms	.35 (4.98)*	.34 (4.86)*	.37 (4.98)*	.40 (5.13)*	.31 (4.57)*
Siding material	.09 (2.76)*	.09 (3.00)*	.09 (2.80)*	.08 (2.31)*	.09 (3.00)*
No. of stories	.05 (1.04)	.05 (1.11)	.04 (.74)	.05 (1.08)	.05 (1.15)
Basement	.21 (2.39)*	.20 (2.35)*	.21 (2.36)*	.18 (1.95)*	.21 (2.51)*
Heating	.04 (1.55)	.04 (1.63)	.03 (1.06)	.05 (1.79)*	.04 (1.73)*
Fireplace	.03 (.82)	.03 (.82)	.03 (.91)	.02 (.70)	.03 (1.05)

(continued)

TABLE E.3b (continued)

Independent Variable+	(h)	(i)	(j)	(k)	(l)
Recreation room	.00 (.03)	-.00 (.08)	-.00 (.08)	.00 (.12)	.01 (.33)
Corner lot	.12 (2.94)*	.12 (2.95)*	.11 (2.76)*	.13 (2.92)*	.12 (3.02)*
Distance from arterial road	-.04 (1.02)	-.04 (1.02)	-.05 (1.25)	-.06 (1.27)	-.07 (1.65)*
Duplex, triplex	.05 (1.27)	.04 (1.19)	.05 (1.23)	--	.03 (.54)
Areas dummy A2	.05 (1.53)	-.12 (.72)	.04 (1.30)	.06 (1.83)*	.08 (2.51)*
A3	.03 (.58)	.09 (1.16)	.04 (.90)	.02 (.43)	.04 (1.00)
A4	.08 (.87)	.22 (1.33)	.13 (1.41)	.05 (.50)	.21 (2.38)*
Train volume	--	.37 (1.01)	--	.32 (.89)	--
Distance from railway	.05 (3.71)*	.05 (3.57)*	.06 (3.10)*	.06 (3.73)*	.04 (3.30)*
Distance from railway squared	--	--	--	--	--
Mortgage variable	-.00 (.34)	-.00 (.01)	-.00 (.60)	.00 (.40)	-.00 (.01)
Age of house squared	--	--	--	--	--

(continued)

TABLE E.3b (continued)

Independent Variable+	(h)	(i)	(j)	(k)	(l)
Lot size squared	--	--	--	--	--
Lot size minus 4000	--	--	.03 (.126)	--	--
LSDR	--	--	-.02 (.78)	--	--
Time trend	--	--	--	--	.41 (3.90)*
Constant	7.9	6.8	9.0	7.7	3.5
N	285	285	285	285	285
R^2	.73	.73	.72	.76	.75

TABLE E.3c

Determinants of Residential Property Price, Regression Results
(Sub-Sample; Linear and Quadratic)

Independent Variable+	Area (1) (m)	Area (2) (n)	Area (3) (o)	Area (4) (p)
Age of house	-100.69 (3.90)*	-73.61 (1.14)	-170.36 (5.63)*	-1147.60 (3.12)*
Garage space	365.99 (.44)	-208.76 (.32)	587.96 (.84)	2966.16 (3.16)*
Bathrooms	1003.67 (.90)	1179.33 (1.18)	1621.94 (2.22)*	3492.18 (2.29)*
Lot size	.34 (1.25)	.55 (3.23)*	.44 (1.64)*	.06 .33)
No. of rooms	1228.64 (3.70)*	863.22 (2.73)*	838.98 (3.30)*	738.18 (.90)
Siding material	594.94 (.74)	1640.18 (1.44)	1909.29 (2.43)*	--
No. of stories	2071.44 (1.25)	1190.01 (1.00)	-264.05 (.28)	--
Basement	3863.49 (2.46)*	3486.69 (1.87)*	472.34 (.35)	--
Heating	--	--	--	--
Fireplace	--	--	--	--

(continued)

TABLE E.3c (continued)

Independent Variable+	Area (1) (m)	Area (2) (n)	Area (3) (o)	Area (4) (p)
Recreation room	--	--	--	1384.06 (1.02)
Corner lot	654.60 (.54)	2496.76 (1.79)*	3857.75 (3.02)*	2484.18 (1.52)
Distance from arterial road	--	--	--	--
Duplex, triplex	427.78 (.26)	1950.33 (1.47)	536.84 (.60)	--
Area dummy A2	--	--	--	--
A3	--	--	--	--
A4	--	--	--	--
Train volume	--	--	--	--
Distance from railway	335.82 (2.38)*	984.30 (1.74)*	925.68 (2.36)*	107.72 (.67)
Distance from railway squared	--	-82.18 (1.50)	-74.84 (2.10)*	--
Mortgage variable	--	--	--	-.01 (.45)
Age of house squared	--	--	--	--

(continued)

TABLE E.3c (continued)

Independent Variable+	Area (1) (m)	Area (2) (n)	Area (3) (o)	Area (4) (p)
Lot size squared	--	--	--	--
Constant	2300	1108	10326	20530
N	47	103	90	45
R^2	.74	.46	.67	.63

Notes: + : The dependent variable is sale price (Table E.3a, E.3c) and ln (sale price) in Table E.3b.

* : Indicates significant at 5% level.

LSDR = Lot size times distance from railway, LSDRR = Lot size times distance from railway squared.

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 sub-samples, we find that this variable is significant at the five per cent level and has the expected sign in three of the four areas. It is a bit surprising to find that this variable is not significant in Area (4), which is 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, 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.

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 (h) in terms of the number of significant variables and explanatory power. The volume of rail traffic variable is not significant in any forms assumed

(Equations (c,d,i,k) in Table E.3).[8]

Equation (e) in Table E.3 specifies the distance from railway variables in a different manner. It was hypothesized that the discount in residential sale prices due to railway externalities would be on a per square foot of lot basis rather than on a per lot basis. To test this hypothesis we specified the equation as follows:

$$P = a + \ldots + rLS + \ldots ,$$

where P = sale price of property;

a = constant (servicing cost, etc.)

r = value per square foot, which depends on distance from railway (DR) according to a quadratic function such as $r = c_1 + c_2\,DR + c_3\,DR^2$ where $c_1 > 0$, $c_2 > 0$, $c_3 < 0$; and

LS = lot size (square feet).

Thus, the regression to be estimated would be:

$$P = a + \ldots + c_1\,LS + c_2\,LS \cdot DR + c_3\,LS \cdot DR^2 + \ldots$$

Our regression results show that LS and $LS \cdot DR$ are significant at the five per cent level. However, $LS \cdot DR^2$ is found to be not significant at the five per cent level.

Since our sample consists of both single-detached and duplex and triplex dwellings, we ran regressions with only single-detached units. The results do not change significantly from those with both types of

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[8] For an explanation of why this variable is not significant, see section B.1.5.e in Chapter IV.

dwellings (see Equation (f) in Table E.3).

As an alternative to adjusting all sale prices into 1972 dollars, we entered a time trend (the London housing price index constructed by Davies and Jackson (89)) as an independent variable. The results are illustrated in Equation (g) in Table E.3. The time trend is significant but there is no important change in the results for other variables.

APPENDIX F

ESTIMATING THE SAVINGS IN RAILWAY REPLACEMENT COSTS

Table F.1 shows the assumptions which we use to derive some estimates of savings in future railway replacement costs as a result of railway relocation. We shall use one example to illustrate our methodology. This is done in Table F.2.

The savings estimated in Table F.2 is based on the assumption that the initial cost of replacement is $1. The initial costs of replacement of certain railway facilities and structures estimated by CUTS for the CNR and Southern schemes are as follows (in $1000):

	(A) Main track and turnouts	(B) Yard tracks, etc.	(C) Buildings, bridges, etc.
CNR	3,500	600	9,235
Southern	7,138	4,318	17,151

As indicated in Table F.1 we assume the life expectancy (in years) of the above items to be as follows: (A) 20, (B) 40, (C) 50. Multiplying these replacement costs by the appropriate value in Table F.2 we obtain the present discounted value of savings in future replacement costs. For example, the initial replacement cost of main tracks under the Southern scheme is $7,138,000. If the average age of existing main tracks is 10 years, then replacing the tracks now would realize a saving of $(7,138,000 x .34) = $2,427,000. The estimated savings of (A), (B), and (C) are added together to obtain total savings under each scheme.

TABLE F.1

Assumptions Used in Deriving Savings in Replacement Costs

1. Length of planning period in years: (a) 30, (b) 50, (c) 100.

2. Life expectancy of railway facilities and structures:

(A) Main tracks - 20 years

(B) Yard tracks and sidings - 40 years

(C) Signals, buildings, grade separations, bridges - 50 years

3. Age of existing facilities and structures in years:

(A) Main tracks - (a) 5, (b) 10, (c) 15

(B) Yard tracks and sidings - (a) 10, (b) 20, (c) 30

(C) Signals, etc. - (a) 15, (b) 25, (c) 35

4. The dollar cost of future replacement is assumed equal to present replacement costs, i.e., $C^i_{sq} = C^i_{rr} = C^o_{rr}$.

5. Except the salvage value of the existing facilities, the present worth of future salvage value of railway structures is not considered.

6. Discount rate (% per annum) is (a) 4, (b) 7, (c) 10.

TABLE F.2

Savings in Future Railway Replacement Costs[a]

Life Expectancy	(20)				(40)				(50)			
	$\frac{C^i_{rr}}{(1+r)^i}$	$\frac{C^i_{sq}}{(1+r)^i}$	$\frac{C^i_{sq}}{(1+r)^i}$	$\frac{C^i_{sq}}{(1+r)^i}$	$\frac{C^i_{rr}}{(1+r)^i}$	$\frac{C^i_{sq}}{(1+r)^i}$	$\frac{C^i_{sq}}{(1+r)^i}$	$\frac{C^i_{sq}}{(1+r)^i}$	$\frac{C^i_{rr}}{(1+r)^i}$	$\frac{C^i_{sq}}{(1+r)^i}$	$\frac{C^i_{sq}}{(1+r)^i}$	$\frac{C^i_{sq}}{(1+r)^i}$
Age of Existing Facilities		(5)	(10)	(15)		(10)	(20)	(30)		(15)	(25)	(35)
Present Value of Replacement Costs[b]	.2584 (20)	.3624 (15)	.5038 (10)	.7129 (5)	.0668 (40)	.1312 (30)	.2584 (20)	.5083 (10)	.0085 (50)	.0935 (35)	.1842 (25)	.3624 (15)
	.0668 (40)	.0937 (35)	.1312 (30)	.1842 (25)	.0044 (80)	.0087 (70)	.0172 (60)	.0339 (50)		.0032 (85)	.0062 (75)	.0123 (65)
	.0172 (60)	.0242 (55)	.0339 (50)	.0476 (45)				.0023 (90)				
	.0044 (80)	.0062 (75)	.0087 (70)	.0123 (65)								
		.0017 (95)	.0023 (90)	.0032 (85)								
Total	.3468	.4882	.6844	.9602	.0172	.1399	.2756	.5445	.0085	.0967	.1904	.3747
Savings[c]		.14	.34	.38		.07	.21	.47		.09	.18	.37

Notes: (a) Project life = 100 yrs.; discount rate = 7%; initial replacement cost = 1.

(b) Number in brackets are years from the initial period that replacement would take place.

(c) Calculated as the sum of $\frac{C^i_{rr}}{(1+r)^i}$ less the sum of $\frac{C^i_{sq}}{(1+r)^i}$ in each category.

APPENDIX G

GRADE SEPARATION CAPITAL COSTS

SCHEME "C" -- CONTINUOUS STRUCTURE
OVERPASSING YORK ST., CNR TRACKS & BATHURST ST.

I CONSTRUCTION COSTS

(a) Structure and Approaches:

1.	Earth Fill - 23,000 cu.yds. @ $0.80	$ 18,400.00	
2.	Sodding of side slopes - 2,000 sq.yds. @ 0.45	900.00	
3.	Structure and Foundations	378,740.00	
4.	Granular backfill at structures - 850 tons @ 1.90	11,115.00	
5.	Guardrail on approaches - 900 lin.ft. @ 2.50	2,250.00	
6.	Excavation for reconstructed pavement - 3,200 cu.yds. @ 1.25	4,000.00	
7.	Concrete curb and gutter - 6,800 lin.ft. @ 2.00	13,600.00	
8.	Granular base course, Class A - 5,450 tons @ 2.50	13,625.00	
9.	Crushed stone upper base course - 3,300 tons @ 3.00	9,900.00	
10.	Asphalt pavement - 2,760 tons @ 9.10	25,115.00	
11.	Storm drainage - 1,200 lin.ft. @ 2.80	3,360.00	
12.	Catch basins - 34 @ 180.00 each	6,120.00	
13.	Concrete sidewalks - 12,700 sq.ft. @ 0.50	6,350.00	
14.	Asphalt paving on island - 8,700 sq.ft. @ 0.25	2,175.00	
15.	Demolition of existing sidewalks, pavement and curb and gutter - L.S.	3,925.00	
			499,575.00

(b) Utilities and Sundry Construction:

	Items 1 to 4 incl. and Item 6 - as in Scheme "B"	$11,600.00		
5.	Demolition of Buildings	51,000.00		
			62,600.00	
7.	Engineering and Contingencies		84,325.00	
				146,925.00
			Construction Total	$646,500.00

II PROPERTY ACQUISITION & LIGHTING COST

1.	Land	$ 67,900.00	
2.	Buildings	277,090.00	
3.	Lighting of Overpass and Approaches	11,000.00	
			355,990.00
	Total Estimated Cost		$1,002,490.00

Source: Margison and Associates (156).

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