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# The Distribution of Benefits from Urban Transportation Investments

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## I. INTRODUCTION

Recent articles have evaluated the income distributional effects of two urban transportation pricing policies: public transit subsidies [10], [28] and road pricing [25]. The present article extends this literature by discussing the evaluation of distributional effects of urban transportation investments.

The purpose of this paper is twofold. First, we provide a general analysis of the nature of the benefits accruing to households from urban transportation projects and the problem of measuring the distribution of these benefits among income groups.[1] Second, we exemplify the method of analysis with an assessment of the distribution of benefits from four public transportation projects which are currently under consideration in Toronto, Canada.

There is an extensive literature by academic economists which applies cost-benefit analysis to the appraisal of urban transportation projects [4], [11], [19], [20], [22], [23], [24]. In addition, almost every large urban area has sponsored at least one major study of transportation investment alternatives by consulting engineers and planners [8]. However, both the empirical transportation economics literature and the land-use and transportation planning literature have generally ignored the distributional effects of urban transportation investments. The principal exception is the

United States literature on transportation and poverty [1], [2], [7], [13], [14], [15], [27], [29]. Unfortunately, the latter literature concentrates almost exclusively on poverty groups, particularly central city blacks, rather than systematically considering effects of transportation investments on all income groups. A second exception is the work by political economists dealing with expressways in the Toronto urban area [16], [22] and rail transit systems in the San Francisco and Washington, D.C. urban areas [3], [5].

## II. NATURE OF BENEFITS

There are several ways that an urban transport project, such as a new rail rapid transit line, can confer benefits upon or increase the well-being of a household. In each case, the benefit can be valued at the increase in consumer surplus or the willingness to pay in money terms of the affected party.[2]

### A. Partial Equilibrium

We begin the analysis of benefits with a partial equilibrium framework which ignores changes in the market for land, i.e., changes in property values and in the location of economic activity, as well as changes in the markets for goods, labour, and other inputs. Within this restricted framework, three categories of benefits from an urban transport project might be considered:

#### 1. Reduction in Expenditure on Travel

As a result of the project, less time and money might be required for people to complete trips which they would have taken even in the absence of the project. In addition, people might be more comfortable while travelling and the accident rate might be lower. Similar benefits might exist in connection with transport of freight.

2. Consumer Surplus on Additional Trips

A reduction in the cost of travel as a result of a project might induce people to take trips which they would not otherwise have taken. For example, if travel costs were reduced, people might do more job hunting and comparative shopping. The difference between what they would be willing to pay for these additional trips and the cost of the trips after the project is a benefit for the people involved.

The United States literature on transportation and poverty places great emphasis on such benefits for unemployed and low paid central city residents, particularly black people, who would allegedly find more and better paying jobs if a project substantially reduced transit travel times between central residential areas and suburban employment areas.[3]

3. Increased Accessibility

Under conditions of uncertainty, people might be willing to pay something for a project which would give them the option of travelling to certain destinations at lower cost, even though the option might not be exercised. For example, some people, particularly members of the secondary labour market, might be willing to pay for transport improvements which would bring a large number of jobs within reasonable commuting cost of their residences, just in case they should want to change jobs at some time.

B. General Equilibrium

In a general equilibrium framework, which would admit changes in property values and in the location of economic activity, changes in the prices of goods, and changes in wages, the nature and distribution of benefits from a transport project would be different from those discussed above. A number of the general equilibrium benefits arise from changes in the structure of asset, commodity, and input prices. In a cost-benefit analysis concerned with aggregate consumption benefits, many of these price changes simply involve transfer payments and can be ignored. However, such pecuniary effects may be important in determining the distribution of benefits among households.

1. Changes in Property Values

Property values are likely to rise in some areas and fall in others as a result of a transport project. Some property owners and renters will benefit from these changes and others will lose. Such changes in prices and rents may have important distributional results; for example, they may transfer benefits from commuters to property owners. If benefits from a reduction in travel costs are capitalized in property values, people will benefit in proportion to their ownership of the affected property rather than in proportion to their travel in the routes affected by the project.

2. Changes in Location and Land Use

In response to changes in travel costs and property values, households and firms may change their locations and use of land. For example, a large general reduction in travel costs might reduce urban property values and increase consumption of land per household in the residential sector. As a result, people might realize benefits largely through increased consumption of land rather than through reduced expenditure on travel or increased accessibility.

3. Changes in Prices of Goods and Inputs

A reduction in the cost of commuting and moving freight might lead to changes in the levels and spatial patterns of commodity prices, wage rates, and other input prices. Such changes would affect the distribution of benefits from a project.

## C. Scope of Study

In this study we focus on the distribution of benefits in one of the categories suggested by the partial equilibrium framework: reduction in time and money cost of trips which would have been taken anyway.[4] In analyzing these benefits we confine our attention to home-based work trips at rush hour.

Our study is thus limited in several ways. First, we ignore non-work trips, non-rush-hour work trips, and transport of freight. Second, we ignore consumer surplus on additional trips and increased accessibility. Third, we carry out the analysis under partial equilibrium assumptions. Thus, we assume that location of residences and employment would not be affected by the transport projects considered, and we ignore changes in property values and other prices.

These limitations are imposed by lack of data and by the present state of urban land-use and transport modelling.

## D. Reasons for Distributional Effects

There are a number of reasons for expecting that the reduction in expenditure on travel resulting from a transport project would be different for members of different income groups. Any transport project will have a disproportionate effect on travel between certain residential and employment zones, by certain modes, and at certain times of day. Moreover, there are likely to be systematic differences between income groups in the location of residences and jobs, in the mode of travel between any given pair of residential and employment zones, in the time of day at which trips are made, and in the number of trips taken.

## III. DISTRIBUTION OF BENEFITS

### A. Zones, Travel Modes, Transport Systems, and Income Groups

For the purpose of measuring the distribution of benefits from a transport project, we are forced to do a considerable amount of aggregation. We assume that the urban area in question is divided into I residential zones (denoted by the subscript $i = 1,2,\ldots,I$) and J employment zones ($j = 1,2,\ldots,J$). The two sets of zones would normally overlap, but the individual zones in the two sets would not necessarily coincide on a one-to-one basis.

We assume that in travelling between residential zone i and employment zone j, individuals choose among K travel modes ($k = 1,2,\ldots,K$).

We use the term transport system to refer to an entire set of K modes connecting I residential zones and J employment zones. In the present analysis we consider G different transport systems (denoted by the superscript $g = 1,2,\ldots,G$), where system G refers to the base system which would exist if none of the G-1 optional transport projects under evaluation were implemented, system 1 refers to the system which would exist if only the first project were implemented in addition to the base system, system 2 refers to the system which would exist if only the second project were implemented in addition to the base system, etc.

We assume further that the urban population is divided into H income groups ($h = 1,2,\ldots,H$), where group 1 has the lowest income and group H the highest.

### B. Cost of a Trip

It is assumed that the cost of any trip by a member of income group h from residential zone i to employment zone j by travel mode k is composed of the value of time required to make the trip and the out-of-pocket money cost.

Both the time required and the money expenditure by any mode k may vary among the G transport systems, i.e., may depend on the optional transport projects under consideration.

Furthermore, it is assumed that all members of a given income group place the same value on their travel time for the journey to work.

Thus:

$$C^{g}_{hijk} = V_{h} \cdot T^{g}_{ijk} + M^{g}_{ijk} \quad (1)$$

where:

$C^{g}_{hijk}$ = value of time plus money expenditure for one rush-hour person-trip by a member of income group h from residential zone i to employment zone j by mode k given transport system g.

$V_{h}$ = value of travel time per minute during journey to work for a member of income group h.

$T^{g}_{ijk}$ = door-to-door travel time in minutes at rush hour from residential zone i to employment zone j by mode k given transport system g.

$M^{g}_{ijk}$ = money expenditure for one rush-hour person-trip from residential zone i to employment zone j by mode k given transport system g.

## C. Reduction in Expenditure on Travel

### 1. Measurement of Expenditure on Travel

The average annual household expenditure on rush-hour home-based work trips for income group h with transport system g could be calculated:

$$F_h^g = \sum_i \sum_j \sum_k N_{hijk}^g \cdot C_{hijk}^g \Big/ P_h \qquad (2)$$

where:

$F_h^g$ = average annual household expenditure on rush-hour home-based work trips for income group h with transport system g.

$N_{hijk}^g$ = annual number of rush-hour home-based work trips for all members of income group h between residential zone i and employment zone j by mode k with transport system g.

$P_h$ = number of households in income group h in the urban area.

In measuring expenditure on travel, we assume that the total number of rush-hour home-based work trips by all modes for members of income group h between residential zone i and employment zone j is independent of the transport system g.

2. Incidence

In evaluating the distribution of benefits from a transport project, we could calculate the average annual reduction in expenditure on travel per household in each income group and express this as a percentage of the average household income for the group. The reduction in expenditure on travel would be the expenditure on travel with the base transport system G minus the expenditure on travel when transport project g is implemented.

Thus:

$$Z_h^g = 100\ (F_h^G - F_h^g)/Y_h \qquad (3)$$

where:

$Z_h^g$ = average annual reduction in expenditure on rush-hour home-based work trips for households in income group h as a result of transport project g, expressed as a percentage of average annual household income.

$Y_h$ = average annual household income in income group h.

## IV. APPLICATION TO TORONTO

As an illustration of the method discussed above, we attempt to calculate $Z_h^g$ for four public transit projects which are under consideration in Toronto for implementation prior to 1981: the Lakeshore light rapid transit option and the Allendale, Eglinton, and Union-Don Mills intermediate capacity rapid transit options. Since there are four optional projects, there are $G = 5$ alternative transport systems to be considered.

The benefits of a reduction in expenditure on travel resulting from a public transit project accrue to three groups of travellers: (i) travellers who use public transit both before and after the project; (ii) travellers who are diverted from private automobiles to public transit as a result of the improvement in public transit; and (iii) travellers who use private automobiles both before and after the project and benefit from the reduction in road congestion which occurs when some automobile users are diverted to public transit.

We confine our attention to the distribution of the annual benefits during 1981, rather than considering the entire lifetime of each project.

The Metropolitan Toronto Transportation Plan Review (MTTPR) area, which has a radius of about 30 miles, was taken as the urban area for the purposes of the study.[5] It was divided into $I = 43$ residential zones and $J = 43$ employment zones.

It was assumed that there were $K = 3$ travel modes, namely (1) auto, or private automobile with one occupant; (2) carpool, or private automobile with two occupants; and (3) public transit.[6]

The household population of the MTTPR area was divided into $H = 4$ income groups of roughly equal size. Table 1 shows the share of the total population belonging to each income group and the level of 1970 incomes for each group. The income groups are defined in terms of shares of the population ranked by income rather than in terms of absolute income levels.[7]

1. Data

In order to calculate $Z_h^g$, we need data on the following variables: $P_h$, $Y_h$, $V_h$, $M_{ijk}^g$, $T_{ijk}^g$, and $N_{hijk}^g$. In this section we discuss the measurement of these variables and sources of data.

a. $P_h$

The total population in each income group in the MTTPR area in 1981 was derived from the MTTPR's estimate of total population (see [18]) and the percentage distribution of population among the four income groups in table 1.

b. $Y_h$

The average annual household income in each income group in 1981 was derived from the 1970 average annual census family income data in table 1 under the assumption that average income in all four groups would increase by the same percentage between 1970 and 1981. Since we also assume in our initial calculations that $V_h$ and $M_{ijk}^g$ increase by this same percentage, the actual percentage increase assumed is unimportant. The same growth factor appears in both the numerator and denominator of formula (3) and hence cancels.

c. $\underline{V_h}$

In line with the empirical literature on the value of time spent commuting to work, we assumed that the value of travel time per minute for members of income group h is 0.4 times the average wage rate per minute of members of that income group.[8] Since we did not have data on the average wage rate in each income group, we assumed that the average wage rate per hour was equal to average annual household income divided by 2000. The estimated values of travel time per hour in 1970 are presented in table 2.

d. $\underline{M^g_{ijk}}$

It was assumed that the money expenditure required for a trip between zones i and j by mode k was independent of the transport system under consideration. In other words, we neglected the effect of the transport projects on vehicle operating expenses and transit fares. As a result, for travellers who do not change mode as a result of a transport project, the only reduction in travel costs which we measured was savings in travel time. For travellers who change modes, however, there may still be a savings in money expenditure, e.g., if the transit fare is less than the operating and parking costs of an automobile.

The money expenditure for a person-trip by auto in 1970 was assumed to be $0.10 per mile plus half the estimated average parking fee in the destination zone. The money expenditure for a person-trip by carpool was assumed to be half of that by auto. The money expenditure for public transit in 1970 was assumed to be equal to the average interzonal transit fare plus an allowance for feeder service where appropriate.

It was assumed that the money expenditure for all three modes would increase between 1970 and 1981 by the same percentage that average annual household incomes would increase.

e. $\underline{T^{g}_{ijk}}$

Interzonal travel times calculated by the staff of the MTTPR were used in this study for the auto and public transit modes. For each pair of zones, the travel time by carpool was assumed to be equal to the travel time by auto plus 15 minutes. The additional 15 minutes was included to allow for the time required to assemble people travelling by carpool.

The major deficiency of these data was that the MTTPR did not allow for the effect of public transport projects on travel times by private automobiles. Cost-benefit studies of public transport projects typically suggest that a significant decrease in travel times for private automobiles would result from reduction in road congestion following diversion of some trips from private automobile to public transit. In our initial calculations we used the MTTPR data and thus ignored benefits related to the reduction in road congestion. However, to test our results for sensitivity to this assumption, we repeated the calculations with the assumption that a public transport project which reduced transit travel times between zones i and j by X minutes would reduce private automobile travel times between zones i and j by X/3 minutes.

f. $\underline{N^{g}_{hijk}}$

The least satisfactory data used in the calculation were for annual number of work trips during rush hour by mode k between zones i and j for all members of income group h with transport system g.

Using <u>ad hoc</u> procedures, the MTTPR estimated the total annual number of work trips during rush hour between zones i and j. It was assumed that number of trips was independent of the transport system. However, there was no breakdown of trips by income group and mode.

In order to get a breakdown by income group for annual number of work trips between zones i and j, we made the rather unsatisfactory assumption that on average households in residential zone i made the same number of work trips to employment zone j regardless of household income. Unfortunately, there are no data on the intra-MTTPR location of employment broken down by skill or income level. The implications of our assumption are discussed below.

In order to get a breakdown by mode for annual number of work trips between zones i and j for each income group, we assumed that for each pair of zones and each transport system, members of each income group choose the mode with the lowest cost per trip. Because value of time depends on income, members of different income groups often choose different modes for the same origin-destination combination.

One of the unsatisfactory features of the simulated data for modal split is that for any origin-destination combination all members of a given income group will travel by the same mode. In fact, because of differences in the value of time within an income group and because of the wide variety of origins and destinations in each zone, one would not expect such uniformity. Our calculations predict that if the average household in income group 1 would travel by transit for a particular origin-destination combination, then all members of income group 1 would benefit from improvements in transit along this route. On the other hand, if the average household in income group 4 would travel by auto for this origin-destination combination, none of the members of income group 4 would benefit. It seems likely that this would generally lead to overstatement of the progressivity of benefits from public transit projects.

The initial simulation of modal split leads to the results in table 3 for the MTTPR area as a whole in 1981, assuming that none of the optional transport projects under evaluation are implemented. For the entire area, the predicted share of trips by transit in 1981 (.44) is greater than what existed in 1970 (roughly .30). This is consistent with the MTTPR's expectation that most of the transport improvements during the 1970's would be in public transit. The predicted average occupancy rate for private cars in 1981 (1.3) is close to what existed in 1970 (roughly 1.4).

For the purposes of the present analysis of the distributional impacts of transit improvements, what is important is whether trips are by transit or by private automobile. If trips are by private automobile, it does not matter whether they are by auto with one person per vehicle or by carpool with two persons per vehicle.

The modal split simulation was carried out for each of the transport systems. Consequently, the calculations allow for the benefits of a public transit project for people who switch from private automobiles to public transit as a result of the project.

2. Results

The results of our calculations of $Z_h^g$ under the initial set of assumptions are presented in table 4. From this table we would conclude that the incidence of benefits from reduction in expenditure on travel during 1981 would be progressive in the case of Allendale, Eglinton, and Lakeshore projects and regressive in the case of the Union-Don Mills project.[9]

3. Sensitivity Analysis

It is important to remember that the conclusions may be affected by some of the assumptions that have been made.

a. Revised Modal Split Parameters

As one check of the sensitivity of our conclusions to our assumptions, we carried out the analysis with a different set of assumptions regarding the determinants of modal choice used to estimate $N^{g}_{hijk}$. We assumed that the money costs of the auto and carpool modes increased by 50 percent relative to the value of travel time and income and that the transit fare declined by 25 percent relative to the value of travel time and income. The simulated share of 1981 trips made by transit increased from .44 to .66. Under the new set of assumptions, the level of benefits (table 5) is typically higher than that in table 4, because people generally use transit for more origin-destination combinations under the new assumptions. The increase in benefits is particularly large for higher income groups. Thus, this change in assumptions leads to a reduction in the progressivity of benefits. However, it does not significantly change any of the major qualitative conclusions regarding the incidence of benefits based on table 4.

b. Effect of Transit Improvements on Automobile Speeds

Improvements in transit will typically divert some users of autos and carpools to public transit. This will reduce road congestion and hence auto and carpool travel times. This effect of transit improvements on auto and carpool travel times was ignored in the above analysis. As one check on the sensitivity of our conclusions to this omission, we assumed that a reduction in the transit travel time between residence zone i and employment zone j would be accompanied by a reduction by one-third as many minutes in the auto and carpool travel times between the same pair of zones. The results of these simulations are presented in table 6. In all cases, under the new assumptions the absolute level of benefits is equal to or greater than that for the initial simulation in table 4. This is because users of autos and carpools are now assumed to benefit from transit improvements. Furthermore, the increase in benefits is particularly large for higher income groups, because a greater share of their trips is by auto or carpool. Thus, this change in assumptions leads to a reduction in the progressivity of benefits. However, it does not change any of the major qualitative conclusions regarding the incidence of benefits based on table 4.

4. Sources of Bias

Three deficiencies in the data appear likely to bias our calculations for Toronto in the direction of overestimating the progressivity of benefits from reduction in expenditure on travel.

a. Number of Work Trips per Household

In the preceding analysis we assumed that on average households in a given residential zone take the same number of work trips regardless of income. In fact, on average households in income group 1 probably make fewer work trips than households in the remaining income groups for two reasons. First, a larger share of households in income group 1 have no one in the labour force. Second, a smaller share of households in income group 1 have two workers.

Consequently, our calculations for 1981 probably overstate the benefits of the transportation projects to members of income group 1 relative to the other income groups.[10]

b. Employment Location

In the preceding analysis we also assumed that for a given residential zone the share of work trips going to each employment zone was the same for each income group. In fact, it appears that, on average, in 1981 suburban jobs may be of more relevance to low income people than central city jobs, while the reverse would be true at high income levels.

The literature on the location of employment in large United States urban areas suggests that at present "the suburbs of the Standard Metropolitan Statistical Areas appear to have a higher number of blue collar jobs, relative to the central cities, while the inner core furnishes a proportionately larger number of white collar jobs" [14, p. 21]. "The low-skill jobs for which ghetto residents are most likely to qualify are relatively dispersed in comparison with total jobs."[11] Moreover, most analysts believe that low-skilled jobs, particularly in manufacturing and retailing, are presently decentralizing faster than high-skilled (professional, technical, and skilled clerical) jobs. In a study of the New York metropolitan region, it was found that the central city "has been losing low- and middle-income jobs, and gaining high-income jobs, relative to the suburbs, and that this change has been associated with a shift to office and service sector activities" [12, p. vi].

The transportation improvements under evaluation for 1981 are largely in radial corridors. Furthermore, station spacing, availability of feeder services, and operating schedules would typically be such that the projects would be more appropriate for commuting inward to the central business district than outward to manufacturing jobs in the suburbs. Thus, the benefits from these improvements depend on the proportion of trips taken to centrally located workplaces. Since it appears that our assumptions overstate the proportion of low income work trips directed to the central business district and understate the proportion of high income work trips directed there, it seems likely that our calculations overstate the progressivity of the 1981 transport projects.

c. Employment Time

Our calculations were made entirely for rush-hour work trips. This emphasis on the rush-hour would not introduce any obvious bias if the ratio of rush-hour to non-rush-hour work trips was the same at all income levels.

However, low income people appear to do a lower share of their commuting to work during the rush hours between 7 and 9 a.m. and a higher share during the rest of the day than is the case for high income people. For example, in Worcester, Massachusetts 45 percent of workers living in a low income neighbourhood arrived at work between 7 and 9 a.m., compared to 57 percent of the workers living in the rest of the urban area. On the other hand, 17 percent of the workers living in the low income neighbourhood arrived at work between 9 a.m. and noon, compared to 9 percent of the workers living in the rest of the urban area [29, p. 87]. It has often been observed in other cities that a disproportionate share of low income jobs are on night shifts.

The effect of the 1981 transport projects on travel costs would almost certainly be greater during rush hours than during non-rush hours. It follows that for this reason also our calculations have probably overstated benefits to low income people relative to high income people.

d. Implications of Bias

Since the biases discussed all operate in the same direction, we can conclude that the incidence of benefits from reduction in expenditure on travel resulting from the Union-Don Mills project would be even more regressive than the data in tables 4-6 suggest. On the other hand, the incidence of these benefits from the Allendale, Eglinton, and Lakeshore projects would be less progressive than the data in tables 4-6 suggest. Our information is not sufficient to determine whether correction for biases would entirely offset the strong progressivity indicated by tables 4-6.

## V. CONCLUDING RESERVATIONS AND SUGGESTIONS

The reader should recall at this point that the distributional analysis in sections III and IV considered only one category of benefits from transport projects and none of the costs, and was carried out in a partial equilibrium framework.

Unfortunately, the partial equilibrium assumptions which many (but not all) economists reluctantly accept as sufficiently accurate for aggregate cost-benefit calculations in the real world are probably more difficult to justify for analyses of distributional effects. This is because many of the excluded effects involve transfer payments which can be ignored in cost-benefit analyses concerned with aggregate consumption benefits. However, such pecuniary effects may be important in determining the distribution of benefits among households.[12]

Apart from suggesting the importance of research to analyze distributional effects in a general equilibrium framework, another problem which this study indicates for further research is measurement and valuation of increased accessibility resulting from transport projects.

Finally, the attempt to apply the analysis to Toronto indicates that analysis of the distributional effects of urban policies is seriously impeded by the failure of urban planning departments, urban public transit authorities, and similar agencies to collect data broken down by income level on such things as the intra-urban spatial pattern of employment, number of trips, and use of different transport modes (auto, carpool, public transit, taxis, etc.).

FOOTNOTES

*I have received helpful comments on this research from Gordon Davies, Ona Frankena, and Juri Pill. I am grateful to John Gartenburg for research assistance, to the Metropolitan Toronto Transportation Plan Review for data, and to the Canada Council for financial support for the computer work.

[1] For a discussion of the nature and distribution of costs, see [9, chapter III].

[2] Apart from the benefits discussed below, there might be a number of minor benefits, e.g., a transportation project might induce a reassignment of workers to jobs in such a way that transportation costs would be reduced, or it might reduce air or noise pollution. Also, while the benefits discussed in the text arise from use of the completed project, benefits may also arise during the construction phase of the project, e.g., for factors employed in building. Finally, the separation of effects into benefits and costs is inevitably somewhat arbitrary, since some effects, such as changes in property values, make some people better off and some people worse off.

[3] A number of demonstration projects have been set up in the United States to improve transit service between central residential areas and suburban employment areas. Some of these new services appear to have enabled some ghetto residents to raise their incomes net of transportation cost [15, p. 2].

[4] In analyzing the reduction in the cost of trips, we ignore increased comfort and reduced accident rates.

For a discussion of measurement of increased accessibility and an application to Toronto, see [9, chapter II]. A major unsolved problem in evaluating the distribution of benefits from increased accessibility is to value in money terms changes in accessibility for each income group.

[5]For a description of the MTTPR area as well as MTTPR planning activities, see [17].

[6]The public transit mode was in reality a composite of several public modes, including buses, streetcars, intermediate capacity rapid transit, subways, and commuter trains, which was constructed by MTTPR planners. Between any pair of zones the time and money costs of this composite mode were equal to those of the "best" available public transit mode, but it is not clear exactly what criterion was used to determine which mode was "best". This formulation of the public transit mode was used because data on $T^g_{ij3}$ were available from the MTTPR only in this form.

[7]At the time this study was carried out, 1971 census data on location of residences by income were available only for census families. Omission of people not in census families could affect our calculations in two ways. First, on average the incomes of people not in census families are substantially lower than the incomes of census families. As a result, the shares of the population in income groups 1 and 2 are probably understated relative to the extent that people who are in a given income group but who are not in census families have a different spatial distribution of residences than the members of that income group who are in census families, our calculations concerning the distribution of benefits from transportation investments will not be entirely accurate.

[8]For a summary of empirical studies of the value of travel time, see [6, pp. 67-73].

[9] The incidence of a benefit is "progressive" if the average value of the benefit as a percentage of income declines as income increases. It is "regressive" if the average value of the benefit as a percentage of income increases as income increases.

[10] In any event, as income increases the average household makes more person trips by vehicle, counting both work and non-work trips [1], [2].

[11] W. F. Hamilton, "Transportation Innovations and Job Accessibility," in [1, p. 28].

[12] For a discussion of the incidence of changes in property values resulting from transportation improvements in a general equilibrium model, see [9, chapter IV].

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TABLE 1

Characteristics of Income Groups

| Income Group | Percent of MTTPR Area Census Families | 1970 Census Family Income | |
|---|---|---|---|
| | | Range | Average |
| 1 | 23.9 | Under $7,000 | $ 4,168 |
| 2 | 22.2 | $7,000 - $10,000 | $ 8,505 |
| 3 | 31.8 | $10,000 - $15,000 | $12,190 |
| 4 | 22.1 | $15,000 and over | $22,935 |

Note: Data cover only census families.

Source: [26].

TABLE 2

Value of Travel Time by Income Group, 1970

| Income Group | ($ per hour) Value of Travel Time |
|---|---|
| 1 | 0.83 |
| 2 | 1.70 |
| 3 | 2.44 |
| 4 | 4.59 |

Source: Table 1

TABLE 3

Simulated Fraction of Trips by Mode for

Each Income Group

| | Income Group | | | | |
|---|---|---|---|---|---|
| Mode | 1 | 2 | 3 | 4 | All |
| Auto | .03 | .15 | .32 | .68 | .29 |
| Carpool | .24 | .37 | .34 | .10 | .27 |
| Transit | .73 | .48 | .34 | .23 | .44 |
| | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

TABLE 4

Incidence of Reduction in Expenditure on Travel during 1981 for Four Transport Projects in Toronto (initial Simulation)

(Percent of household income)

| Income Group | Transport Project | | | |
|---|---|---|---|---|
| | Allendale | Eglinton | Lakeshore | Union-Don Mills |
| 1 | .394 | .266 | .231 | .035 |
| 2 | .268 | .133 | .175 | .034 |
| 3 | .185 | .081 | .119 | .042 |
| 4 | .092 | .018 | .033 | .047 |

TABLE 5

Incidence of Reduction in Expenditure on Travel during 1981 for Four Transport Projects in Toronto (Revised Modal Split Parameters)

(Percent of household income)

| Income Group | Transport Project | | | |
|---|---|---|---|---|
| | Allendale | Eglinton | Lakeshore | Union-Don Mills |
| 1 | .417 | .297 | .228 | .035 |
| 2 | .326 | .264 | .218 | .036 |
| 3 | .229 | .183 | .202 | .047 |
| 4 | .119 | .082 | .078 | .057 |

TABLE 6

Incidence on Reduction in Expenditure on Travel
during 1981 for Four Transport Projects in Toronto
(Effect of Transit Improvements on Automobile Speeds)

(Percent of household income)

| Income Group | Transport Project | | | |
|---|---|---|---|---|
| | Allendale | Eglinton | Lakeshore | Union-Don Mills |
| 1 | .404 | .287 | .231 | .035 |
| 2 | .292 | .196 | .181 | .035 |
| 3 | .219 | .169 | .136 | .044 |
| 4 | .120 | .138 | .068 | .057 |

TABLE 6

Incidence on Reduction in Expenditure on Travel
during 1981 for Four Transport Projects in Toronto
(Effect of Transit Improvements on Automobile Speeds)

(Percent of household income)

| Income Group | Transport Project | | | |
|---|---|---|---|---|
| | Allendale | Eglinton | Lakeshore | Union-Don Mills |
| 1 | .404 | .287 | .231 | .035 |
| 2 | .292 | .196 | .181 | .035 |
| 3 | .219 | .169 | .136 | .044 |
| 4 | .120 | .138 | .068 | .057 |