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Urban Transportation Economics and Canadian Public Policy

Mark W. Frankena

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IMPACT OF THE PUBLIC SECTOR
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Research Study 04

URBAN TRANSPORTATION ECONOMICS
AND CANADIAN PUBLIC POLICY

Mark W. Frankena

February, 1977

Department of Economics
The University of Western Ontario
London Ontario Canada
URBAN TRANSPORTATION ECONOMICS
AND CANADIAN PUBLIC POLICY

Mark W. Frankena *

Department of Economics
University of Western Ontario
London, Ontario, Canada

February 1977

This survey paper was written primarily for use as a text in urban economics courses.

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For people who live and work in Canadian urban areas, two of the major concerns with urban transportation are rush-hour congestion and availability of public transit. Most of the important issues in urban transportation economics involve the use of government pricing, regulatory, and investment policies to deal with congestion and public transit. The purpose of this paper is to enable the reader to analyze and evaluate such public policy issues.

A. URBAN TRAVEL PATTERNS

1. Trends in Travel Time and Service

In view of complaints about traffic congestion and availability of public transit, it would be useful to know whether there has been deterioration or improvement in transportation services in Canadian urban areas. Existing data are too incomplete to permit firm conclusions. What data there are suggest that on average travel times by automobile and public transit remained steady or declined between the mid-1950s and mid-1960s. However, there is some fragmentary evidence that after 1965 travel times increased in some cases, at least for automobiles in the central cities of Canada's major metropolitan areas.

A 1956 study reported that in the early postwar period the speed of surface public transit in Toronto declined because of increasing automobile traffic. However, speeds for both automobiles and public transit increased in Toronto between the mid-1950s and mid-1960s because of improvements in traffic engineering, including computer control of a demand-responsive system of traffic signals, replacement of some streetcar lines with buses, and expansion of highways, grade-separated rail rapid
transit, and commuter railways. Average peak-hour line-haul travel speeds for trips between the Toronto suburbs and the central business district (CBD) increased between 1953 and the mid-1960s as a result of the opening of the first three subway lines, Highway 401, the Gardiner Expressway, the Don Valley Parkway, and a number of connecting and by-pass facilities.\(^2\)

However, MacKinnon reports that door-to-door travel times for peak-hour automobile travel to and from the Toronto CBD increased between 1964 and 1969. Among other things, there was an increase in terminal time in the CBD. On the other hand, MacKinnon reports that there was a reduction in travel times by automobile for circumferential trips during the same period. Transit travel times generally increased except in areas served by new subway lines or GO Transit commuter railways.\(^3\)

In the City of Montreal, the average off-peak speed of automobiles increased steadily from 21 to 26 m.p.h. between 1956 and 1965 but then declined through 1971.\(^4\)

Between 1960 and 1970, the national average speed of urban buses and streetcars remained constant at 10 m.p.h. In addition, during this period the total route, vehicle, and seat mileages of urban public transit systems in Canada increased by 50, 25, and 40 per cent respectively,\(^5\) and there were similar increases again between 1970 and 1975. While expansions were most significant in new subdivisions and suburbs, they occurred in other areas as well. In Toronto between 1961 and 1971, vehicle miles of public transit service increased by 30 per cent in non-suburban areas.\(^6\) Among other things, the Toronto subway system, which was opened in 1954, has been expanded steadily and a subway system was opened in Montreal in 1966.
However, while public transit service may have remained steady or improved in the central parts of urban areas, the service available in the expanding suburban areas is clearly inferior to that in central areas. Consequently, as the share of urban population and employment which is located in suburban areas increases, on average accessibility by public transit has probably declined.

In addition, because of increasing public opposition to construction of urban highways, during the present decade automobile congestion may increase in many urban areas. Whether this will occur depends on many aspects of urban transportation policy and on the extent of decentralization of employment in urban areas.

In any event, however, trends in travel times do not provide much guidance for evaluation of government policies. The objective of public policies should be to increase the efficiency of resource allocation and, perhaps, to achieve a more equitable distribution of economic well-being among households. Maintaining or improving travel times or service levels in urban transportation is not in itself an acceptable policy objective.

In order to evaluate transportation policies, it is important to be familiar with several travel patterns which are common to all or most urban areas and with the underlying determinants of these patterns, namely the demand for transportation services, the costs of transportation services, and existing government transportation policies. We now turn to these topics.
2. **Peaking of Travel**

One familiar feature of urban transportation is the large variation in the level of travel and extent of congestion between different hours of the day (see Chart 1). Typically about 30 per cent of weekday trips take place during four morning and evening rush hours. Much of urban transportation pricing and investment policy is concerned with this peak-load problem.

This peaking is a result of the importance of work trips in urban travel and the standard hours of most employment. Consequently, policy analyses dealing with congestion focus on work trips. In Edmonton, Hamilton, and Metropolitan Toronto and Region in 1961-64, from 37 to 46 per cent of all trips were between home and work. Work trips are much more concentrated in the morning and evening peaks than are non-work trips. In Toronto in 1956, work trips accounted for 73 per cent of morning peak-hour trips and 66 per cent of evening peak-hour trips. In Winnipeg in 1962-63 work trips accounted for 87 per cent of all auto and public transit trips during the morning peak hour and 72 per cent during the evening peak hour.

3. **Modal Split of Travel**

Another familiar feature of urban passenger transportation is the dominant role of the private automobile. In 1969, 80 per cent of all person miles by either private automobile or public transit in Metropolitan Toronto were made by private automobile. In Edmonton and the Ottawa-Hull area in 1961-63, 71 to 74 per cent of person trips (excluding walking trips for purposes other than work) were by private automobile and 15 to 21 per cent were by public transit. In the Montreal region
CHART 1

Peaking of Travel During the Average Weekday in Metro Toronto and Region, 1964

in 1970, the breakdown by mode of all intraurban person trips (including walking trips for purposes other than work) was: private automobile, 42 per cent; public transit (including school buses and commuter railways), 31 per cent; taxi, 1 per cent; and walking, 25 per cent.12

Moreover, since 1946 the share of urban trips made by automobile has increased while the share made by public transit has decreased. Between 1950 and 1970 the percentage of all persons crossing the downtown traffic cordon in Toronto who used public transit declined steadily.13 In fact, while the number of urban person trips by automobile has increased continually since World War II, the number of person trips by urban public transit in Canada declined substantially during the late 1940s and the 1950s and then remained almost constant between 1960 and the early 1970s (see Chart 2). Furthermore, the automobile occupancy rate declined by about 15 per cent between the early 1950s and the early 1970s.14 Consequently, the percentage increase in automobile vehicle trips has been greater than the percentage increase in automobile person trips. Reductions in the share of trips by mass transit and in the automobile occupancy rate combined with an increase in total urban travel help to explain current concern over automobile congestion and pollution.

Another important feature of urban travel is that the share of public transit trips varies substantially with trip purpose, time of day, location of origin and destination, sex of traveller, and population of the urban area. The share of public transit is higher for work trips than for nonwork trips; for peak-hour trips than for off-peak trips; for trips in the CBD and for radial trips to and from the CBD than for non-CBD-oriented trips; for women than for men; and for large
CHART 2

Urban Transit Passengers in Canada by Type of Vehicle

Note: Chart is plotted from annual data for 1943-1972 and 1975. Data for 1975 are slightly less inclusive than data for earlier years.

### Table 1
Percentage of Private Automobile and Public Transit Person Trips Made by Public Transit

<table>
<thead>
<tr>
<th>Metropolitan Area</th>
<th>Metro Toronto and Region</th>
<th>Toronto</th>
<th>Vancouver</th>
<th>Ottawa-Hull</th>
<th>Winnipeg</th>
<th>Hamilton</th>
<th>Edmonton</th>
<th>Quebec</th>
<th>Calgary</th>
<th>London</th>
<th>Kitchener-Waterloo</th>
<th>Kingston</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (000)</td>
<td>2730</td>
<td>2074</td>
<td>824</td>
<td>529</td>
<td>499</td>
<td>392</td>
<td>391</td>
<td>380</td>
<td>331</td>
<td>194</td>
<td>127</td>
<td>72</td>
</tr>
</tbody>
</table>

#### ALL ORIGINS AND DESTINATIONS

<table>
<thead>
<tr>
<th>All day</th>
<th>All purposes</th>
<th>Work trips</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>21&lt;sup&gt;d&lt;/sup&gt;</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>23&lt;sup&gt;d&lt;/sup&gt;</td>
<td>40</td>
</tr>
<tr>
<td>Peak hour</td>
<td>All purposes</td>
<td>Work trips</td>
</tr>
<tr>
<td></td>
<td>29&lt;sup&gt;a&lt;/sup&gt;</td>
<td>36&lt;sup&gt;ae&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>24&lt;sup&gt;b&lt;/sup&gt;</td>
<td>20</td>
</tr>
</tbody>
</table>

#### CBD-ORIENTED

<table>
<thead>
<tr>
<th>All day</th>
<th>All purposes</th>
<th>Work trips</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>52&lt;sup&gt;cf&lt;/sup&gt;</td>
<td>47&lt;sup&gt;cg&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>37&lt;sup&gt;ch&lt;/sup&gt;</td>
<td>31</td>
</tr>
<tr>
<td>Peak hour</td>
<td>All purposes</td>
<td>Work trips</td>
</tr>
<tr>
<td></td>
<td>49&lt;sup&gt;a&lt;/sup&gt;</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>48&lt;sup&gt;a&lt;/sup&gt;</td>
<td>40&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Notes:
- a: Morning peak hours.
- b: Evening peak hours.
- c: Data from cordon counts rather than origin-destination studies.
- d: Data for motor vehicle trips rather than private automobile person trips.
- e: Data for 1964.
- f: Data for 1960.
- g: Data for 1953.
- h: Data for 1957.
- i: 1966 population of urbanized core of census metropolitan area, except in case of Metro Toronto and Region, where figure is the 1964 population of the HTARTS area.

Sources:
urban areas than for small ones. In short, the share of public transit is substantially higher for CBD-oriented rush-hour work trips than for other trips and for women and is highest in the largest urban areas. These generalizations are supported by the data in Table 1.\textsuperscript{15}

We now turn to the problem of explaining these modal split patterns.

B. MODAL CHOICE BEHAVIOR

It is necessary to know what influences people's choices between alternative transportation modes in order to understand several issues in urban transportation which are relevant to current policy debates: the decline in public transit ridership since World War II, the influence of highway and transit pricing and investment on traffic congestion and transit use, and the merits of investment in rail rapid transit versus investment in highways.

1. Determinants of Modal Choice

The cost to an individual of taking a trip includes not only the out-of-pocket money cost of operating and parking a car or transit fares but also the value of the time required to take the trip. Thus, one might write:

\[ C_i = M_i + V \cdot T_i \]

where

- \( C_i \) = total cost of a trip by mode \( i \)
- \( M_i \) = out-of-pocket money cost of a trip by mode \( i \)
- \( V \) = value of travel time per hour
- \( T_i \) = door-to-door travel time in hours by mode \( i \).
Economists usually hypothesize that among the alternatives available an individual chooses the mode of travel with the lowest total cost, \( C_i \). This theory suggests that the major determinants of choice of mode are: (a) out-of-pocket money costs of the modes; (b) door-to-door travel time of the modes; and (c) value of travel time per hour of the person making the trip. One would expect that the value of travel time per hour, in turn, would depend on the income of the person taking the trip.

Studies of travel behavior in Metropolitan Toronto and Region and in Winnipeg support this type of model of modal choice behavior. They report that the proportion of trips made by public transit was higher when the relative out-of-pocket cost, travel time, and comfort and convenience of service were more favourable for transit and when the income of the tripmaker was lower. 16

2. **Explanations for Observed Modal Splits**

The influence of both money and time costs on choice of mode helps to explain why the share of trips made by public transit is greatest in the case of CBD-oriented, rush-hour, and work trips. First, the out-of-pocket cost for the private automobile is relatively high in the case of trips to the CBD because parking fees are much higher in the CBD than elsewhere in the urban area. Second, in cases where public transit operates on separate rights-of-way, the relative travel time of the private automobile is higher in the case of rush-hour trips because of congestion. Third, because there are indivisibilities in the provision of public transit service, density and frequency of service are greater, and hence walking and waiting times are lower, in areas of the city and at times of day which have high volumes of travel, particularly along
corridors to the CBD at rush hour. Fourth, the automobile has several advantages over public transit which are more important for nonwork trips than for work trips: additional family members can travel in an automobile without an increase in out-of-pocket cost, and the automobile is more convenient for movement of goods and small children.

Similar considerations explain why the share of trips made by public transit is higher in larger cities. Parking costs are higher and the density and frequency of public transit service are greater in larger urban areas.

The greater proportion of trips made by public transit, other things equal, by lower-income people reflects (a) their lower rate of automobile ownership and the lower dollar value they place on savings in travel time and on comfort, and (b) the fact that public transit typically has a lower out-of-pocket money cost but requires more travel time and is less comfortable than the automobile. Because of its lower out-of-pocket cost, low income people are more likely to choose public transit than are high income people, given the same travel options, in spite of public transit's greater travel time and lesser comfort.

3. Trend in Transit Ridership

Urban public transit ridership declined substantially from its peak in 1946 until 1960 and then remained almost constant between 1960 and the early 1970s (see Chart 2) in spite of a steady increase in total urban travel. Several factors contributed to this decline. First, transit ridership in 1946 was inflated by restrictions imposed on automobile use during World War II. Urban transit passenger trips increased by about 110 per cent during the war largely because of restrictions on
the supply of gasoline, automobile parts, and new automobiles for private use and because of increased central city employment in wartime industries. One explanation for the decline in transit ridership in the early postwar period was the relaxation of controls on automobiles.

Second, existing public transit systems generally provide services which are inferior goods. As incomes have increased, people have been willing to pay higher out-of-pocket costs to reduce travel time and increase comfort and convenience, and automobile ownership per capita has increased substantially. Consequently, people have switched from public transit to private automobiles.

Third, public transit fares in Canada increased substantially relative to the cost of living and relative to the price of gasoline between 1945 and 1970 (see Table 2). This naturally deterred people from using public transit.

Fourth, the decline in public transit trips in absolute terms and compared to automobile trips is further explained by the decentralization of urban areas. In large part because the private automobile is the lowest-cost mode of transportation between dispersed origins and destinations, the transit service provided in suburbs is generally inferior to that in the higher density central parts of urban areas. For example, if Metropolitan Toronto is divided into a central service area with a population of one million and a surrounding suburban service area with an equal population, one finds that public transit accounts for twice as many trips per capita and twice as large a share of total person trips in the central area as in the suburban area. Consequently, as an increasing share of population, employment, shopping, and travel has been located in low-density suburban areas, an increasing share of trips
TABLE 2
Real Urban Transit Fare and Gasoline Price in Canada

<table>
<thead>
<tr>
<th>Year</th>
<th>Urban Transit Fare</th>
<th>Gasoline Price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Canadian Urban Transit Association</td>
<td>Statistics Canada</td>
</tr>
<tr>
<td></td>
<td>(Base: 1950 = 100)</td>
<td>(Base: 1949 = 100)</td>
</tr>
<tr>
<td>1940</td>
<td>118</td>
<td>n.a.</td>
</tr>
<tr>
<td>1945</td>
<td>105</td>
<td>n.a.</td>
</tr>
<tr>
<td>1950</td>
<td>100</td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>1955</td>
<td>115</td>
<td>140&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>1960</td>
<td>130</td>
<td>156</td>
</tr>
<tr>
<td>1965</td>
<td>166</td>
<td>169</td>
</tr>
<tr>
<td>1970</td>
<td>163</td>
<td>214</td>
</tr>
<tr>
<td>1971</td>
<td>167</td>
<td>212</td>
</tr>
<tr>
<td>1972</td>
<td>165</td>
<td>204</td>
</tr>
<tr>
<td>1973</td>
<td>153</td>
<td>186</td>
</tr>
<tr>
<td>1974</td>
<td>142</td>
<td>169</td>
</tr>
<tr>
<td>1975</td>
<td>154</td>
<td>169</td>
</tr>
</tbody>
</table>

Notes: Each index was computed by dividing an index of nominal prices by the consumer price index.

<sup>a</sup>1949.
<sup>b</sup>1956.

Sources: <sup>c</sup>Average ticket fare for members from Canadian Urban Transit Association, 1975-6 Transit Fact Book, Toronto, 1976, Table 12, and consumer price index from Statistics Canada (formerly Dominion Bureau of Statistics), Prices and Price Indexes, Cat. No. 62-003, Information Canada (Queen's Printer), Ottawa, monthly 1953-1975.

<sup>d</sup>Indexes of local transit fares and gasoline prices and consumer price index from Statistics Canada, ibid.
has been by private automobile. Moreover, population and employment levels have declined in central cities which accounted for a major share of transit ridership in certain metropolitan areas, such as Ottawa and Toronto.

With all of these factors encouraging a decline in transit ridership, it is natural to ask why there has not been a further decline in ridership since 1960. The major explanation is undoubtedly that there was a 60 per cent increase in the number of vehicle miles of public transit service supplied between 1960 and 1975, primarily as a result of increasing government ownership and subsidization of public transit. Among the more important increases in supply have been the expansion of the Toronto subway system and introduction of a subway system in Montreal, in both cases with large government subsidies. In addition, between 1971 and 1975 transit fares fell relative to the cost of living and the price of gasoline.

4. Public Transportation Modes

Urban areas are faced not only with choices between private automobiles and public transportation but also with choices among public modes. The ridership and route mileage of different public modes are shown in Chart 2 and Table 3.

Over time, the relative importance of different public modes has changed for reasons related to both cost and demand conditions, including technological innovations and changes in travel densities. For example, in Toronto public transportation began with horse-drawn omnibuses in 1849 and horse-drawn street railways in 1861, but use of horses ended soon after the introduction of electric street railways in 1892. Since
TABLE 3
Public Transit Route Mileage in Urban Areas by Population, 1975

<table>
<thead>
<tr>
<th>Population of Urban Area (1966)</th>
<th>Subway</th>
<th>Street Railway</th>
<th>Trolley Bus</th>
<th>Motor Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>500,000 and over</td>
<td>109</td>
<td>158</td>
<td>141</td>
<td>5,272</td>
</tr>
<tr>
<td>250,000 - 500,000</td>
<td>-</td>
<td>-</td>
<td>145</td>
<td>4,633</td>
</tr>
<tr>
<td>100,000 - 250,000</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2,959</td>
</tr>
<tr>
<td>50,000 - 100,000</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1,068</td>
</tr>
<tr>
<td>Less than 50,000</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1,070</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>109</td>
<td>158</td>
<td>286</td>
<td>15,003</td>
</tr>
</tbody>
</table>

Note: Data are for members of the Canadian Urban Transit Association only.

Source: Canadian Urban Transit Association, _op. cit._
then, Toronto has introduced interurban electric railways (which were used by commuters until the 1920s), motor buses (introduced in 1921), electric trolley buses, subways (1954), and specialized commuter railways (revived in 1967). In 1971, the distribution of number of fares collected in Toronto among these modes was: motor buses, 43 per cent; subways, 30 per cent; electric street railways, 19 per cent; trolley buses, 6 per cent; and commuter railways, 2 per cent. These shares are substantially different from those for Canada as a whole (see Chart 2) because Toronto is one of the few cities which still uses trolley buses, only Toronto and Montreal have subways and commuter railways, and since 1964 only Toronto has used street railways. In most Canadian cities, the motor bus is now the dominant or only public mode.

5. **Diversion from Automobiles to Mass Transit**

It has often been proposed that reduction of transit fares, increases in road user and parking charges, reservation of lanes for exclusive use by buses, or investments in mass transit be used to induce travellers to switch from automobiles to public transit and thus reduce road congestion. There would, for example, be a substantial reduction in congestion if the modal split could be returned to the level prevailing two or three decades ago.

Several researchers in the U.K. and U.S. have investigated the diversion which would result if fares on existing transit systems were reduced or eliminated. Studies by Lave, McGillivray, and Quarmby suggest that between 11 and 22 per cent of work trips would be diverted from automobile to transit if fares were eliminated. A study by Kraft and Domencich suggests a lower figure of 7 per cent for rush-hour work trips.
and 3 to 5 per cent for all rush-hour trips.\textsuperscript{25} Applying the Lave, McGillivray, and Quarmby results to a representative urban area where initially 75 per cent of work trips are by automobile and 25 per cent are by transit, one would conclude that between 15 and 29 per cent of automobile work trips would be diverted to transit and that transit ridership for work trips would increase by 44 to 88 per cent. In the specific case of Boston, the study by Kraft and Domencich suggests that about 6 per cent of all automobile trips would be diverted to transit and that transit ridership would increase by about 28 per cent.

This same group of studies suggests that the elasticity of transit ridership with respect to the fare is between \(-.17\) and \(-.87\) for work trips, i.e., a reduction in fares by \(t\) per cent would increase transit ridership for work trips by \(.17t\) to \(.87t\) per cent. Kraft and Domencich estimate that the elasticity for shopping trips is \(-.32\) compared to \(-.17\) for work trips, which indicates that the elasticity of transit ridership for all trips may be greater than for work trips alone.\textsuperscript{26} Frankena estimated that the elasticity of demand for urban bus trips with respect to the fare is \(-.38\) in Canada.\textsuperscript{27}

The data on elasticities of modal choice and transit ridership cited above are usually interpreted as casting doubt on the potential for use of transit fare reductions to achieve a substantial decrease in traffic congestion. Most people would continue to use automobiles even if no fare were charged on existing public transit systems because of the greater speed, comfort and convenience of automobiles. Another implication is that, since the fare elasticity of transit ridership is evidently between zero and minus one, transit companies would increase their losses if they reduced fares.
Another means of inducing people to switch from automobiles to transit for CBD-oriented trips would be to raise CBD parking fees. A study of modal choice behavior in Toronto estimated that an increase of $1.85 in the daily parking charge in the core area would divert 25 per cent of morning rush-hour automobile trips to the core area to public transit.\textsuperscript{28}

Large investments in rail rapid transit systems have sometimes been proposed as a method of reducing automobile congestion. In most cases economists have predicted that only a modest share of automobile trips would be diverted to the new transit systems, basically because the cost per trip (in terms of time and money) by automobile would be lower than that by the new systems for most travellers who were previously going by automobile, except those whose origins and destinations are close to transit terminals or whose trips are very long.

While 54 per cent of the initial riders on Toronto's GO Transit commuter railway previously travelled by automobile,\textsuperscript{29} the volume of traffic diverted to the railway was small compared to the volume of traffic on the parallel expressway. When the Yonge Street subway opened in Toronto in 1954, a large majority of the riders were people who had previously used other public transit modes. A study of 1960 riders on the Yonge Street subway found that 85 per cent previously used other public transit and only 13 per cent previously used automobiles.\textsuperscript{30}

The Winnipeg study cited earlier uses its findings on the determinants of modal choice to predict the effect of alternative transportation investment programs on the share of work trips which would be made by transit and automobile in 1991. The study predicts that addition of a 48.5 mile rail rapid transit system involving an extra capital outlay of
$525 million would divert 15 per cent of automobile work trips to the downtown area to public transit and would reduce the average automobile work trip time by 12 per cent because of the reduction in road congestion.

6. Inferring the Value of Travel Time from Modal Choice Behavior

It is important to have estimates of the value of travel time, or how much people would be willing to pay for a reduction in delays caused by congestion, in order to make correct decisions regarding whether to invest in additional transport facilities and how much to charge for use of existing congested facilities.

Economists have estimated the amount people are willing to pay per hour to save travel time by observing how much additional money they are willing to spend in order to travel by a faster mode. Many people have a choice between travelling by auto and by public transit in a situation where travel by auto would be faster but more expensive in money terms. They have the option of going by auto and thus paying some additional money to save some travel time. If such a person decides to go by auto, economists infer that the value he places on the savings in travel time by auto is greater than the extra money cost. If he decides to go by transit, economists conclude that the value placed on the savings in travel time by auto is less than the extra money cost.

For example, suppose a person has a choice of commuting 5 miles to work by auto or transit. The money cost for a round trip by auto, assuming an operating cost of $.15 per mile and a daily parking fee of $1.00, is $2.50; the money cost for a round trip by transit, assuming a one-way fare of $.30, is $.60. Suppose that the door-to-door travel
time for a round trip by auto would be 1 hour while that by transit, including waiting time, would be 2 hours. In this case, the individual has the option of travelling by car rather than by transit and spending an additional $1.90 ($2.50 minus $.60) to save 1 hour. Consequently, if the individual actually travels alone by auto, economists infer that he values travel time at more than $1.90 per hour, while if he travels by transit he values travel time at less than $1.90 per hour.

Using methods similar to this, Beesley, Quarmby, and others have concluded that on average people at each income level actually value in-vehicle travel time per hour during the journey-to-work at 20 to 50 per cent of their before-tax hourly wage rate. People value walking and waiting time at two to three times as much as in-vehicle time. With an average wage rate among motorists in Canada of about $6 per hour, this suggests that on average motorists value their in-vehicle travel time during the journey-to-work at about $1.20 to $3 per person per hour. With an average occupancy rate of 1.4 people per auto, reductions in travel time per vehicle for such motorists would be worth about $1.70 to $4.20 per hour. Of course, on average people who earn low wages, who are not in the labour force, or who are shopping rather than commuting to work value their travel time less than this.

C. PRICING POLICIES

1. Congestion Charges

A major objective of public policy should be to achieve efficient use of existing transportation facilities. Facilities are used inefficiently if some users would not be willing to pay the marginal social
cost of producing the trips they take. To prevent people from taking trips which they value at less than marginal social cost, economists argue that user charges should be set so that travellers are required to pay the marginal social cost of their trips.

This recommendation implies that each road vehicle should be charged for three categories of costs which may be increased by its use of the road: (a) wear and tear of the road; (b) pollution damage or other costs imposed on non-users; and (c) time lost and vehicle operating expenses for other road travellers due to congestion. Similarly, given the number of mass transit vehicle hours of service, each rider should be charged for congestion costs imposed on other riders in the form of increased discomfort and travel time. Time per trip by mass transit increases with number of riders in the short run when the number of vehicle hours of service is constant because additional riders increase the frequency and duration of stops and thereby reduce both the average speed of transit vehicles and the frequency of service.

In order to apply these principles, one must understand congestion costs. In the case of a road, as long as the number of vehicles per mile is low each vehicle can travel at the maximum speed permitted by traffic laws or considerations of safety. Beyond some level, however, as the number of vehicles per mile increases, speed decreases and travel time per mile increases because it is not safe or even possible to maintain the same speed as the distance between vehicles is reduced. In addition, vehicle operating cost and the risk of accidents may increase. As a result, travel cost per vehicle mile, which consists of the value of the traveller's time, the vehicle operating cost, and the value of the expected losses due to accidents, increases as the density of
vehicles increases. Eventually, after the density of vehicles reaches a high level, a further increase in the number of vehicles using the road reduces speed so much that the flow of vehicles actually decreases.

A hypothetical numerical example (see Table 4) should clarify the nature of congestion. We suppose that until the number of vehicles per mile of road (column 1) reaches 40, each vehicle can maintain an average speed (column 2) of 40 m.p.h. As the density of vehicles is increased beyond 40, the speed declines so that by the time there are 200 vehicles per mile of road the average speed is only 4 m.p.h. The time required to travel one mile (column 3) is inversely related to the speed and declines from 1.5 minutes when the speed is 40 m.p.h. to 15 minutes when the speed is 4 m.p.h.

Suppose we now wish to determine the total number of vehicle miles of travel that take place per hour (column 4) corresponding to each density of vehicles on the road. When there are 20 vehicles per mile of road, each vehicle travels 40 miles per hour. Consequently, the total vehicle miles of travel per hour is 800 (20 vehicles times 40 miles per hour). Thus, the flow of vehicles (column 4) can be obtained by multiplying density of vehicles (column 1) times speed (column 2). It can be seen from the table that as the number of vehicles using the road increases from 20 to 120, the total number of vehicle miles of travel increases from 800 to 3600. However, any increase beyond 120 per mile in the number of vehicles using the road leads to a decline in the total amount of travelling that takes place. Once the density of vehicles reaches 200 per mile, we approach what is popularly known as a traffic jam.

For the purposes of further discussion, we can give labels to the
### TABLE 4
Hypothetical Example of Congestion on a One-Way Road

<table>
<thead>
<tr>
<th>Density of Vehicles (Vehicles per mile of road)</th>
<th>Speed (Miles per hour)</th>
<th>Time per Vehicle Mile (Minutes)(^a)</th>
<th>Flow of Vehicles (Vehicle miles of travel per hour)(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>40</td>
<td>1.50</td>
<td>800</td>
</tr>
<tr>
<td>40</td>
<td>40</td>
<td>1.50</td>
<td>1600</td>
</tr>
<tr>
<td>60</td>
<td>39</td>
<td>1.54</td>
<td>2340</td>
</tr>
<tr>
<td>80</td>
<td>37</td>
<td>1.62</td>
<td>2960</td>
</tr>
<tr>
<td>100</td>
<td>34</td>
<td>1.76</td>
<td>3400</td>
</tr>
<tr>
<td>120</td>
<td>30</td>
<td>2.00</td>
<td>3600</td>
</tr>
<tr>
<td>140</td>
<td>25</td>
<td>2.40</td>
<td>3500</td>
</tr>
<tr>
<td>160</td>
<td>19</td>
<td>3.16</td>
<td>3040</td>
</tr>
<tr>
<td>180</td>
<td>12</td>
<td>5.00</td>
<td>2160</td>
</tr>
<tr>
<td>200</td>
<td>4</td>
<td>15.00</td>
<td>800</td>
</tr>
</tbody>
</table>

Notes:  
\(^a\) Time per vehicle mile in minutes is calculated by dividing 60 (minutes per hour) by speed in miles per hour.  
\(^b\) Flow of vehicles is calculated by multiplying density of vehicles times speed.
various degrees of congestion in this example. First, until the density of vehicles exceeds 40 per mile, there is no congestion since one more vehicle using the road does not slow down the others. Second, from a density of 40 vehicles per mile to a density of 120 vehicles per mile there is moderate congestion. Although an additional road user slows down other users, total flow of vehicles (column 4) is still increasing in this range. Third, at a density of 120 vehicles per mile, maximum flow of vehicles is reached. Fourth, beyond 120 vehicles per mile any increase in the number of vehicles using the road slows down others so much that the total number of vehicle miles of travel declines; this situation can be described as bottleneck congestion.

In what follows, we will begin with a detailed analysis of the moderate congestion situation and then discuss the bottleneck congestion problem.

(a) Moderate Congestion

The relation between cost of travel per vehicle mile, C, and vehicle flow (not density) on the road or number of trips per hour when there is no congestion or moderate congestion is illustrated by the curve C'C in Figure 1. In this hypothetical example (which uses different numbers from the example in Table 4), congestion is assumed to start at a vehicle flow of 30. At a flow of 100, the cost is 29.8 cents per vehicle mile. If the flow increases to 101, the cost increases to 30 cents. A 101st vehicle imposes an additional cost per mile of 0.2 cents on each of the other 100 vehicles. Thus, a 101st vehicle imposes a total of 20 cents (0.2 cents per vehicle times 100 vehicles) in congestion costs on other road users.
FIGURE 1

Model of an Existing Road

Cents per vehicle mile

Vehicle trips per hour
The short-run marginal social cost per mile of a 101st trip is the sum of two items: (a) the cost of 30 cents borne by a 101st vehicle plus (b) the additional congestion costs of 20 cents borne by all other road users combined. Consequently, the marginal social cost of the 101st trip is 50 cents per mile.

The relation between short-run marginal social cost (SRMC) for the last trip and vehicle flow is illustrated by the curve C'SRMC in Figure 1. The vertical distance between the C'SRMC and C'C curves at each level of vehicle flow measures the extra congestion costs or external diseconomies imposed on other road users by the last trip. Since there are no congestion costs at flows below 30 vehicles, the two curves coincide in this range. At a flow of 101 vehicles, the additional congestion cost as a result of the last trip, and hence the distance between the two curves, is equal to 20 cents.

If the government does not charge for use of transportation facilities when there is congestion, then facilities will be used inefficiently. If they do not pay for the congestion costs they impose on others, users would not bear the full marginal social cost of their trips. Consequently, some people would take trips which they value at less than marginal social cost.

Figure 1 can be used to demonstrate the nature of this inefficiency. Suppose that during rush hour the demand curve for vehicle trips per hour is represented by DD_p. The equilibrium level of vehicle flow would be 101 in this case. If 101 trips were produced the cost per trip would be 30 cents, and this is exactly the price of trips at which 101 trips would be taken. If fewer than 101 trips were being taken, the cost per trip would be less than 30 cents. At this price more people would be
induced to take trips, and the flow would increase until the cost per trip was 30 cents and the flow was 101.

This level of road use is inefficient, however. The demand curve indicates that when 101 trips are being taken, one of the road users values a trip taken at only 30 cents. We have already seen that the marginal social cost of a 101st trip is 50 cents. Thus, production of a 101st trip for the person who values a trip at only 30 cents involves a net waste of 20 cents in resources. The source of the problem is that in deciding whether to use the road people ignore the congestion costs imposed on others. They compare the value of the trip to the cost, C, which they bear personally rather than to the marginal social cost, SRMC.

In fact, at the equilibrium level of 101 trips there are 21 vehicles taking trips which are valued at less than their respective marginal social costs. The demand curve $D_D^p$ intersects the SRMC curve at a trip level of 80, where SRMC equals 35 cents. When only the 80 people who value trips most highly are using the road, there is no other potential traveller who would be willing to pay the marginal social cost for an 81st trip. Thus, from the point of view of efficiency, only 80 trips should be produced, and they should be taken by the 80 people who value them most highly.

One way to achieve efficient use of the road would be for the government to impose on all vehicles a user charge per vehicle mile equal to the distance between the SRMC and C curves at the level of road use at which the $D_D^p$ and SRMC curves intersect. In the present example the charge would be 10 cents per vehicle mile, which would be equal to the increase in congestion costs imposed on all other road users combined
by an 80th vehicle trip. If the cost of travel for each vehicle was increased by 10 cents per mile, only the 80 people who valued their trips most would use the road. Thus, road use would be efficient. The 21 people who were using the road prior to imposition of the charge would decide not to use the road if they were required to pay a charge equal to the congestion costs which an 80th vehicle trip imposes on others.

It is important to understand that in this case efficient road use does not correspond to a situation with no congestion or to a situation with the maximum possible flow of vehicles. The user charge which would lead to efficient road use would reduce but not eliminate congestion. Public policies should not restrict the level of road use below 80 in order to reduce congestion further. When 80 trips are being taken, all road users value their trips at least as much as the marginal social cost, including increased congestion costs, of the last trip.

The preceding analysis applies to hours of the day during which there is moderate congestion. Suppose now that we consider hours, such as the middle of the night, when the demand for trips is so low that the flow of vehicles is less than 30 and hence there is no congestion. In this case the demand is represented by a curve like $D'D_0$ in Figure 1. Since the SRMC and C curves coincide for low vehicle flows, the equilibrium number of trips that will be taken (which is determined where $D'D_0$ intersects $C'C$) and the efficient number of trips which should be taken (where $D'D_0$ intersects $C'SRMC$) are the same. Consequently, the government should not impose any charge (other than that related to wear and tear of the road and pollution damage) during hours when there is no congestion.
(b) **Bottleneck Congestion**

When the demand for road use is very high, if the government does not charge appropriate congestion tolls vehicles may continue to crowd onto the road until "bottleneck congestion" occurs. It is easy to see that bottleneck congestion always represents an inefficient allocation of resources. For example, suppose that in the example in Table 4 there were 200 vehicles per mile of road. In this case, the flow of vehicles would be 800 per hour and the travel time per vehicle mile would be 15 minutes. The same flow of 800 vehicles could be achieved if there were only 20 vehicles per mile of road, and in this case only 1.5 minutes would be required per vehicle mile. Obviously, it would be more efficient to produce the 800 miles of travel at a time of 1.5 minutes per mile than at a time of 15 minutes per mile of travel. Thus, whenever there is bottleneck congestion it would be possible to have the same amount of travelling done at a lower cost per trip in terms of travel time and other real resources.

Since the bottleneck congestion situation is somewhat more complex than the moderate congestion situation depicted in Figure 1, we will not analyze the bottleneck case geometrically. The fundamental results are the same. Unless the government charges a congestion toll for use of the road, too many vehicles will use the road and the allocation of resources will be inefficient. An efficient allocation of resources (which will still involve moderate congestion) can be achieved if the government charges a congestion toll. The congestion toll per trip should be equal to the additional congestion costs imposed on other road users by one more trip at the efficient level of road use. This congestion
toll would, of course, be greater than one required during a period when there would be only moderate congestion in the absence of a toll.

It can be concluded that the charge which the government should collect in order to achieve efficient use of roads varies with the extent of congestion. The charge should be relatively high on downtown streets and in the direction of peak flow on urban arterial roads during rush hour, and it should be low or zero on suburban residential streets, on rural roads, and during non-rush hours generally.

(c) **Further Discussion of Congestion Tolls**

It will be evident to the reader that road user charges should be imposed at the same rate for all automobiles regardless of the number of people riding in the car. This is because the road user charge should be equal to the marginal external cost imposed by the car, and that does not depend on the number of occupants of that car. A policy of charging a lower toll for a car with more occupants would be inefficient. People sometimes support such a policy on the grounds that it would encourage car pooling and hence reduce congestion, but this line of reasoning is incorrect. First, charging a reduced toll for cars with many occupants would encourage some people to travel in car pools at rush hour when it would have been more efficient to have them travel either at a less congested time or by public transit. Thus, such a policy would encourage excessive use of automobiles at rush hour by some people. Second, the policy would encourage formation of car pools, which might indeed reduce congestion. However, not all measures which reduce congestion are efficient. In this case, subsidization of car pooling would encourage inefficient car pooling activity, e.g., the time some people would waste
forming car pools with people whose locations or desired travel times did not correspond with their own would exceed the time saved by all road users combined because of the elimination of a few extra cars. Of course, this does not mean that all car pooling is inefficient; indeed, the efficient level of car pooling would be encouraged by a uniform toll per car regardless of number of occupants. But car pooling becomes excessive when the additional costs outweigh the additional benefits.

It should be kept in mind that the justification presented for congestion tolls has been exclusively as a rationing device to achieve efficient use of existing transportation facilities. We have not argued that users of transportation facilities should be taxed in order to pay for the existing facilities, or to finance additional facilities, or to raise revenue to compensate people who are adversely affected by the congestion of the facilities.

In a study for Toronto, Dewees estimated that considering time costs alone the external cost of an additional automobile ranges from zero under uncongested conditions to over one dollar per mile in the direction of peak flow at rush hour. On average this external congestion cost for inbound automobiles was 38 cents per mile during the morning rush hour and 1.4 cents at mid-day.35

Walters made a rough estimate that in 1959 the user charge for passenger cars in the more congested parts of U.S. urban areas should have been around 12 to 17 cents per mile during peak traffic periods and 6 to 10 cents per mile for off-peak daytime traffic.36 Presumably the corresponding charges during the 1970s would be higher.

The only important charges presently collected for use of roads by passenger cars in Canada are the federal and provincial gasoline
taxes, which amount to 1 to 3 cents per mile. Since this is much lower than the desirable level for congested urban roads, it might be useful to raise the gasoline tax somewhat in urban areas, and perhaps to charge a higher tax in urban areas than in rural areas. However, the gasoline tax has only limited potential as a mechanism to allocate urban road space efficiently because the charge per mile does not vary significantly with amount of congestion. Thus, the charge per mile would inevitably be either too low or too high in most situations.

A number of proposals have been made for supplementing gasoline taxes with use of special meters or electronic equipment to record the mileage each vehicle travels on congested roads. Walters has suggested that vehicles be equipped with meters, similar to those used by taxis, which would record mileage when the 'flag' is up. Street signs would indicate when the flag should be put up, and fines would be imposed on vehicles which failed to put up their flags. Vickrey has suggested that vehicles be equipped with electronic identifiers. Roadside scanning devices would measure the mileage of each vehicle in congested zones as well as the extent of congestion. In either case, billing could be handled by mail on a monthly basis, so it would not be necessary to delay cars at toll booths or hire an army of toll collectors. Of course, conventional toll booths might be practical on limited access expressways and major bridges.

Another policy which has been proposed would require all vehicles travelling in the CBD at rush hour to display a special license which would be sold by the city government. Such a policy might induce many cross-town commuters who travel through the CBD without stopping to bypass the CBD. A problem with this policy is that once a vehicle
purchased a license it would have no incentive to restrict its use of congested roads in the CBD.

In addition, parking fees in congested areas might be set, with differentiation between rush hour and non-rush hour road users, in such a way that automobiles would in effect be charged for the use of congested roads. This proposal will be discussed below in the section on parking policy.

Introduction of substantial road user charges would deter use of vehicles on congested roads. An increase in the money cost of travel on congested roads would encourage people, particularly low income motorists, to advance or postpone vehicle trips to times when congestion and user charges would be lower, to divert vehicle trips to less congested routes, to combine vehicle trips by the formation of car pools, to substitute public transit trips for trips by private automobile, to choose residences and jobs which are closer together, and to make fewer trips. Similarly, road user charges would increase the incentive for firms to locate in less congested areas or to operate during off-peak hours in order to reduce transport costs for customers, employees, and freight.

An important objection to the imposition of user charges designed to increase the efficiency of road use is that such a policy might have an undesirable effect on the distribution of well-being among households at different income levels. Imposition of road user charges would have three major effects which should be considered in a distributional analysis: (a) the money cost of using congested roads would increase; (b) the time cost of using congested roads would decrease; and (c) the increase in revenue from road user charges would permit a reduction in other taxes. An analysis by Richardson suggests that as far as (a) and
(b) are concerned road pricing would probably increase the average well-being of high income households (who value savings in travel time highly) and very low income households (who rely heavily on public transit) while making middle income households worse off. However, a great deal depends on how the government uses the revenues from the road user charges.

Apart from roads, the analysis of congestion costs has important implications for pricing the use of other transport facilities to achieve an efficient allocation of resources. Tolls for bridges and tunnels and taxi fares should vary with congestion. Provided efficient congestion tolls are collected for use of roads, public transit fares should also be higher when riders impose greater congestion costs on each other. This suggests that transit companies should charge higher fares during rush hours than during the rest of the week. In a study for a large U.S. urban area, Mohring estimates that if the bus system followed efficient investment, operating, and pricing policies, the peak-hour fare would be 2.4 times the off-peak fare. However, Mohring does not consider the effect of transit pricing on road congestion. An analysis by Glaister which considers the effect of transit pricing on road congestion suggests that if efficient road user charges are not collected then the appropriate ("second-best") peak-hour fares would not necessarily be greater than and might even be less than off-peak fares.

At present there are only a few cases in Canada where urban transport user charges differ between rush hours and less congested times of the day. In a few cities, including Oakville, Vancouver, and Victoria, public transit fares are $.10 to $.15 lower in off-peak periods; in other cities, including Hull and Quebec, lower off-peak fares are
restricted to children and/or senior citizens. In Ottawa lower off-peak fares have been charged for dial-a-ride bus services. Toronto, Vancouver, and Victoria offer passes which reduce the fare on Sundays and holidays for heavy users of transit. On the other hand, several cities, including Calgary, Edmonton, Regina, and Winnipeg offer monthly passes which effectively reduce the fare for heavy users of transit, most of whom would probably be rush-hour commuters.

2. Parking Policy

In the case of automobiles, transport facilities include not only road rights-of-way but parking space. Widespread provision of parking space below marginal social cost in congested areas presently contributes to excessive use of congested roads.

Municipal governments frequently permit curbside parking at a low or zero price and subsidize publicly-owned lots. Firms often supply free parking to employees and customers, a practice which is encouraged by municipal land-use controls and by provincial and federal tax laws. Tax laws enable firms to deduct from their taxable income the cost of parking space provided to employees, but employees are not required to pay income tax on this fringe benefit. The significance of free parking is suggested by a 1967 survey which found that 48 per cent of a sample of 132 people who commuted to central Toronto by automobile were provided with free parking by their employers.41

In order to increase the efficiency of use of both roads and parking facilities, parking fees should be increased to the level of marginal social cost. In addition, if road user charges are not collected by metering road use, charges for the use of congested roads might be
collected at the same time as parking fees. In congested areas of the city, the parking fee could consist of two parts: (a) a "basic parking charge" equal to the marginal social cost of using a parking space; and (b) a "road congestion charge" equal to the congestion costs imposed by a vehicle on its way to and from its destination. The parking fee would thus depend heavily on the time of day at which a vehicle entered and left the parking space, since the latter would affect the "road congestion charge." Vehicles parked from 9 a.m. to 5 p.m. would be charged more than vehicles parked from 11 a.m. to 7 p.m. because the former would use roads during more congested periods. Such a policy could be implemented by fixing appropriate fee schedules for publicly-owned parking spaces and by imposing excise taxes on parking in privately-owned lots.

As an example of this policy, the parking fee for the public in the lot under Toronto's City Hall is higher if a vehicle enters between 8:15 and 9:15 a.m. or leaves between 4:30 and 5:30 p.m. Ironically, however, senior members of the city government park free.

One important limitation of using parking fees as a means of collecting road congestion tolls in the downtown area is that about half the vehicles entering the downtown of the typical urban area now pass through without parking. Another limitation, suggested by work done by Gillen, is that an increase in CBD parking fees due to imposition of a "road congestion charge" might simply induce people to park outside the CBD rather than to reduce their use of congested arterial roads by switching to public transit or by travelling at a less congested time of day.42
3. Subsidies

In analyzing user charges designed to achieve efficient use of transportation facilities, nothing was said about the relation between the revenues from road user charges and transit fares and the costs to the government or transportation authority of providing roads and transit services respectively.

If three conditions hold, the revenues from such user charges would exactly offset the costs to the government or transportation authority of providing the facilities, and hence no subsidy would be required and no profit would be made. The first condition for self-financing operation is that use of the facilities not impose any pollution damage or other external costs on non-users, or alternatively that user charges not reflect this part of marginal social costs. If any portion of the user charge is justified by costs such as pollution damage imposed on non-users, and if the next two conditions are fulfilled, then the facility will operate at a profit equal to the revenue from this portion of the user charge.

The second condition for facilities to be self-financing is that the government is simultaneously following an efficient policy with regard to investment in transportation facilities, providing exactly those facilities which are justified by cost-benefit analysis. More precisely, the government should be providing the facilities consistent with minimizing the long-run total social cost of producing the level of trips at which the demand curve for trips intersects the long-run marginal social cost curve. If the government provides less than the correct amount, its costs would be lower. At the same time, because congestion
and hence user charges would be higher, its revenues from user charges would be higher, assuming that the demand curve is inelastic. Hence, if the government provides less than the correct amount of transport facilities, it would earn a profit from the user charges discussed.

The third condition for self-financing operation of transportation facilities is that the long-run average social cost (LRAC) per trip of road or transit travel be the same at all levels of travel. The relevant costs include both costs borne by the transit authority for such things as rights-of-way and transit vehicles and costs borne by users, including the value of travel and waiting time. If the LRAC of travel is lower at higher levels of travel because of economies of scale, however, the revenues from the appropriate user charges will be less than the costs borne by the government. In this case, the transportation facilities will require a subsidy if they are priced in the way which would lead to efficient use. 43

We thus come to the argument for subsidization of urban mass transit based on economies of scale. The LRAC per trip by mass transit declines as the number of trips increases, for two reasons. First, in the case of commuter railways, rail rapid transit, and other systems which use separate rights-of-way, an increase in the number of trips often does not require an expansion of rights-of-way. Consequently, as the number of trips increases, the cost per trip of providing rights-of-way decreases. Second, in the case of most mass transit systems, in the long run an increase in ridership would be accompanied by an increase in number of vehicle hours and frequency of service and hence a reduction in the cost per trip of waiting time for users. It follows from these economies of scale that the LRAC curve for mass transit trips per hour
would be negatively sloped, and the long-run marginal social cost (LRMC) curve would lie below the LRAC curve, as in Figure 2.

The objective of achieving an efficient allocation of resources between mass transit and other uses requires that transit trips should be produced for all people who are willing to pay the LRMC of their trips, but only for these people. If we ignore the complications which arise due to differences in the demand for trips during rush and non-rush hours, the efficient number of trips is determined where the demand and LRMC curves for transit trips intersect. Assuming DD represents the demand for transit trips per hour, OQ trips per hour should be produced and these trips should be taken by the people who are willing to pay the most for them.

If the transit system provides the amount of rights-of-way and the number of vehicle hours of service which would minimize the long-run total social cost of producing OQ trips, the short-run marginal social cost (SRMC) curve would intersect the LRMC curve where the latter intersects the demand curve. The SRMC curve in Figure 2 corresponds to that in Figure 1, except that in the former the curve refers to the cost of person trips by transit rather than the cost of road vehicle trips. In the case of transit, the SRMC of a trip includes (a) the value of travel time of a last person who takes a trip plus (b) the congestion costs imposed by a last rider on other transit users.

If we take the point of view of an individual transit rider and ignore the congestion costs imposed on others, we could measure the value of time required to take a trip at each level of transit ridership in the short run when the size of rights-of-way and number of vehicle hours of service are fixed. This private time cost (which does not
FIGURE 2
Model of a Mass Transit System with Economies of Scale

Cents per trip

Trips per hour

SRMC
LRAC
LRMC
include the transit fare) is represented by the curve C'C in Figure 2.

From our analysis of user charges, we know that in order to achieve efficient use of the facilities it provides, the transit authority should charge a fare equal to the additional congestion costs imposed by the last trip at the level of travel where the demand curve intersects the SRMC curve. In this case, the appropriate fare would be BE. If this fare was charged, OQ trips per hour would be taken, and the allocation of resources would be efficient. The revenue raised per hour by a fare of BE collected on OQ trips would be OQ x BE.

We must now compare the transit system's fare revenue with the cost of providing rights-of-way and vehicles. OQ measures the LRAC per trip when OQ trips are produced. QB measures the portion of this cost borne by each of the users in terms of value of travel time. Thus, BG (OQ minus QB) measures the cost per trip borne by the transit system, and the total cost per hour to the transit system of providing OQ trips would be OQ x BG. Comparing the transit system's fare revenue with its costs, we find that costs exceed revenues by OQ x EG (EG equals BG minus BE) per hour.

In summary, if there are economies of scale in mass transit, then efficient allocation of resources between mass transit and other uses can be achieved in the long run only if the transit system is subsidized. If mass transit were required to be self-financing, a fare higher than BE would be charged and fewer than OQ trips would be produced. This would be inefficient because the higher fare would deter some people from taking transit trips even though they would be willing to pay the marginal social cost of producing these trips.

Mohring estimated that economies of scale could justify a subsidy
of roughly 50 to 60 per cent of the costs borne by the transit authority for a bus system in a large U.S. urban area in order to achieve an efficient allocation of resources between mass transit and other uses.45

We have now discussed the user charges for automobiles and public transit which would lead to an efficient allocation of resources among use of roads, use of mass transit, and other activities. If transit fares were set according to these principles but use of roads continued to be charged according to present practices, then the allocation of trips between public transit and automobiles would be inefficient. As we have seen, present road user charges are much too low in circumstances where there is a high level of congestion and pollution. Consequently, the number of trips in the downtown area and at rush hour by private automobile would be above the efficient level while the number by transit would be below the efficient level.

Under these circumstances, the most efficient policy would be to adopt appropriate user charges for automobiles as well as public transit. However, as long as such automobile user charges are not collected in practice, the next most efficient ("second best") policy might be to set transit fares in the downtown area and at rush hour low enough that the shares of trips by transit and automobile would be close to their efficient levels.

In this case, in situations where there is congestion on roads, transit fares would be below the level suggested by our preceding analysis and indicated in Figure 2. Consequently, the revenues from transit fares would be even lower than those indicated in Figure 2, and transit would require even larger subsidies.

There are two limitations to "second best" pricing of public
transit at less than its marginal social cost as an alternative to using tolls to price automobile use at its marginal social cost, however. First, if both automobile use and public transit use are priced below marginal social cost, people will be induced to do more than the efficient amount of travelling in urban areas. Second, if public transit fares were less than the efficient road use and parking charges, even complete elimination of transit fares could not offset the effect on modal choice of failing to collect congestion tolls for automobile use.

Apart from the case which has been made for subsidizing urban transit of efficiency grounds, based on considerations of economies of scale and "second best" arguments, transit subsidies might be supported on the basis of their income distributional effect. On average, the percentage of family income spent on urban public transit decreases as family income increases (Table 5). Consequently, if all transit fares were reduced by the same percentage as a result of a government subsidy, the direct benefit of the subsidy as a percentage of income would be greater for low income people than for high income people. Provided the subsidy were financed by a proportional or progressive tax, so that low income people would pay an equal or lower percentage of their incomes to finance the subsidy program than would high income people, the net effect of the subsidy would be to make low income people better off.

Subsidization of public transit by municipal, provincial, and federal governments is a standard practice in Canada. In 1974 bus and integrated bus-subway systems in most urban areas received subsidies of 15 to 50 per cent of their costs, and special services such as suburban commuter railways and dial-a-bus typically received subsidies of over 50 per cent of their costs. The most extensive program of subsidies has
TABLE 5
Expenditure on Urban Public Transit and Taxicabs
by Families and Individuals in Eight
Canadian Urban Areas, 1972

<table>
<thead>
<tr>
<th>Annual Income ($000)</th>
<th>Average Percentage of Income Spent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Public Transit</td>
</tr>
<tr>
<td>4-5</td>
<td>1.84</td>
</tr>
<tr>
<td>5-6</td>
<td>1.52</td>
</tr>
<tr>
<td>6-7</td>
<td>1.24</td>
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<tr>
<td>7-8</td>
<td>1.43</td>
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<tr>
<td>8-9</td>
<td>.80</td>
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<tr>
<td>9-10</td>
<td>.77</td>
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<tr>
<td>10-12</td>
<td>.70</td>
</tr>
<tr>
<td>12-15</td>
<td>.56</td>
</tr>
<tr>
<td>15-20</td>
<td>.49</td>
</tr>
<tr>
<td>20-25</td>
<td>.38</td>
</tr>
</tbody>
</table>

been operated by the Ontario provincial government, which paid 75 per cent of the costs of all new transit rights-of-way and vehicles plus 50 per cent of the operating deficit of each urban transit system in the province during 1971-1976. In terms of dollars, the largest subsidies have been in Toronto and Montreal, where municipal and provincial governments have paid about $570 million since 1949 for construction of subways. In addition to this subsidy of capital costs, during 1975 the Toronto and Montreal transit systems received $85 million in municipal and provincial subsidies to cover their operating deficits.

Unfortunately, the fact that a case can be made for some form of government subsidies for urban public transit on both efficiency and income distributional grounds does not imply that existing subsidy programs necessarily contribute to efficiency of resource allocation or a more equal distribution of well-being.

For example, when the government subsidizes capital expenditures by a transit system by a greater percentage than other costs, it encourages the transit system to adopt an excessively capital-intensive technology. If the subsidy for purchase of new buses is at a higher rate than the subsidy for maintenance of existing buses, transit companies will be encouraged to scrap their old buses too soon in order to avoid maintenance costs. This will increase the average social cost of supplying bus trips. Similarly, transit companies will be encouraged to adopt capital-intensive rail rapid transit systems rather than rely on bus systems even when the latter would involve a lower average social cost per trip.

In addition, the fact that a transit company is receiving a subsidy does not necessarily imply that the subsidy is being used to
reduce the fare to the efficient level. It is possible that the transit system would choose to use the subsidy to introduce a new route in a low density suburb where the demand did not justify the cost of providing service. In this case, the subsidy might bring about a less efficient allocation of resources.

Criticisms of some existing transit subsidies can also be made on the basis of their income distributional effects. A study by Frankena finds that subsidy rates are generally highest on transit services used heavily by upper income groups. These include: (a) suburban commuter railways, such as Toronto's GO Transit; (b) dial-a-bus systems in low-density residential neighbourhoods; and (c) bus and subway routes into outlying low-density residential neighbourhoods.47

D. REGULATORY POLICIES

1. Rationing Road Use Without Tolls

The purpose of the congestion tolls discussed above was to ration the use of transportation facilities. There are a number of ways to ration use of transportation facilities without the use of tolls, e.g., congestion on an expressway could be reduced by using stop lights on entrance ramps to prevent cars from entering when the density reached a certain level, or use of urban roads at rush hour by large trucks could be banned. While some policies of this type might be more efficient than doing nothing, in general it would be more efficient to use road user charges rather than direct controls to ration transportation facilities.

Suppose, for example, that traffic lights were used to restrict
the number of cars on an expressway to the same number that would be there if an efficient toll were applied. Although the same number of cars would travel on the expressway at the same speed whether lights or tolls were used, the two policies would differ in important ways. First, some of the people travelling would be different. Use of lights to restrict entry would lead to formation of queues at the lights, and consequently use of the expressway would be rationed to people who are willing to wait the longest in the queues. While tolls would ration use of the expressway to people willing to pay the most for trips (in terms of money and the value of time), rationing by the use of waiting time in queues would (a) induce some people who value their time very little to take trips even though they would not be willing to pay much for the trip and (b) deter some people who value their time highly from taking trips even though they would be willing to pay a good deal for the trip. Consequently, lights would not ration use of the expressway to people willing to pay the most for trips, and hence would be inefficient relative to tolls.

A second difference between use of tolls and lights is that in the case of tolls expressway users would pay money to the government while in the case of lights they would use up time waiting in queues. Even if an individual road user were indifferent between the two schemes, from society's point of view the lights are very inefficient since real resources (time, gas, ramp space) are wasted by people waiting in line. Finally, of course, if the expressway were not built with provision of enough space on ramps for the cars waiting at lights, a system of lights could lead to an even greater waste of real resources by causing traffic jams on surrounding roads.
2. Regulation of Roads to Improve Bus Service

A major shortcoming of conventional bus service is that buses not only operate on the same congested rights-of-way as private automobiles but make frequent stops. Consequently, they are slower than automobiles. In Winnipeg in 1962-63, the line-haul portion of trips by bus to the downtown area during the morning peak hour took twice as long as by private automobile. In Hamilton in 1961, door-to-door travel times for off-peak CBD-oriented bus trips were between 1.5 and 2.5 times as long as for auto trips, with the relative travel time for transit greatest on longer trips into outlying areas, including low-density suburbs. In Ottawa-Hull, CBD-oriented trips took about 2 to 2.5 times as long by bus as by private automobile during rush hours and 4 times as long during non-rush hours.\textsuperscript{48}

It has been argued by Kain and others that urban areas which have expressway systems could improve bus service by operating express buses either on separate expressway lanes reserved exclusively for buses or on relatively uncongested shared expressways.\textsuperscript{49} Urban areas could provide uncongested shared expressways for "bus rapid transit" services if they would use traffic lights at entry points or tolls on existing limited-access highways to restrict the number of private automobiles to a level at which congestion would be low. If traffic signals on entry ramps were used, buses would be given priority access on special on-ramps and would by-pass the automobile queue. Because of the reduction in automobile traffic during rush hour, buses would travel at speeds higher than those currently achieved.

Studies by Meyer, Kain, and Wohl, Smith, and Dewees provide
evidence that bus rapid transit would be more efficient than construction of additional freeways for private automobiles or construction of rail rapid transit facilities in many circumstances. Bus rapid transit has several advantages compared to rail rapid transit. First, at the residential and downtown ends of the trip buses can provide their own local collection and distribution of passengers while most users of rail rapid transit would have to walk, drive, or take local buses to stations and then transfer. Second, buses are small enough to pick up a full load in one residential area and then drive non-stop to one destination area. By contrast, rail vehicles must make stops along the route to pick up and discharge passengers, so no one is able to travel express. Third, while buses can pass each other, rail vehicles cannot. As a result of these three advantages, bus rapid transit may be able to achieve faster door-to-door travel times than rail rapid transit.

Bus rapid transit has three other significant advantages over rail rapid transit. First, the costs of bus rapid transit to the transportation authority are lower than those of rail unless the volume of passengers carried is extremely high, particularly if expressways already exist. Second, it is relatively inexpensive to try express buses on an experimental basis and drop them if they do not attract a sufficient number of riders. This is not true of rail rapid transit, which requires special rights-of-way. Third, if travel patterns change in the future, express bus routes could be changed and expressway capacity could be reallocated to automobiles. Rail rapid transit routes, by contrast, are inflexible and the rights-of-way could not easily be used for other purposes.

A number of urban areas in Canada have recently experimented with
more limited methods of increasing the line-haul speed of buses during rush hours. In Ottawa and Toronto, lanes on a few major radial routes are reserved exclusively for buses. In Vancouver, buses by-pass the auto queue at the Lions' Gate bridge. Calgary, Montreal, Toronto, and Ottawa operate suburban-CBD express buses, which do not lose time making local stops. However, while such experiments improve bus service, it is not clear that their benefits have always exceeded their costs in terms of increased travel time for other road traffic and bus operating expenses. Consequently, a number of such experiments have been abandoned.

3. Regulation of Taxis

Development of transportation modes other than private automobiles and conventional mass transit has been restricted by most Canadian municipal governments. Licensing restricts the number of taxis, and private automobiles are prohibited from carrying riders for money. Furthermore, taxis are not permitted to carry more than one party at a time and thus cannot act as minibuses or jitneys, picking up and discharging passengers at different points along a route. Partly for these reasons, taxicabs account for less than 1 per cent of urban trips.

Such regulations have adverse effects on efficiency of resource allocation. By restricting the range of transportation services and the output of taxi services, these regulations divert resources from the uses in which they would have the greatest value to consumers. They also weaken competition among suppliers of transportation services.

The restriction of supply enables taxis to raise their fares so that they earn monopoly profits. This is true even though municipal governments regulate fares, since municipal governments generally show
more concern for the profitability of the taxi industry than the efficiency of resource allocation or welfare of riders when they set fares. These profits are reflected in the price of medallions which give the right to operate a taxi. In order to operate a taxi in Toronto, in 1974 new proprietors paid $22,000 each to buy medallions from people leaving the business. In London, Ontario medallions sold for $2,000 to $3,000 in 1975.

The increase in taxi fares which results from government regulation has an adverse effect on the distribution of well-being. Because low income people spend a larger share of their incomes on taxis than do high income people (see Table 5 above), the burden of the higher fares falls disproportionately on low income people.

Relaxation of restrictions on the number of taxis would thus have a number of favourable effects on resource allocation and income distribution. However, such a relaxation would reduce the price of medallions, perhaps to zero, and this would impose a serious hardship on taxi owners, many of whom purchased the medallions at high market prices. The municipal government could use tax revenues to reimburse taxi owners for the value of their medallions.

E. INVESTMENT POLICIES

1. Cost-Benefit Analysis

Now that we have analyzed pricing and regulatory policies which would achieve efficient use of existing transportation facilities, we must consider the problem of evaluating investment projects which would expand facilities. Such projects would include widening roads, constructing
new expressways and rail transit lines, and relocating interurban railways which impose delays on road users in urban areas.

Economists use the technique of cost-benefit analysis to evaluate such investment projects. A project is acceptable on the grounds of efficiency of resource allocation when the aggregate benefits accruing to all members of society exceed the aggregate costs, and the excess of benefits over costs is as great as that of any alternative project.

Benefits from transportation investments typically include such things as reductions in travel times, vehicle operating costs, and risk of accidents and increases in comfort and convenience. Economists attempt to estimate the magnitude of these effects and then value them in money terms at the amount that the people affected by the project would be willing to pay for them. Project costs, or opportunity costs, are the things which people must forego when resources are allocated to the project. They include both resources accounted for in the budget of the transportation authority and uncompensated social and environmental costs, such as destruction of neighbourhoods and pollution damage. The latter costs can be evaluated at the amount of money that the people affected would have to receive to be compensated for bearing them.

These project benefits and costs occur in different years and often over a long period of time. Since a unit of benefits which is not received until the later years of a project's life is worth less than a unit of benefits in the early years, when benefits occurring in different years are added together the benefits in later years are given less weight (or discounted more) than benefits in earlier years. The weighted total or "present discounted value" of benefits during the lifetime of the project is then compared to the similarly-defined present discounted
value of costs in order to determine whether the project should be undertaken.

2. Road Widening

In order to understand cost-benefit analysis, it is useful to apply the technique to a hypothetical road widening project. Consider a one mile, two-lane, two-way road on each direction of which the relation between vehicle flow per hour and cost per vehicle mile (including value of time, vehicle operating cost, and value of the expected losses due to accidents) is depicted by the curve $C'C_1$ in Figure 3. If the road were widened to two lanes in each direction, the curve depicting cost per trip would shift rightward to $C'C_2$. The new curve $C'C_2$ would lie below $C'C_1$ at all vehicle flows at which congestion would have occurred on the original road because at any such vehicle flow there would be less congestion on the wider road. Because of the lower level of congestion, the time requirement, vehicle operating cost, and expected loss due to accidents per mile would probably all be lower on the wider road.

Suppose that, whether or not the road is widened, $D_D$ depicts the demand for vehicle trips per hour in each direction which exists during three peak hours daily except Sundays and holidays, or 900 hours per year. $D'D_0$ depicts the demand for vehicle trips per hour in each direction which exists at all other times.

If we suppose that there is no charge for use of the road whether or not it is widened, then during each peak hour 1000 trips will be taken at a cost of $.35 per trip if the road is not widened while 1100 trips will be taken at a cost of $.25 per trip if the road is widened.

We can distinguish between two categories of benefits during each
FIGURE 3
Model of a Road Widening Project

Cents per vehicle mile

\( \text{D}' \)
\( \text{D}_e \)
\( \text{D}_p \)
\( \text{C}_1 \)
\( \text{C}_2 \)

Vehicles per hour
peak hour from the road widening project:

(a) For each of the 1000 trips which would be taken even in the absence of the project, the cost would be reduced by $.10 due to the reduction in congestion. These savings in travel costs during each peak hour in one direction would amount to $100. With 900 hours of peak travel in each direction, the annual savings in travel costs would be $180,000.

(b) The reduction of $.10 in the cost per trip would induce people to take 100 additional trips on this road. Since the height of the demand curve at each level of vehicle flow measures willingness to pay for an additional trip, the value of these trips ranges from $.35 (the willingness to pay for an additional trip when 1000 trips are being taken) down to $.25 (the willingness to pay for an additional trip when 1100 trips are being taken). On average, the willingness to pay for each of these 100 additional trips is half-way between $.35 and $.25, i.e., $.30. If the road is widened, the cost per trip borne by the vehicles that take the additional trips (in terms of value of time, vehicle operating costs, and value of expected losses due to accidents) is $.25. Assuming that each of these additional trips also imposes $.01 in additional wear and tear on the road and pollution damage, the difference between willingness to pay and social cost, or net benefit, per trip averages $.04. With 100 additional trips during each peak hour in one direction, the annual net benefit of additional trips would be $7,200.

Consequently, adding the two categories of benefits, annual benefits of the road widening project during peak hours would be $187,200. During each off-peak hour, 200 trips will be taken at a cost of $.20 per trip whether or not the road is widened. Since there is assumed to be
no congestion on the road during off-peak hours, the road widening project has no effect on travel and no benefits during off-peak hours.

In order to simplify the analysis, we have supposed that the reduction in congestion on the road in question which would result from the project would not affect the level of use of other congested roads. If the project would divert traffic from nearby roads to the road in question, and if efficient road user charges were not charged on those nearby roads, then there would be a third category of project benefits in addition to those already discussed: users of nearby roads would benefit from the reduction in congestion which would occur when some traffic was diverted to the improved road.\footnote{51}

Suppose that the demand for trips, the value of time, and other conditions are expected to remain unchanged so that the project will yield $187,200 in benefits each year during the project's life. Suppose also that the project would take one year to complete, so that benefits would commence one year after initiation of the project, and that benefits would be received for a period of 50 years. Finally, suppose that $1.00 in benefits in any year is given the same weight as $1.06 in benefits one year later, i.e., the social discount rate is 6 per cent per year.

In this case, the present discounted value of the benefits received in the first year after the road opens is $187,200/1.06 = $176,604. The present discounted value of the benefits received in the second year is $187,200/(1.06)^2 = $166,607. Finally, the present discounted value of the benefits received in the last year of the project's life is $187,200/(1.06)^{50} = $10,162. The present discounted value of the entire stream of benefits received over the 50-year life of the project is:
\[
\sum_{i=1}^{50} \frac{\$187,200}{(1.06)^i} = \frac{\$187,200}{1.06} + \frac{\$187,200}{(1.06)^2} + \ldots + \frac{\$187,200}{(1.06)^{50}}
\]

\[
= \$176,604 + \$166,607 + \ldots + \$10,162
\]

\[
= \$2,950,000
\]

Now that we have determined that the present discounted value of benefits is $2,950,000, we must compare this to the present discounted value of costs. Suppose that the costs of the project are as follows:

(a) Expenditures of the transportation authority for acquisition of properties for the expanded right-of-way, including the market value of housing and commercial buildings which must be demolished and compensation of moving costs for displaced households and firms: $1,000,000. From this must be deducted the present discounted value of the scrap value of the project at the end of its 50-year lifetime: $20,000. Thus, the net cost is $980,000.

(b) Expenditures of the transportation authority for clearing land and constructing road: $1,500,000.

(c) Uncompensated opportunity cost of publicly-owned frontage, which for practical purposes extends the front yards of houses along the road: $400,000, reflecting the willingness to pay of households that live along the road.

(d) Uncompensated opportunity cost of publicly-owned trees, which must be cut down to widen the road: $200,000, reflecting the willingness to pay of households that live along the road and of passersby.

(e) Additional uncompensated congestion costs imposed upon motorists and pollution costs imposed upon households along the route during the
period that the construction is taking place: $100,000.

Thus, the present discounted value of project costs is $3,180,000. Since the present discounted value of costs exceeds the present discounted value of benefits by $230,000, it would be inefficient to undertake the project.

Three additional points should be made in connection with this cost-benefit analysis. First, if the uncompensated costs in categories (c)-(e) had been ignored in this case, it would have appeared, incorrectly, that benefits would exceed costs for the project. Thus, if planners ignore uncompensated social and environmental costs, they may recommend inefficient investments.

Second, the analysis demonstrates that it might be inefficient to undertake a project even though it would reduce congestion, because the cost of reducing congestion might exceed the benefits. Thus, while efficient resource allocation is an acceptable objective of urban transportation policy, reduction or elimination of congestion regardless of cost is not.

Finally, it should be noted that a road widening project has some effects which are neither aggregate benefits nor costs and which should therefore not be included in a cost-benefit analysis. For example, because the road widening project would involve a loss of publicly-owned frontage and trees and an increase in pollution damage due to additional traffic, it would reduce the value of properties along the road. However, the change in property values is not a separate category of costs but rather a result of costs which have already been included in the analysis. Inclusion of the change in property values as an additional
cost would involve double-counting.

3. Expressway Construction

In 1971, during the controversy over the Spadina Expressway which was under construction in Toronto, both the Metropolitan Corporation of Toronto (MCT), which supported the project, and the Spadina Review Corporation (SRC), which opposed it, prepared cost-benefit analyses of the six and a half mile, six-lane, limited-access highway. 52

The categories of benefits and costs of a new expressway are similar to those for the road widening project discussed above. The first category of benefits computed was savings in travel costs on trips which would be taken even in the absence of the project. In the corridor in which the expressway would be constructed travel costs would be reduced not only for vehicles which would use the expressway but also for vehicles which would continue to use existing arterial roads, since the diversion of some traffic to the new expressway would reduce congestion on nearby arterial roads. The MCT calculated that savings in travel costs would amount to $1,889,000 per year for each mile of expressway constructed. The SRC argued that the MCT's figure was based on overestimates of the amount of traffic that would be diverted to the new expressway, of the number of arterial roads that would experience a reduction in congestion, and of the number of days during the year when there would be congestion if the expressway were not constructed. Because of this disagreement, the SRC calculated that savings in travel costs would be only $1,099,500 per year for each mile of expressway.

The second category of benefits computed was net benefit of additional road vehicle trips which would be taken because of the reduction
in the cost of trips if the expressway were built. These additional road vehicle trips would include trips diverted from public transit as well as trips which would not otherwise be taken. The MCT calculated that the net benefit of these trips would amount to $404,000 per year for each mile of expressway. The SRC figure was again lower, $235,500 per year, because of the disagreement mentioned above.

Counting both categories of benefits, the MCT and SRC thus calculated that after completion of the project benefits would be $2,293,000 and $1,335,000, respectively, per year per mile of expressway. Assuming that it would take five years to complete the expressway, that annual benefits would be constant throughout an expected 50 year lifetime of the project, and that the social discount rate is 6 per cent per year, the present discounted value of benefits per mile of expressway would be $28,628,000 using the MCT annual figure and $16,667,000 using the SRC annual figure.

The MCT and SRC quantified only the capital costs of the expressway which would be borne by the transportation authority, i.e., the costs corresponding to categories (a) and (b) in the discussion of road widening above. They estimated these capital costs at $24,000,000 per mile of expressway. Assuming that these costs were spread evenly over a five year construction period, the present discounted value of these costs would be $21,433,000 per mile of expressway. In addition, there would be operating costs and social and environmental costs, including disruption of traffic during construction, destruction of established neighbourhoods, additional air and noise pollution, and use of publicly-owned land. While the latter costs were not quantified, David and Nadine Nowlan argue that they would be substantial.53
Table 6 summarizes the cost-benefit analysis based on MCT and SRC calculations. Considering only the quantified categories of costs, the present discounted value of net benefits would be $7,195,000 and -$4,766,000 per mile based on the MCT and SRC calculations respectively. Based on such calculations, the MCT argued that the present discounted value of net benefits would be positive and that the expressway should be built. The SRC argued that the expressway should not be built because the present discounted value of the quantified net benefits was negative and because there were many important uncompensated social and environmental costs which were not reflected in this calculation.

This exercise demonstrates that, because of difficulties of measuring and valuing benefits and costs in money terms, in practice cost-benefit analysis does not always lead to clear policy recommendations.

In the Spadina case, after two miles of expressway had been completed the Ontario provincial government decided in 1971 not to continue the project. This decision was made as part of a shift in urban transportation policy from emphasis on expansion of facilities for private automobiles to improvement of public transportation.

One shortcoming of the preceding cost-benefit analyses is that they ignore the effect of transport projects on the distribution of well-being among income groups. Even if a project is efficient because benefits exceed costs, it might be undesirable if costs exceed benefits for low income people. One serious criticism of radial expressways and rail rapid transit lines which would connect outlying suburbs with the CBD is that benefits would accrue largely to high income commuters, suburban landowners, and downtown businessmen. Yet, low income people might bear a significant share of the costs in terms of higher taxes,
### TABLE 6
Benefits and Costs of the Spadina Expressway
(per mile of expressway)

<table>
<thead>
<tr>
<th>Item</th>
<th>MCT</th>
<th>SRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Benefits</td>
<td>$2,293,000</td>
<td>$1,335,000</td>
</tr>
<tr>
<td>Quantified Capital Costs</td>
<td>24,000,000</td>
<td>24,000,000</td>
</tr>
<tr>
<td>Present Discounted Value of Benefits</td>
<td>28,628,000</td>
<td>16,667,000</td>
</tr>
<tr>
<td>Present Discounted Value of Quantified Capital Costs</td>
<td>21,433,000</td>
<td>21,433,000</td>
</tr>
<tr>
<td>Present Discounted Value of Quantified Net Benefits</td>
<td>7,195,000</td>
<td>-4,766,000</td>
</tr>
</tbody>
</table>

neighbourhood disruption, and higher rents if part of the low-income housing stock was demolished to make way for the transportation right-of-way. Because of such distributional effects, in carrying out cost-benefit analyses it is desirable to break down benefits and costs by income group to determine which income groups receive positive net benefits.

4. Railway Relocation

Cost-benefit analysis can also be used to evaluate proposals for relocation of the interurban railway lines which pass through many urban areas. For example, Canadian National Railways (CNR) and Canadian Pacific Railways (CPR) trains pass through London, Ontario on two major and two minor routes. In 1974 planners in London were considering two alternative projects: the "CNR Scheme" would consolidate the CNR and CPR services onto a single rail line through the city while the "Southern Scheme" would relocate the rail services onto a new line south of the city.

According to Poon, these projects could be expected to have four major categories of benefits: (a) Relocation would reduce the delays imposed on road traffic as trains pass level crossings, and consequently travel time and vehicle operating expenses would be reduced for motorists. (b) Relocation would reduce the risk of accidents. (c) Land previously used for railway rights-of-way would be released for other purposes, such as housing, commercial development, and roads. (d) Removal of railways would reduce noise, air, and visual pollution and hence would improve surrounding areas. Of course, corresponding to each category of benefits, there might be certain costs imposed at the new location of
the railway, but in each case there was expected to be a net benefit.

On the other hand, the railway relocation projects would involve four major categories of costs: (a) Relocation would involve capital costs of acquiring properties for new rail rights-of-way and building new tracks and other structures. (b) Since the new track locations would involve a change in mileage, railway operating and maintenance costs might change. (c) Persons and companies which use the railways would incur greater transportation costs commuting and moving freight to the new rail terminals or would incur relocation costs if they moved to the new location. (d) Vehicle traffic would be disrupted and delayed while construction was in progress.

Table 7 summarizes Poon's calculations for the value of benefits and costs under each heading and in total, comparing each of the two relocation schemes with the alternative of maintaining the status quo. While Poon makes his calculations under a variety of assumptions, the data presented here are based on a time horizon for benefits of 50 years, a discount rate of 7 per cent per year, and a value of travel time of $1.25 per person hour.

Poon did not quantify the fourth category of costs. Nevertheless, he was able to conclude that the total costs would exceed the total benefits for both relocation schemes.

5. Alternative Investments for Different Modes

Investment decisions in urban transportation frequently involve choices among alternative projects which would increase facilities for different modes. For example, in a particular transportation corridor, an urban area may have to decide whether to expand the road system for
TABLE 7
Benefits and Costs of Railway Relocation in London
(present discounted value in million dollars)

<table>
<thead>
<tr>
<th></th>
<th>CNR Scheme</th>
<th>Southern Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BENEFITS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Savings in travel time and vehicle operating expenses</td>
<td>4.7</td>
<td>4.5</td>
</tr>
<tr>
<td>b. Reduction in accidents</td>
<td>1.5</td>
<td>1.6</td>
</tr>
<tr>
<td>c. Land released</td>
<td>6.7</td>
<td>8.0</td>
</tr>
<tr>
<td>d. Improvement in surrounding areas</td>
<td>2.2</td>
<td>3.1</td>
</tr>
<tr>
<td><strong>Total benefits</strong></td>
<td>15.1</td>
<td>17.2</td>
</tr>
</tbody>
</table>

| **COSTS**             |            |                |
| a. Capital costs      | 25.5       | 36.8           |
| b. Increased operating and maintenance | -1.3       | 3.5            |
| c. Transportation and relocation | 0.0        | 1.2            |
| d. Delay in traffic during construction | +a         | +a             |
| **Total costs**       | > 24.2     | > 41.5         |

Note: "Positive, not quantified.

Source: C. L. Poon, op. cit., Table 3b.
use by all road vehicles, to invest in separate rights-of-way or lanes for express buses, or to invest in rail rapid transit. Such options are likely to be mutually exclusive in the sense that if any one of them is undertaken then the others could not be justified by a cost-benefit analysis. In such a situation, the urban area should invest in the alternative with the greatest excess of benefits over costs.

Some people believe that urban areas should invest in rail rapid transit rather than expand their road systems. They argue for rail rapid transit on the basis of its advantages (or alleged advantages) compared to the automobile: (a) provided the volume of travel is large enough, the explicit cost per trip for land, capital, fuel, and wages is lower for rail transit; (b) rail transit involves less loss of public open space and trees and less displacement of households and firms because less land is required; (c) rail transit causes less pollution and congestion; (d) rail transit does not promote as much decentralization of economic activity in the urban area; and (e) rail transit provides greater benefits to low income people who do not own cars.

Economists generally argue that in spite of these advantages additional rail rapid transit investments are rarely likely to be justified in Canada. First, investments in rail rapid transit are much less divisible than investments in roads. While investments in roads can be scaled more or less to meet demand, investments in rail rapid transit are inevitably large. The capital cost per mile of rail systems is extremely high. While this presents no problem if the volume of travel by public transit is very high, it makes rail rapid transit service much more expensive than the automobile or buses for the volumes of travel which occur in small and medium size urban areas.
Second, the preceding list of advantages of rail transit ignores two important disadvantages: (a) except for trips which both originate and end close to transit terminals, rail transit has a higher cost in terms of door-to-door travel time than does the automobile; and (b) travel is less comfortable by rail transit than by automobile when allowance is made for walking, waiting, transferring, and standing in crowded cars as well as for the loss of privacy.

Third, the benefits of a transport project are mainly reductions in travel costs for people who use the new facility and for people who use existing facilities which become less congested when some people are diverted to the new facility. Thus, the benefits of a project depend heavily on the number of people who actually use the new facility rather than on the capacity of the new facility. Economists argue that in many situations ridership on a new rail transit line would be low, compared to use of a new road, because the private cost (in terms of time and discomfort in addition to money) of travel by automobile on the existing road system would be lower than that of travel on the new rail transit line for most trips. This is largely a result of the time required to travel between origins and destinations and rail transit terminals. Of course, if efficient user charges were collected for use of roads, then ridership on and benefits of a new rail transit facility would be greater than under present pricing policies.

Fourth, in comparing investments in roads and rail rights-of-way, one should keep in mind that roads are used not only by private automobiles but also by taxis, buses, and trucks while rails are used only by rail transit vehicles. While taxis, buses, and trucks would benefit from decongestion of roads resulting from rail transit investments, they
would probably benefit considerably more from alternative projects which would expand the road system.

Economists generally infer from these cost and demand considerations that additional investment in rail rapid transit can be justified only if origins and destinations are dense enough to produce a very high demand for trips in a given corridor. Sufficient densities occur only along the major radial suburban-CBD routes and within the CBDs of urban areas with populations exceeding 2 million, i.e., Montreal and Toronto, and in most of these cases rail transit already exists. It is important to recognize that average residential density in the Toronto central city is already more than twice the maximum anticipated for the Ottawa central city by the end of the century. Because of the trend toward decentralization of employment and population, it is unlikely that in the future densities will increase sufficiently to justify rail rapid transit in other Canadian urban areas.

One possible exception to this evaluation of rail rapid transit would be in situations where rail rights-of-way and usable tracks already exist because of interurban railways. A single, 4½ mile rail rapid transit route is currently under construction in Edmonton. While one mile of the line in the CBD will be underground, the remaining 3½ miles will use the existing CN railway line. The projected 5,100 passengers per hour in each direction during rush hour is much less than is normally required to justify rail rapid transit.

Of course, the scope for rail rapid transit might increase as a result of new technological developments in the area of intermediate capacity rapid transit. The federal and Ontario provincial governments are subsidizing development of prototypes and demonstration projects
using new intermediate capacity technologies.

Because of the limited scope for investments in rail rapid transit, it follows that for all but the largest urban areas, and in many parts of the largest urban areas as well, improvements in public transit will depend primarily on changes in pricing, regulatory, and investment policies to improve the service offered by buses.

In the area of pricing, introduction of user charges on congested roads would reduce the level of congestion and increase the speed of buses. In the area of regulatory policy, one possibility is discussed above in the section on regulation of roads to improve bus service. In the area of investment, urban areas could increase the sizes of their bus fleets and the number of vehicle hours of service in order to increase the number of route miles or the frequency of service. Another possibility is discussed below in the section on dial-a-ride.

6. Dial-a-Ride

One of the major disadvantages of conventional mass transit compared to the private automobile is the cost, particularly in time, of collection and distribution of passengers. In order to operate a mass transit system at reasonable speed on the line-haul portion of a trip, passengers must be assembled at a limited number of stops. Passengers must walk, take a local bus, drive or be driven to the stations. An indication of the importance of such costs is given by the fact that in 1963-66 in Quebec, Ottawa, and St. John's 37 to 57 per cent of the average door-to-door travel time for bus trips was spent walking, waiting or transferring. In the case of rapid transit on separate rights-of-way, the walking, waiting, and transfer times typically more than offset
any line-haul time advantage of public transit compared to private
automobiles except for passengers who live and work close to stations or
for very long trips.

A number of urban areas in Canada have been experimenting with
demand-responsive residential collection and distribution as a way of
reducing the cost and improving the service of public transit available
in low-density residential areas. The major experiments have been with
dial-a-ride services as feeders for fixed-route line-haul mass transit
systems. A dial-a-ride system typically uses small buses without fixed
routes to pick up passengers at their doors in response to telephone
calls. A dial-a-ride service has operated in Bay Ridges as a feeder for
the Toronto GO Transit commuter railway since 1970. In 1971 Regina
began operating a dial-a-ride system as a feeder service to the CBD-
oriented fixed-route bus system. A study for 1971-72 found that the new
Regina dial-a-ride service led to an increase in ridership on the connecting
fixed-route transit system. Both the Bay Ridges and Regina dial-a-ride
systems have been extended to serve local destinations such as shopping
centres and schools in addition to providing feeder service, and dial-a-
ride services have been introduced in a number of other urban areas,
typically in low density areas or off-peak periods.

However, in some of these other areas dial-a-bus service has been
discontinued after an initial experimental period because of low ridership
and high costs. One problem with dial-a-ride as an alternative to a
fixed route system is that, while walking time is lower for dial-a-ride,
in-vehicle travel time is typically higher unless patronage is very low
because each rider goes along while other riders are picked up and
discharged at their doors. The higher in-vehicle time limits the ability
of dial-a-ride to increase patronage and raises vehicle operating costs per trip.

A second problem with dial-a-ride systems is that the operating cost per hour of a small bus is not much lower than that of a large one, because the dominant component of cost in both cases is the wage of the driver. Moreover, dial-a-ride systems involve the additional cost of a dispatching facility. At current fare levels, dial-a-ride experiments have seldom recovered more than half of their costs from the fare box.

G. URBAN TRANSPORTATION PLANNING IN PRACTICE

Since the late 1950s most Canadian urban areas have sponsored at least one major transportation study, including recommendations for investment in highway and public transit systems during the next 20 to 25 years. These studies and related plans and decisions concerning investment in urban transportation have been severely criticized both by social scientists and by citizen groups.

The studies of the 1960s have been criticized because they assumed that a proper objective for transportation investment was expansion of facilities to accommodate estimated future peak-hour travel, usually while achieving some increase in travel speeds. In short, investment projects to limit or reduce congestion were recommended regardless of cost. There was rarely any attempt to base recommendations on serious cost-benefit analyses of projects and their alternatives, or to determine whether people benefitting from the proposed facilities would be willing to pay the costs. This approach to investment decisions was in part a reflection of the fact that these transportation studies were carried
out by people trained in engineering and planning rather than economics.

A second criticism is that when costs were calculated, many social and environmental costs were ignored. As a result, there may have been a bias toward overinvestment in transportation facilities and, in particular, a bias toward the private automobile as opposed to public transit. For example, estimated costs of expressway construction and operation typically included only actual government outlays and not the uncompensated costs involved in displacement of families and businesses, traffic congestion and neighbourhood disruption during construction, use of park land, air and noise pollution, and unsightly views. Recently, however, there has been increased consideration of such costs because of pressure from citizen groups.

A third criticism of these studies concerns the methods used to estimate future transportation demands. Typically, the studies projected locations of residences and employment in the urban area and then derived estimates of future travel from relationships between land-use and travel in the base year. One problem with this method is that land-use and travel projections were naive. The land-use projections employed in transportation studies were usually taken from city land-use plans, which in turn were drawn up on the basis of official aspirations concerning future development or extrapolations based on scanty data concerning past trends, with little concern for the market process involved in determination of land use. Moreover, this method fails to allow for the effect of investment in transportation facilities on residential and employment location and the number of trips.59

Fourth, the studies were biased toward reliance on investment in rights-of-way as a solution to urban transportation problems. Little
concern was given to other areas of policy such as pricing of road use and parking, regulation of taxis, or regulation of roads to improve the functioning of bus systems. More recently, however, as political opposition to highway construction has increased, greater attention has been given to traffic regulations which would improve the performance of buses compared to private automobiles.

A fifth criticism is that transportation studies and plans were oblivious to the distribution of benefits and costs of the transportation system among people of different incomes. Some critics are also concerned with neglect of the effect of transportation decisions on the employment opportunities of low-income people and with the fact that transportation plans have not given special attention to the transportation demands of the poor.

Sixth, it is argued that there was inadequate citizen participation in planning and decision-making in urban transportation. Land-use and transportation plans were used without being publicized and officially adopted, and decisions were made without public discussion and then presented as faits accomplis by planners and city politicians. More recently, however, many urban transportation studies have had elaborate provisions for public participation.

Furthermore, in some cases, it has been argued that planners and politicians were more concerned to serve the special interests of large property owners and developers than to promote the well-being of city residents in general or residents of affected neighbourhoods in particular, and that planners mislead the public in attempts to win acceptance for transportation systems which could not be justified objectively.
FOOTNOTES

* The author is associate professor of economics at the University of Western Ontario. The author would like to acknowledge helpful comments from Gordon W. Davies, Donald N. Dewees, and Herbert Mohring.

1 Metropolitan Toronto Planning Board, East-West Rapid Transit Line and Expressway, Toronto, 1956, p. 31.

2 Traffic Research Corporation, An Analysis Report on the 1964 Home Interview Survey, Metropolitan Toronto and Region Transportation Study, Toronto, 1965, p. 23, and Metropolitan Toronto and Region Transportation Study, Growth and Travel Past and Present, Toronto, 1966, p. 48. In addition to data on speeds, one would like to have data on the length of the rush-hour period, which may have shortened.


14 It is estimated that the automobile occupancy rate in the morning peak period in Toronto declined from 1.65 to 1.4 between the early 1950s and 1974. Metropolitan Toronto Transportation Plan Review, Car Pooling: Technical Analysis, Report 35b, Toronto, 1974, p. III-36.

15 Since Metro Toronto and Region includes Toronto, Hamilton, and several smaller urban areas, the share of public transit there is naturally lower than for Toronto alone. J. H. Shortreed, ed., "Urban Bus Transit: A Planning Guide," Department of Civil Engineering, University of Waterloo, Waterloo, 1974, p. 28, reports that females accounted for 60-77 per cent of transit trips in eight Ontario cities.


17 A small share of the decline is spurious. Elimination of zone fare systems in many urban areas during this period reduced double-counting of passengers.
Dominion Bureau of Statistics, Canada Year Book, Ottawa, 1939 to 1946.


See footnote 5 and Canadian Urban Transit Association, op. cit., Table V.

These tables do not include commuter railways. The number of revenue passenger trips on commuter railways in Canada increased from 8.3 million in 1961 to 16.6 million in 1970. Dominion Bureau of Statistics, Urban Transit, 1961-1970, Table 10.

Toronto experimented with trolley buses in 1922-25 but did not use them again until after World War II.

Prior to the introduction of GO Transit in 1967, there were commuter rail services on three interurban routes into Toronto, but service was very infrequent and ridership was low, about 0.2 per cent of total transit ridership in the Toronto area.

range of point predictions rather than interval predictions indicated by the three studies.


27 M. Frankena, op. cit.


32 To simplify the discussion of congestion costs, in the following analysis we assume there is no wear and tear of the road or pollution damage. Dewees suggests that the appropriate charge for air and noise pollution caused by an automobile in urban areas would be $.01-.02 per mile. D. N. Dewees, "Travel Cost, Transit and Control of Urban Motoring," p. 19.

33 This treatment of accident costs simplifies matters by ignoring risk aversion. It would be preferable to consider willingness to pay to avoid the risk of accidents.

34 Cost per vehicle mile is defined to exclude existing road user charges such as the gasoline tax since the purpose of the exercise is to determine the efficient level of such charges.


pp. 82-85. See also M. Frankena, "Distributional Effects of Road Pricing: Further Analysis," Department of Economics, University of Western Ontario, 1975.


44 If the demand curve happened to lie below the LRAC curve at all levels of output, the transit system could not finance itself by any uniform fare. However, it might still be able to operate without a subsidy by charging a two-part tariff or by practicing price discrimination.


Metropolitan Corporation of Greater Winnipeg, op. cit., vol. 1, p. 88; C. C. Parker and Parsons, Brinckerhoff, op. cit., p. 16; and Regional Municipality of Ottawa-Carleton Planning Department, op. cit., pp. 74-75.


See H. Mohring, Transportation Economies, Ch. 8.


57. Several of these transportation studies have been cited in earlier footnotes in this chapter.

Case Study of London," Department of Economics, University of Western Ontario, 1974.

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