Factors Affecting Urban Transit Ridership

**Harold M. Kohn**[1]

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Introduction

The use of urban transit services (buses, urban rail, subways and streetcars) in Canada grew steadily in the seventies and eighties, reaching a peak of 1.53 billion passengers in 1990. Ridership then declined to 1.37 billion in 1996, but in 1997 and 1998, the trend began to reverse, reaching 1.43 billion in 1998[3]. The longer term trend is uncertain.

Many have postulated reasons for the decline in the early nineties: increased suburbanization leading to an increase in automobile usage; lower perceived operating costs of the automobile; a preference for the convenience of the automobile[4]; increasing fares, decreasing subsidies, an aging population with a preference for the comfort and security of personal transportation; and varying levels of public support for urban transit across jurisdictions[5].

Number of Urban Transit Passengers
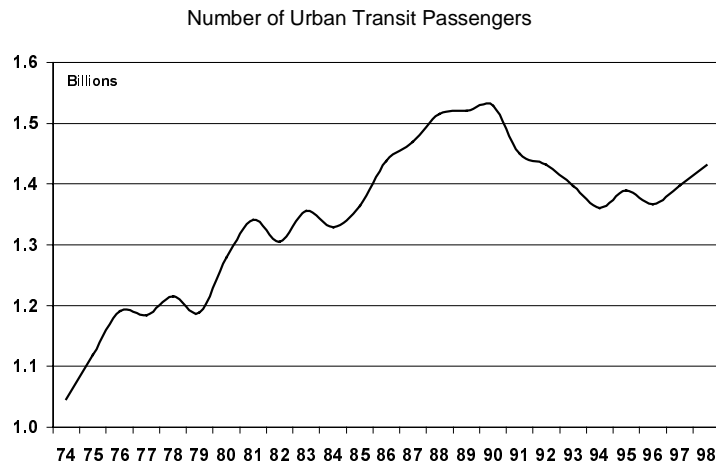
Source: *Passenger Bus and Urban Transit Statistics*, Statistics Canada, Catalogue 53-215-XIB

Within the urban environment, the automobile is by far urban transit's greatest competitor. The 1996 Census revealed that only 10 percent of urban workers utilized public transit. About 81 percent of urban workers travelled to work by personal vehicle. The remainder walked or used bicycles.

Around the world, constituencies that have implemented policies that support urban transit have, in some cases, encouraged people to switch from the automobile to forms of public transportation such as buses, streetcars and subways. For example, in Austria, which has one of the world's highest urban transit ridership rates[6], government has implemented policies that encourage public transit (for example, by providing supporting infrastructure such as bicycle park and ride). Other constituencies, such as Singapore, require automobile drivers to purchase special permits at high fees that allow the driver access to the downtown core. Thus, public transit is encouraged.

Prohibitive taxing and pricing policies (e.g. fuel taxes) have the potential to force drivers out of their cars into urban transit vehicles[7]. Nevertheless, with the exception of a handful of major population centres, most communities in Canada are sparsely populated, which makes the provision of urban transit services relatively expensive and difficult to offer on a comprehensive basis (that is, providing all parts of the community with frequent service). Changes in work patterns such as "work-at-home", shift work outside the traditional 9 to 5 time frame, the location of work sites away from downtown areas and other similar factors have given urban transit planners a multitude of challenges.

The cost of providing comprehensive services, especially for communities that are characterized by urban sprawl, has meant a requirement for subsidization. In 1998, governments in Canada paid approximately $2.4 billion in capital and operating subsidies to urban transit companies[8]. Nevertheless, transit companies have sought out new sources of revenue such as fees from parking lots and advertising. Revenues from these sources grew from $82.4 million in 1995 to $110.4 million in 1998.

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Demand and Supply

Most would agree that there are many factors that affect both the demand for and supply of urban transit. These include:

- family size – Families with children may choose to use personal vehicles rather than urban transit because the monthly cost of transit passes may be (or is perceived to be) more expensive;
- economic changes (e.g. employment opportunities, taxes, fuel costs, parking fees, automobile insurance costs, vehicle operating costs, subsidies, investment, etc.);
- demographic impacts such as population growth, immigration rates and fertility rates;
- ridership loyalty (that may be affected by events such as bus strikes);
- parking rates and distance to work;
- other factors such as convenience, a change in work schedules and the "work-at-home" phenomenon; and
- community size – Large cities with long commutes, expensive downtown parking and relatively greater distances to destination points may positively influence the use of public transit because of the level and frequency of service as well as time and cost savings. Travel times in smaller communities may not be as lengthy, although in smaller communities, the availability of urban transit may not be as comprehensive as in larger cities. For example, the Toronto metropolitan area has an extensive commuter and urban transit system compared to many other Canadian cities. According to the 1996 Census of Canada, 22 percent of the employed population in the Toronto Census Metropolitan Area used public transit to travel to work, and the median one-way travel distance to work was 9.3 kilometres (implying that half commuted further and that half had a shorter commute). On average in Canada, 10 percent of urban workers use public transit.

Factors that affect supply and demand are complex, constantly changing and difficult to identify and discern. For example, in the 1990s, in Toronto, Canada's most populated city, subsidies fell 39 percent, fares increased 50 percent, service levels decreased 12 percent and ridership fell 20 percent[9]. These data imply that fare increases, and subsidy and service reductions combined to produce a drop in ridership. At the same time, however, there was "*a major economic downturn in the Toronto region resulting in a substantial reduction in work trips...demographic factors related to age, female workforce participation and a flow of population and employment to the suburbs (that) reduced ridership...and...two work stoppages/work-to-rule actions*"[10]. This evidence suggests that there may be many factors that influence transit ridership.

Price Elasticity

Economic theory states that, in general, as the price of a good or service increases, the demand decreases. In the real world, differences in the way that consumers react to price changes depend on several factors, including the ability to substitute goods and services, the degree to which consumers react to price changes and wealth and income effects. These factors may be defined in terms of price elasticity. If a product or service has an inelastic demand, consumers will still have a tendency to purchase the product or service when the price increases. This may be true for commuters who must, for various reasons, utilize urban transit services. Conversely, a company that offers a product or service that has an elastic demand will find that demand (and revenue) will change noticeably with a change in price. Commuters who may have alternative methods of urban travel may have demand curves that are more elastic than those dependent upon urban transit.

With regards to urban transit, it is generally believed that demand is inelastic[11]. Thus, there could be a tendency to increase fares on the assumption that revenues will increase. In the Toronto study[12], the assumed fare elasticity was 0.3[13]. (A price elasticity of demand of less than 1.0 is considered to be inelastic). However, in Toronto, ridership and revenues fell as fares increased, indicating that demand was more elastic than expected.

Objective of the Study

In view of the complexity of factors that may impact urban transit ridership, a quantitative study was undertaken in an attempt to identify those factors that may affect supply and demand. The research utilized an extensive database gathered by the Canadian Urban Transit Association directly from member transit companies. These data are collected on an annual basis, and provided in raw form to Statistics Canada. Specifically, data from approximately 85 urban transit companies were used. These companies carry about 97 percent of all urban transit passengers in Canada. Data elements included demographics, hours of service, fare structure, vehicle statistics, energy consumption, employment, passenger statistics, revenues and expenditures. Seven years of data were used, from

1992 to 1998. Because the data represent many of the same cities over a period of seven years, the database was in the form of cross section - time series data.

Average Fares, Revenues and Ridership

Although the database consisted of fares and the number of passengers broken down by adult, child, student, senior citizen and other, it was not possible to obtain revenues for each of these categories. Therefore, an average fare was developed by dividing passenger revenue by the total number of passengers.

Using this measure, it was found that average fares have increased, on an aggregate basis across Canada, from a low of $0.93 in 1992 to $1.14 in 1998 (in current dollars)[14]. During the same time period, the number of passengers using urban transit remained almost constant, but revenues increased from $1.2 billion to $1.5 billion.   On the surface, it might appear that there was a positive correlation between fares and revenue but almost no relationship between fares and the number of passengers.

The data were segregated by year, by population distribution and by province. Little variation was observed in terms of the statistical relationship noted in the previous paragraph.

Regression analysis was then used to test the various data elements provided by the transit companies themselves, to determine if one or more variables could be used to explain the variation in ridership.

Result of Multiple Regression Analyses[15]

As a first step, average fares were regressed against the number of urban transit passengers using the entire database. The result produced an R square value not significantly different from zero (i.e. the independent variables explained almost none of the variation in the number of passenger trips). Variations of this model were tested, such as using only cities where the number of transit passengers was greater than 100,000, 500,000, 1 million, etc. There was little improvement in the model's statistical tests (e.g. R square, t statistics, F ratio, etc.)[16].

In the next stage of analysis, the population of the service area (as defined and provided by each urban transit company) was added as an independent variable to try to explain the variation in the number of urban transit passengers. The R square value obtained was 0.39, which was lower than expected. However, this was a significant improvement over the use of average fares in the single equation single variable model described in the previous paragraph.

These two variables were then combined into one model, producing an R square value of 0.51, again an improvement but still not sufficiently strong. A number of variations were tested, such as clustering the data by population, average fare, province or region, urban size, etc. The R square, t statistics and F ratios were statistically insignificant for the most part, indicating little statistical relationship between the explanatory variables and passenger trips.

Other independent variables were then added for testing purposes. They were included mostly in the form of dummy variables[17]:

- for each year of data (to account for any differences on an annual basis);
- for cities that have populations in excess of one million; this dummy variable assumed that larger cities have more comprehensive transit systems, more traffic, a greater dispersion of people geographically, longer commute times, and, perhaps, a greater tendency towards transit ridership;
- for cities with more than one million urban transit passengers; this dummy variable was similar to the preceding variable for cities with populations in excess of one million; despite the apparent similarity, the correlation between the 2 variables was only 0.19; and
- for cities with populations less than 100,000; this dummy variable assumed that cities with populations less than 100,000 people have less comprehensive transit systems, less population dispersion, shorter commute times and, perhaps, a lower tendency to use public transit than cities with greater populations.

By using all these variables, the R square value improved to 0.7 and the F ratio was 111, statistically significant at the 99 percent level of confidence. Most of the t statistics were statistically significant and none of the independent variables were correlated.

Despite the fact that an acceptable R square value was obtained, the residual analysis did not provide strong results at a micro basis (i.e. on a city by city basis). (In the residual analysis, the estimate of the number of passengers was

compared to the actual number of passengers). In most cases, the individual data points exhibited large residual errors[18]. Further refinement of the model was undertaken.

Ridership rates (to compare cities) were introduced through the use of a dummy variable. The dummy was applied to communities where the ridership rate was greater than 100 (that is, 100 trips per person per year).

The results of one of the earlier models are shown in Table 1. Although this iteration demonstrated some positive qualities, it lacked other desirable characteristics.

- All signs on the coefficients were as hypothesized. The average fare coefficient was negative, indicating that as fares increased ridership decreased. The negative coefficient on the dummy variable for communities with less than 100,000 passengers was also as expected, indicating that people in smaller communities rely more on other modes of transport rather than buses (smaller communities are more likely to have lower levels of urban transit service than larger communities).
- Although the R square, t statistics and F ratio were acceptable, the model produced high residual errors, except in a few cases.
- Sensitivity analysis was restricted because of the large number of dummy variables compared to variables with observable and useful data. As a result, it was difficult to conduct meaningful sensitivity analysis since estimations would be similar if the dummy variables were consistent.

TABLE 1 – Statistical Results of an Early Model			
Independent Variable	**Coefficient**	**Standard Error**	**t Stat**
Intercept	28,249,639	3,422,054	8.3
Average Fare	-27,257,012	2,971,573	-9.2
1 Million Passenger Dummy	8,231,286	2,023,896	4.1
1 Million Population Dummy	144,450,347	5,376,838	26.9
Dummy - cities with less than 100,000 passengers	-1,515,797	3,136,120	-0.5
Ridership Rate Dummy	160,505,085	5,908,999	27.1
R square = 0.88	F Ratio = 755.7 (99% significant)		

Service and Other Variables

At this point, other independent variables from the urban transit database were introduced: revenue vehicle hours, revenue vehicle kilometres and a series of population variables.

In general, all population variables (such as the population of the primary city, the population of its service area, the population of the metropolitan area and the population of the metro service area) all produced coefficients with negative signs. This was deemed to be unacceptable since intuitively, the larger the population, the greater the urban transit ridership. The population variable was dropped at this point.

The one million passenger dummy variable was highly correlated with both service variables, as might be expected, since larger population centres (with higher ridership levels) would be characterized by longer travelling times and distances travelled. The sign on the dummy variable was also negative, which is counterintuitive. This dummy variable was dropped.

The ridership rate dummy variable was also highly correlated with both service variables, and was deleted from any further analysis.

Further, the two service variables were correlated. It was necessary to choose one. Since the kilometres driven consistently produced a negative coefficient, it was dropped in favour of revenue hours.

The introduction of revenue vehicle hours was desirable since it provided an indication of service levels (a point of discussion and importance in the Toronto study mentioned earlier) and it provided a proxy for population, level of service, complexity and comprehensiveness of the urban transit system in any community.

The model then consisted of four independent variables:

1. revenue vehicle hours;
2. average fare;
3. the one million population dummy variable; and
4. the dummy variable for communities with less than 100,000 passengers.

Although the model produced strong statistical results, the sign on the 100,000 passenger dummy variable was positive (which was counterintuitive) and was, therefore, removed. The one million population dummy variable was also dropped because it was not statistically significant.

Final Model[19]

Several other combinations of variables were tried, both to produce signs and statistical characteristics that were intuitively correct and statistically significant, and to improve the residual error rates. Subsequently, a final model was developed that included 2 independent variables: revenue vehicle hours and average fares, as shown in Table 2.

TABLE 2 – Statistical Results of Research Model			
Independent Variable	**Coefficient**	**Standard Error**	**t Statistic**
Intercept	5,099,953	2,232,952	2.28
Average Fare	-7,976,442	2,024,021	-3.94
Revenue Vehicle Hours	49.58	0.41	119.85
R square = 0.97	F Ratio = 7190 (99% significant)		

This model displayed several positive characteristics as follows:

1. The model is relatively easy to use since it consists of only 2 independent variables. One of these measures the level of service and acts as a proxy for complexity of the urban transit system, population, ridership levels, etc.
2. Statistically, the model is strong.
3. The sign on the average fare is negative, indicating that as fares increase, ridership levels decrease. The positive sign on service hours indicates that as service hours increase, more passengers utilize buses. Both are intuitively correct.
4. The residuals were better than earlier models.
5. It is possible to conduct sensitivity analyses because the 2 independent variables can be established for any community.
6. There are no dummy variables needed.
7. The model was first developed using 1992 to 1997 data. The introduction of 1998 data produced little variation in coefficients and statistical results, indicating relative stability in the model.

The Model's Estimation Abilities

Table 3 shows results for 8 of Canada's busiest urban transit centres. These cities account for approximately 84 percent of all urban transit in the nation. The table shows:

- the changes that occurred between 1992 and 1998 in vehicle service hours, average fares, ridership and revenue; and
- the estimate of the number of passengers in 1998 using the model compared to the actual number of passengers.

City[20]	% Change 1992-98				Difference Between Estimate & Actual Number of Passengers 1998
	Vehicle Revenue Hours	Average Fare	Number of Passengers	Revenues	
1	2	-5	30	23	5
2	-10	7	3	11	-58 *
3	-4	35	-21	7	-27
4	-20	12	1	13	31
5	-14	12	-11	0	2
6	-4	33	-4	28	-0
7	16	39	-3	34	-50
8	-6	40	-17	15	-53

TABLE 3 – Eight Canadian Cities

* - negative sign = the model overpredicts

Observations:

1. The model predicts well for cities 1, 5 and 6.

2. The model overpredicts the number of passengers for cities 2, 3, 7 and 8. The reason for this may be that people in these cities do not use urban transit to the same extent as the national average, or, at the same level as some of Canada's larger cities. On a national basis, per capita ridership fell from 92 trips per person in 1992 to 84 in 1998.

   In 1998, for cities 2, 3, 7 and 8, per capita ridership rates were 65, 37, 76 and 63 respectively. Other cities, more dependent on urban transit, have exhibited per capita rates between 160 and 190. In cities 2, 3, 7 and 8, per capita ridership rates have also been falling. Per capita ridership in city 7 fell from 93 in 1992 to 76 in 1998, and in city 8, the rate fell from 77 to 63. In the case of city 3, per capita ridership in 1992 was 53 whereas in 1998, the rate had fallen to 37.

3. The model underpredicts for city 4. This city's per capita ridership is the highest in Canada at 192 trips per year in 1998, an increase from the 189 trips in 1992.

4. The table also shows the impact on ridership after the transit companies in these communities changed the level of service and fares. Between 1992 and 1998, in city 1, average fares declined and at the same time, the number of service hours increased (that is, revenue earning hours that buses are on the road). Passenger growth was 30 percent and revenues increased just over 23 percent. City 7 showed an increase in service hours but fares grew just over 39 percent. The impact was a 3 percent drop in passengers and a 34 percent increase in revenues. In the other 6 cities, service hours decreased and average fares increased. Impacts, however, varied. In city 2, both the number of passengers and revenues increased. A 35 percent fare increase in city 3 coupled with a 4 percent service decrease resulted in a 21 percent drop in ridership and a 7 percent increase in revenues. Average fares increased by almost 12 percent in city 4 and service hours decreased by 20 percent, but the result was an increase in both the number of passengers and revenues, 1 and 13 percent respectively. City 5's increase of 12 percent in fares along with a 14 percent drop in service hours produced an 11 percent drop in ridership and a small increase in revenues. City 6 increased fares by 33 percent and decreased service by just under 4 percent. The result was a 28 percent increase in revenues and a 4 percent drop in ridership. Finally, in city 8, a 6 percent decrease in service and a 40 percent increase in fares resulted in a 17 percent drop in ridership and a 15 percent increase in revenues.

5. These results indicate that both service declines and fare increases will generally have a negative impact on ridership but a positive impact on revenues. Thus, it appears that urban transit ridership is, indeed, inelastic.

6. It may be that revenue or ridership declines prompted transit companies to raise fares and/or decrease service levels on marginal routes. Despite the fact that most bus companies raised fares, reduced levels of service and suffered declines in ridership, they did realize greater revenues. This indicates that if the objective of the bus companies was to increase revenues, they were successful in achieving this goal, even though ridership may have declined.

Conclusions

In the 1990s, most Canadian urban transit operators implemented both service and fare changes. Generally, service hours have decreased whereas fares have increased. The general impact has been a decrease in ridership coupled with an increase in revenues. Results vary on a city by city basis.

The fact that revenues have generally increased along with the average fare indicates that the demand for urban transit services is, in general, inelastic, that it, commuters continue to use urban transit services even though fares have increased. The fare increases may be seen as marginal, when compared to the costs of operating automobiles and downtown parking.

The results also show the diversity in urban transit ridership across the country and how different policies affect cities in varying ways.

[1] The views expressed in this paper are those of the author and do not necessarily represent the policies of Statistics Canada or the Government of Canada.

[2] The views expressed in this paper are those of the author and do not necessarily represent the policies of Statistics Canada or the Government of Canada.

[3] Source: *Passenger Bus and Urban Transit Statistics*, Catalogue 53-215-XIB, Statistics Canada

[4] Based in part on notes from a speech by Mr. M.A. Charlebois, of the Canadian Urban Transit Association, Ottawa, June, 1997.

[5] Some may interpret subsidy decreases as an example of a reduced commitment to urban transit.

[6] Source: From information contained in a speech by Mr. David Bayliss, Director of Planning, London Regional Transport, London, Great Britain, to the delegates attending the International Union of Public Transport conference held in Toronto in May, 1999.

[7] Mr. Ken Ogilvie, one of the co-chairs of the Transportation Climate Change Table (a discussion table established by the Government of Canada to study the Kyoto Protocol), in speeches made at the Canadian Transportation Research Forum (CTRF) held in Montreal in May, 1999, as well as at the International Union of Public Transport/Canadian Urban Transit Association Conference held in Toronto in May, 1999, indicated that significant gasoline fuel tax increases, as well as other policy options, have the potential to divert people from private to public transport. A senior Transport Canada analyst made the same comments at the CTRF conference and published an article in the 1998 CTRF Proceedings which made a similar reference to the impact of fuel taxes: *Canada's Commitment on Greenhouse Gas Emissions under the Kyoto Protocol and the Potential for Reductions in Transport* by John Lawson, Economic Analysis, Transport Canada 1998 CTRF Proceedings, May, 1998, p 465.

[8] Source: *Passenger Bus and Urban Transit Statistics*, Statistics Canada, Catalogue no. 53-215-XIB.

[9] *Optimising Transit Service Decision Based on Ridership: Good for Passengers and the Community*, Bill Dawson, Superintendent, Service Planning and Monitoring, Toronto Transit Commission, Toronto, presented at Workshop #5 Service Planning at the UITP International Congress 1999 Toronto, May, 1999.

[10] ibid p2

[11] Based on informal discussions with planning officials of OC Transpo (the provider of urban transit services for the Regional Municipality of Ottawa-Carleton).

[12] ibid p 6

[13] For those not familiar with elasticities, the following is provided as an example. In the Dawson paper, a 10 percent fare increase was multiplied by the elasticity of 0.3 and the product multiplied by the number of passengers to produce an estimate of the number of passengers lost as a result of the fare increase: 372 million passengers times 0.3 times 0.1 = 11.16 million passengers lost.

[14] An examination of constant dollars may be warranted in future research. However, for purposes of regression analysis, current dollars were used to ensure maximum variability for this independent variable.

[15] Not all results are described in this paper because of space constraints. Only highlights and major steps are outlined.

[16] Although it may appear that the emphasis is on the R square, this is, in fact, not the case. For each model that was tested, a full range of statistical tests were run. These tests included the F ratio, t statistics and a residual analysis. For brevity, not all the statistical results are presented for every regression model tested.

[17] For those readers who are unfamiliar with the use of dummy variables: Dummy variables are structural indicators, that is, variables that attempt to define the structure of the economy. A common example is a model attempting to explain changes in GDP over time. Dummy variables may be used for years in which nations are involved in major wars (such as World War II) because the nature, or structure, of the war economy is different than the same economy in peacetime. Dummy variables are normally binary (that is either 0 or 1 – off or on). Care must be taken not to use dummy variables that are linear (e.g. 0, 1 and 2) since linear forms will impart a bias in the data results.

[18] Large residual errors can occur even if a model's statistical tests are positive. A model of this type may be relatively strong on an aggregate basis but on a micro basis the model may be weak, at least for some of the observations. In other words, the model may be able to predict well on an aggregate basis (such as for a nation's Gross Domestic Product) but for individual sectors (e.g. banking, aviation, agriculture, etc.), the same model may not have the reliability or accuracy to estimate each sector well. On balance, the errors may cancel out producing a relatively good model on an aggregate basis. This may be the best a researcher can expect to achieve in some cases.

[19] Although called the "Final Model" the research is continuing.

[20] Cities are coded for purposes of confidentiality.