THE UNIVERSITY OF MANITOBA

THE ECONOMICS OF MODAL CHOICE IN URBAN TRANSPORT

by

Eugene M. Ludwick

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF ARTS

Department of Economics
Winnipeg, Manitoba

May, 1977

"THE ECONOMICS OF URBAN TRAVEL: A CHARACTERISTICS APPROACH TO CHOICE OF MODE"

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ABSTRACT

This thesis is concerned with the choice of urban travel mode between urban public transit by motorbus and the use of private automobiles. As urban centres have developed, problems involving urban mobility and the beneficial utilization of urban landspace have become increasingly acute. Trends in major Canadian cities indicate that, as urban centres continue to grow, continuing and increased emphasis will be placed on the use of the private automobile at the expense of urban public transit to the general detriment of urban centres in an urban land use and development sense.

The thesis examines the hypothesis that the observed tendency of the relative use of private automobiles, compared to urban public transit, to increase in a developing urban environment is a reversible phenomenon. In order to determine the degree to which the private automobile trend is reversible, the nature and characteristics of the modes of travel were examined as an introduction to the economic analysis of choice of mode and modal split. A number of factors characteristic of urban public transit have contributed to its relative decline while certain inherent characteristics of

the private automobile have led to its increased utilization. In light of these considerations it appears that the characteristics of the modes of travel have played at least as important a role in individuals' modal choices as have pecuniary criteria.

In the analysis of choice of mode by economic theory, the classical income-leisure approach was found to be deficient inasmuch as it is incapable of analyzing changes in the qualitative characteristics of the modes of travel. Therefore, in order to account for the influence of non-price factors in the choice of mode, the Lancastrian characteristics theory of demand was used to explain modal choice. Particular attention was given to differences in social and individual economic modal choice decision-making criteria and the resulting difference between the socially optimal and individually preferred mix of urban travel modal choices.

In order to make predictions concerning the mix of modes or the car/transit balance, a shortcut modal split model was used. This model, which is general enough not to be influenced or biased by city-specific urban transportation problems, has been used to determine the effectiveness of a number of public policy interventions in reversing the private automobile trend.

Public policy interventions or automobile trend-reversing strategies tested included manipulations of the cost, speed and modal characteristics of urban travel. In this analysis it became apparent that none of the individual solutions is sufficient in isolation. However the most promising solutions involve improvements in the characteristics of the public transit mode as solutions affecting the costs and speed of urban travel appear to have serious limitations especially in terms of their technical implementation.

However, apart from any technical difficulties associated with possible solutions to the urban transportation problem, there exist a number of institutional factors which will independantly pose problems in the implementation of trend reversal. Such factors may be not only technological but also financial, political and even ideological. The initiation of public policy interventions in the public transit field will meet problems of financing and physical implementation and will require more supportive urban planning and development methods.

After due consideration of potential solutions, their limitations, and associated implementation problems it is the conclusion of this thesis that the observed tendency of the relative use of private automobiles, compared to urban public transit, to increase in a developing urban environment is a reversible phenomenon.

ACKNOWLEDGEMENTS

Certainly in any major thesis undertaking such as this, the author must express gratitude to a number of people without whose assistance, aid, patience and devotion, such work could not be undertaken. The present author is no exception.

I would like first of all to thank Professor Ralph Harris who encouraged me to further pursue my interests in transportation economics and urban transportation at the graduate level. In fact, the first exposure I was given to transport economics was in Professor Harris's Advanced Industrial Organization course in the final year of my honours program. Since that time I have continued to receive his helpful guidance and direction in both my graduate program as a whole and in thesis preparation as well as his assistance in a number of other areas for all of which I owe him considerable thanks.

I am also indebted to a great number of professionals in the transportation field across Canada who have assisted me in many ways. Notable among these are Mr. Roy Church (Manager) and Mr. Bob Bob Ferguson (Superintendant of Schedules) of the Winnipeg Transit System who were often willing to take time from their hectic schedules to educate me in the intricacies of the urban public transportation industry.

Thanks must also be extended to the Manitoba Department of Industry and Commerce with which I have been employed for the last three years as an air transport research economist(?) for their support and assistance. In particular I express gratitude to my colleagues in the Manitoba Transportation Economics Councel Secretariat for their ongoing moral support, encouragement and interest.

Finally, I thank my wife Trudy for her help, patience and understanding throughout the three years it has taken me to complete the Master's program and for the many hours she has spent typing my numerous papers and this thesis. I am most indebted to her as the completion of this thesis would not have been possible without her encouragement and help.

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CHAPTER I

PROBLEMS, TRENDS, AND PROSPECTS IN CANADIAN URBAN PUBLIC TRANSPORT

Introduction - The Urban Transportation Problem

> There is little doubt that the problem of transporting persons and goods in our urban areas is one of the most frustrating our nation faces. We stand on the verge of enormous technological advances which will enable us to travel at supersonic speeds to distant planets. Yet, twice each twenty-four hours, millions of persons battle traffic congestion at speeds more reminiscent of pioneers in their covered wagons. Traffic congestion is not a new phenomenon. Crowds and teeming streets have been the trademark of cities for thousands of years. But new methods of transportation have changed the nature of congestion.[1]

The automobile, the transport vehicle of the random-route system, has freed the urban traveller from the restrictive fixed routes and schedules of public mass transit, thereby making possible the flight to suburbia by homeowners, as well as business and industry. Simultaneously, the random-route or automobile-expressway-parking lot system has failed to accommodate properly the heavy volumes of suburbia-

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[1] Lewis M. Schneider, Marketing Urban Mass Transit, (Boston: Harvard Business School, 1965), p. 1.

central-city traffic required to sustain high density central city activity. The growth of automobile ownership which has caused this performance failure has limited the development of the central city area and has accelerated the growth of suburbs. This growth, in turn, has contributed to the decline in urban public transit patronage.

Such results are encouraged by acquiescent or even supportive attitudes towards the accommodation of the private vehicle in urban centres. At substantial expense, construction programs and projects to modify and expand roadway systems are undertaken continually in order to accommodate peak traffic loads. However, it is difficult to point out any urban expressway, new or old that is free of congestion in peak hour periods. Stated quite simply the number of vehicles is growing at a much faster rate than the roadway network and therefore traffic congestion will tend to worsen.

Similarly, another constraint is the fact that the urban landspace within city centres is finite. As population increases, landspace once available for parking must be devoted to the construction of buildings in a time when parking demands are growing at a rate corresponding to the growth of private vehicle usage.[2] Urban expressways are built and expanded to fulfill the great and ever growing access demands and at the same time are dumping more and more vehicles into the land space that simply cannot properly accommodate all of them.

Furthermore, a major source of dissatisfaction with urban transportation systems in general is the impact on city configuration, that is, on the patterns of urban land use and on the aesthetic qualities of the urban centre. The larger the city, the greater is the proportion of its land that must be devoted to transportation (assuming a constant mix of transportation modes). R.J. Smeed has come to the conclusion that the proportion of urban ground space required for travel increases with the number of people travelling by surface transportation in a central area.[3]

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[2]It is estimated that an automobile parked in downtown Toronto while its owner is at work is occupying $30,000 - $40,000 worth of land and 1/3 of downtown Toronto is devoted to the automobile. (G. Warren Heenan, "Rapid Transit and Property Value", Community Planning Review, Spring 1967, p. 5.)

[3]R.J. Smeed, The Traffic Problem in Towns, (Manchester Statistical Society, 1961) and "The Space Requirements for Traffic in Towns," in T.E.H. Williams, ed., Urban Survival and Traffic (London, 1962).

Depending on different assumptions about the average number of persons per vehicle the average journey to work by automobile at about 20 miles per hour requires six to 45 times as much road space as does a transit bus travelling at the same speed. Furthermore, the differentials increase when considering higher speeds. Also, as the size of the urban centre increases, this differential between space requirements of the automobile and other transport modes, becomes even greater.[4]

The random route system which allows people to travel freely in their private vehicles does not appear to be a system with a very healthy future. Since vehicle usage is increasing beyond the capacity of roadways and parking space there is little to risk in predicting major system breakdowns in a number of urban areas in the form of massive traffic jams.

Such a trend is aggravated further if traffic engineering and management are inadequate. The general assumption that there is sufficient expertise within traffic engineering, traffic management and road

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[4]Lyle C. Fitch and Associates, Urban Transportation and Public Policy, (San Fransisco: Chandler Publishing Company, 1964), p. 14.

building agencies to guard against the overall automobile/roadway system from becoming less functional than it already is may not be valid and expertise in these fields is really not sufficient to solve the urban transportation problem in an efficient manner.

The predominant road-building philosophy today is one of continually providing better access whenever and wherever such access is deemed to be necessary. In order to discover when and where better access is required, the existing roadway network is subject to constant monitoring. Such pulse-taking establishes not only patterns of congestion build-up but also overall "desire lines of travel", which means that the roadways used by significant traffic loads (primarily peak hour movements) can be identified. Based on current congestion problems on these roadways and as well as population (and thence, automobile) growth projections, road construction programs are designed.

Quite often such road building programs simply consist of boosting the sizes of the existing roadways by the addition of extra lanes. However, for the most part patterns will build up in certain areas gradually without existing street configurations either appropriate or readily adaptable by expansion to the loads.

The most usual result of this set of circumstances is that the area in question becomes subject to massive amounts of property expropriation and clearance in order to make way for an ongrade or elevated expressway. After all, the priority consideration here is continuous traffic flow.

The highway-oriented urban planner, however, is in a dilemma. It is his responsibility to maintain traffic flows which means that in order to eliminate bottlenecks he must continually adjust the total roadway network. The development of cloverleaf intersections, computer-coordinated signal lights, and other innovations have been hailed for years as innovative, effective, and efficient traffic flow handlers. However, innovation means very little in this regard when the real problem is the accommodation of a rapidly growing private automobile population on a road network that can simply not grow as fast or keep pace.

There is a two-fold problem here. First is the goal of providing universal accessibility (which of course means providing a capacity for the movement of peak loads) for the flow of automobiles is most likely not achievable as long as the automobile population sustains its growth rate. This is true regardless of the amount of urban and sub-urban land space that is committed to roadways. Unfortunately, some highway planners do not seem to recognize any limit to this commitment. Secondly, the goal of achieving universal accessibility whether it is attainable or not neglects the problem of handling parked automobiles at those points made so conveniently accessible.[5]

The amount of urban land space that cities can afford to devote to the routing and parking demands of the automobile-roadway system is limited. If the choice is not made to seek alternative solutions and to determine proper land use now while there are still some features of the urban environment worth saving, the land use will be determined for us when the urban landspace becomes saturated with structures devoted to the random route system, including huge automobile parking structures and multiple-level urban expressways. Urban priorities

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[5]Tabor Stone comments: "Watching our random route system agencies frantically building expressways in order to funnel the great and growing numbers of automobiles into densely packed urban activity centres, where the parked automobile is the least desirable from any standpoint of land use, reminds me of the old Texas adage regarding the dubious prospects of trying to place twenty pounds of manure into a ten pound gunny sack." (Tabor R. Stone, Beyond the Automobile: Reshaping the Transportation Environment, (Englewood Cliffs, New Jersey: Prentice-Hall Inc., 1971), p. 36.)

and objectives have been confused. In the process of attempting to maintain functionality in an urban transport system which is supposed to serve urban areas, its capacity for environmental destruction is merely being escalated.

As has been stated earlier, the random route car-road system planner is posed with the dilemma of trying to find solutions to problems that are a product of the system itself. Certainly, the most realistic alternative to the random route system is the public transit system to which large scale commitments will have to be made if functional flow problems are to be resolved. This does not mean that the urban public transit planner intrinsically has a superior approach, but in public transit, options with positive land use planning benefits exist that are simply not available with the private automobile/ freeway system. The inherent functional limitations of this system therefore outline the basic argument against its perpetuation in its present form.

The need for comprehensive alternative planning policies involving all aspects of both transportation planning and land use planning to preserve urban centres is clear. "Transportation determines much more about the nature of the physical environment than we commonly recognize — in fact, transportation is the foremost single form-determining element of the man-made environment and deserves our immediate attention as such."[6]

The fact that the private automobile/roadway system has been allowed to develop at the rate that it has and to the detriment of the general development of urban centres might lead one to believe that the continued rapid growth of private automobile utilization is inevitable. It is this urban transport trend that is the central concern of this thesis and the basis for its hypothesis. The hypothesis proposed is that THE OBSERVED TENDENCY OF THE RELATIVE USE OF PRIVATE AUTOMOBILES, COMPARED TO URBAN PUBLIC TRANSIT, TO INCREASE IN A DEVELOPING URBAN ENVIRONMENT IS A REVERSIBLE PHENOMENON.

The Evolution of Urban Transportation, Urban Development and Urban Land Use

It is useful now to place transportation in an urban development perspective. While theories and

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[6] *Ibid.*, p. 2.

models explaining the spatial expressions of urban growth are not developed in this thesis, the operation of certain forces in shaping urban patterns will be examined. Regardless of the fact that no two cities are exactly alike, a generalized picture of the sequence of events which help to shape the evolving urban area can be presented. It is submitted that the evolution of the urban pattern is closely related to the changing forms of urban passenger transportation.[7]

Before the introduction of mechanized transport, those areas which could be described as "urban" were necessarily small because of the slow speed of the two transport modes of the day — namely pedestrian and animal-drawn transportation. Since, in the pre-industrial city, places of work and residence were not typically separated by distances of any consequence, the typical "journey to work" as it is

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[7]The material contained in the following discussion is based on the section dealing with transport in: Harold M. Mayer, The Spatial Expression of Urban Growth, (Washington D. C.: Association of American Geographers, 1969). Mayer's work is in turn based on material contained in the following books: (a) Lyle Fitch and Associated, *op. cit.*; (b) J.R. Meyer, J.F. Cain, and M. Wohl, The Urban Transportation Problem, (Cambridge: Harvard University Press, 1965); (c) Robert B. Mitchell and Chester Rapkin, Urban Traffic, A Function of Land Use, (New York: Columbia University Press, 1954); and (d) Wilfred Owen, The Metropolitan Transportation Problem, (Garden City, New York: Doubleday & Co., 1966).

known today was unknown. The form of the city prior to modern transportation tended to be circular. However, this urban form was rapidly superseded by new forms with each successive improvement in transportation technology.

For nearly a century beginning in the 1820's, the shape and form of North American urban areas were dominated by the patterns of mass public transportation routes. With the development of each successive form of transport, major changes in the growth, spread and internal patterns of cities took place.

The earliest form of urban public transit was the horse-drawn omnibus which operated on fixed routes in the early part of the nineteenth century. Before long, the omnibus was placed on rails which greatly increased the speed and efficiency of the horse power and which resulted in greater and wider accessibility. Because of this, cities could expand beyond the physical limits imposed by the earlier free-wheeling horse-drawn vehicles. While new urban growth could take place it was still limited by the motive power speed of the horse-drawn railway street car. Moreover, since rail lines could only be placed on a limited number of streets, some shifts in the internal structure of cities took place. Streets having rail lines began more and more to develop into axes of higher density and the lineal arrangement of businesses was greatly intensified along such streets. The spread of this form of urban public transit was great and by the end of the 1860's was the dominant mode of internal public transport in most cities.

In this era, cities began to depart from their circular form and began to assume somewhat of a star-shaped outline as the horse-drawn railway extended routes further and further. Land along such routes was in great demand and the resulting higher land costs led to higher density land development. This resulted in the establishment of high-density, high-value ridges of land development including strings of commercial outlets along the street railway routes. Such ridges were usually radial, focusing upon the central city thus reinforcing its status as the principal location of business and industry.

Such effects upon the urban form were greatly accentuated by the introduction of mechanical power to the street railways. The introduction of the cable-car and then the electric trolley again accelerated the movement of the population and economic activity toward the periphery of cities and beyond. These greatly facilitated the separation of place of residence from place of work, and allowed for freedom of choice of employment. However, as early as the 1830's, the steam railroads began the operation of commuter services in New York and later in Chicago and other American cities and much later in Canada in Montreal and Toronto. In cities offering suburban train service, the railroads became the vectors of urban expansion, with individual suburban stations serving as nucleii of residential and commercial development. Therefore beyond the principal urban concentration, and normally separated from it by open area (farmland, etc...), suburbs developed along the railway lines emanating from the centre of the main urban centre. As these suburbs became urbanized, they would incorporate as municipalities, and annex surrounding lands and eventually the physical separations between suburbs disappeared as the expansion taking place along the railway line became such that adjacent suburban municipalities often merged and formed radial corridors along the rail lines.

At the same time mass transportation was often provided beyond the ends of the principal radial transport lines by suburban street railways which connected with the vectors of the radial urban public transit system. Since these extensions would tie the inner suburbs to the central city resulting in the development of continuous urban characteristics in both the city and the inner suburbs, the two became indistinguishable.

The suburbs of the late nineteenth and early twentieth centuries were primarily the residential areas of the affluent central city commuters. However a number of industrial satellite suburbs sprang up near some of the large cities, and such suburbs contained the residences of the people employed in the nearby plants. Reverse commuting from central city residences to industrial suburban employment areas, nor crosstown commuting through the central city from one suburban end of the city to another had yet developed to any significant degree.

Meanwhile another new form of public transportation - rapid transit - was introduced in some of the largest cities. This innovation was, in part, a solution to the increasing congestion on major streets where, particularly in the higher density areas which had developed along street railway lines, traffic had become very dense thus increasingly delaying the street cars.

The combination of electric street railways and rapid transit within the main urban concentration of cities together with increased electric railway service in the radial chains of suburbs allowed for the even more rapid areal spread of urban areas. Even greater separation of residence and place of employment took place and in spite of greater trip lengths, there was no substantial increase in travel time.

The evolution and improvement of urban public transportation systems had several effects. The major suburban cities were given improved access to the larger central city populations thus extending the threshold in central cities for such Central Business District[8] functions as retailing, service and entertainment. Simultaneously the convergence of trans-

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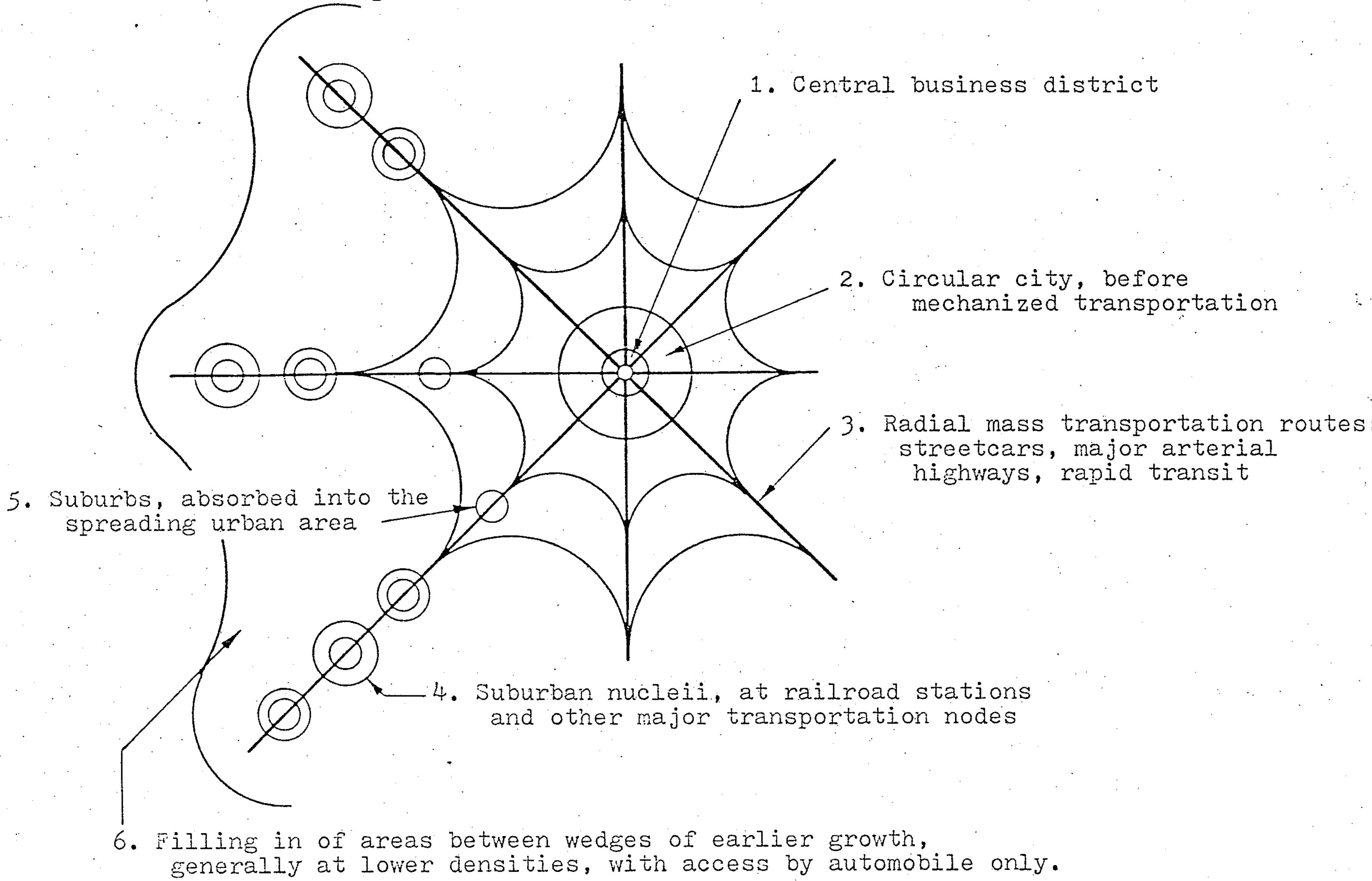
[8]The Central Business District will subsequently be referred to as the CBD.

portation routes in the downtown area increasingly attracted manufacturing and wholesale establishments which were dependant upon metropolitan markets from where also these could draw their labour force. Soon, however, many such establishments found that they could successfully locate outside the central area, on transit lines, and still be perfectly accessible by both the market and the labour force. Such locations became even more popular when the commercial motor truck came into general use in the 1920's and provided greater flexibility for the receiving and shipping of goods than did the railways. On the other hand the electric street railways and the rapid transit lines encouraged the development of major outlying centres for retail and service outlets. Finally, the availability of good public transportation throughout the cities and into the suburban areas facilitated out-migration from the central core areas of many cities thus helping to alleviate the extreme overcrowding of inner cities.

The early twentieth century however witnessed the introduction of an entirely new and different type of transportation in the form of the private automobile and during the last several decades, the automobile has made steady inroads into urban mass transport and in every city with the exception of the central areas of the largest cities, the private automobile has become easily the dominant carrier of urban travellers. With the growing popularity of the automobile, the decline of mass transportation has been precipitous, although declines in rapid transit patronage have not been quite so severe and have recently shown signs of "bottoming out" with prospects in some cities for the reversal of the trend.

Certainly the automobile has encouraged decentralization within urban areas thus facilitating the rapid spread of urbanization as had the introduction of new transportation modes earlier. However, the increased utilization of the automobile has produced somewhat different specific urban patterns. What the private automobile has really produced is a far greater range and flexibility of choice in residential and industrial or commercial location and in travel patterns, accompanied by a greatly increased area of accessibility. Whereas formerly the availability of earlier mass transportation routes, while helping to expand urban areas nevertheless, placed certain constraints upon locational choices in urban areas, today most economic units (i.e., households or businesses) can locate away from such routes as they desire for even industrial establishments (other than the "heavy" industries) are no longer dependant upon railroads and waterways and have become highly oriented towards truck transport. Therefore, due to the convenience of the automobile, not only has residential development decentralized with this new freedom of choice but so also has industry which employs people and generates by far the largest portion of urban travel. Consequently, a growing segment of the journey to work no longer originates nor terminates in the older core sections of central cities. Figure 1.1 summarizes the evolution of urban transportation modes and its impact on the development of the urban form. Today radial axes or suburb-CBD corridors, which characteristically developed in the days when urban public transit was the dominant mode of urban travel, are still important but as a declining portion of total trips originate from or are destined to the central city, the relative importance of such corridors is changing. "Desire lines of travel" present a much more diffuse pattern of trips and routes than before. In many cities the CBD is still

Figure 1.1: The Sequence of Urban Development*



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*Source: Harold Mayer, The Spatial Expression of Urban Growth.

the greatest trip generator but because industrial and residential developments on the periphery of the urban area are made easily accessible by freeways, expressways etc., peripheral trips are of increasing significance and fewer trips have anything to do with the CBD.

Usually these freeways are built in a radial-circumferential design so that both CBD and non-CBD trips are facilitated. The interchanges between the circumferential and the radial expressways (and the intersections of major arterials and corridors) have become the centres of new elements of economic activity unknown in pre-automobile days. These include major shopping centres, clusters of office towers, entertainment centres, and in the background planned housing developments consisting of high-rise apartment buildings, row housing as well as detached housing, and interior open areas. In forming a multi-nodal urban complex at lower densities than those previously characteristic of urban areas, the development of major outlying nucleii has increasingly modified the relative dominance of the older central cities.

In addition to their contribution to the decline of the CBD, such low density multi-nodal urban complexes which were created by the freedom of movement afforded by the automobile/roadway random route system, have conditioned changes in urban land use in another sense. Figure 1.1 illustrates the evolution of urban transport technology and its intimate relationship to the development of the form and structure of the city. As more and better public transportation became available, urban activity spread out further and further along the radial axes of public transportation routes. However, with the introduction of the private automobile and its extensive use, the urban land space devoted to transportation necessarily had to increase.

Consider again the proposition that the proportion of urban ground space required for travel increases with the number of people travelling by surface transport in a central area.[9] This holds serious implications for land use in terms of the amount of land space that must be diverted from cultural, commercial, and residential use to urban travel use. In the early days of the rising utilization of the private automobile, while existing transit right-of-way

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[9]See note #3.

likely had the capacity to handle all of the travel demand, as an increasing number of urban travellers were diverted from public to private transport, more and more roadway had to be constructed to accommodate this vehicular traffic. Further, as urban areas expanded along the periphery in low densities, and away from public transportation routes, yet more landspace had to be devoted to roadway construction. Finally as cities continue to increase in population and area, the result is necessarily the further development of the low-density multi-nodal complex referred to earlier.

Unfortunately, this lower-density multi-nodal complex has made mass urban transit, which is best adapted to carrying large masses of travellers on high-density routes, impractical for many people. Since urban public transit is primarily designed to move peak-period traffic to and from the CBD, its future is inevitably dependant upon the CBD's future prospects. Unfortunately CBD's are not growing as fast in population or economic activity as are the rest of their respective metropolitan areas and where these used to be points of maximum accessibility, they are now stifled by their inability to handle increasing volumes of automobile and even motorbus traffic. To the detriment of CBD's, "this condition exists in spite of the fact that in most cities, the central area, including the fringe surrounding the CBD, has half or more of its land devoted to movement and parking of motor vehicles."[10]

Given the proposition regarding the relationship between requirements for increased transport facility space and increased travel demand it is certainly plausible to think that cities, as the demand for travel continues to grow, would orient solutions for the supply of facilities to meet this travel demand toward those which encourage a minimum consumption of urban "people use" land. This is not to say that there is no place for the automobile in our urban centres, for certainly there is, but to occupy large parcels of land to meet increased travel demand is not in the best interest of urban centres because solutions exist which would be far less costly to society in terms of land utilization. Given that the automobile uses 6 to 45 times as much roadspace for the journey to work than does the bus travelling at

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[10] Harold M. Mayer, op. cit., p.44.

the same speed,[11] it would be expected that cities would encourage the use of a transport mode that does not unduly consume urban land which could be put to better use for the people living in cities. Unfortunately, however, this has not been the case.

Trends in Canadian Urban Transportation

Trends in Canadian cities show results quite different from those which would be expected if there were an efficient allocation of urban transportation and urban land use resources. First consider Table 1.1 which shows how the urban proportion of the Canadian population has been changing over the last seventy years. In the years from 1901 to 1971, Canada's urban population has doubled in proportional importance and the absolute number of urban dwellers today has increased nearly tenfold. The change in the number of urban dwellers from 1.9 million in 1901 to 16.4 million in 1971 (76.1 per cent of the total population) is a good indication of the degree of urban transport problems facing Canada's urban centres in light of the earlier discussion on the relationship between urban transportation and urban development.

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[11] See Note #4.

Table 1.1: THE CANADIAN URBAN POPULATION - 1901 to 1971

YEAR	CANADIAN POPULATION	% URBAN	NUMBER URBAN **
1901	5,371,315	34.8	1,867,260
1911	7,206,643	41.7	3,007,576
1921	8,787,949	45.3	3,977,064
1931	10,376,786	49.7	5,160,901
1941	11,506,655	50.9	5,853,603
1951	14,009,429	53.6	7,511,539
1961	18,238,247	71.1	12,971,927
1966	20,104,880	73.6	14,726,759
1971	21,568,315	76.1	16,410,785

* Source: (a) 1901 to 1961 - Census of Canada 1961, Vol. 7, pt. 1. General Review - Population and Labour Force, Dominion Bureau of Statistics, Ottawa, Canada, 1961.

(b) 1966 and 1971 - Census of Canada 1971, Vol. 1, Sec. 7. 1-2 Population, Statistics Canada, Ottawa Canada, 1971.

** Urban population as defined in source (a) above.

Table 1.2 and accompanying Figure 1.2 depict trends in the growth of Canadian urban population, urban public transit ridership and passenger automobile registrations from 1931 to 1971. Urban population has grown steadily and, as might be expected, has been accompanied by even more substantial growth in the ownership of private automobiles at the expense of which public transit ridership has been faring rather poorly. Perhaps the most interesting feature of Figure 1.2 is the peak in transit ridership as shown in 1951. Actually transit ridership was at its highest in Canada during the years of the Second World War when resources for the production of such items as automobiles were diverted to the production of defense-related transport vehicles (planes, ships,...) and products.[12] It is interesting to see that at a time when resources are scarce, people (or cities) make use of the more economically efficient mode of transport but in more prosperous times, consumers shift to the socially less efficient but individually more desirable mode. What urban travellers are not recognizing fully today is

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[12] While the phenomenon is not visible in Figure 1.2 not only did transit ridership increase, but automobile registrations decreased significantly during the war.

Table 1.2 Canadian Urban Population, Public Transit Ridership, And Passenger Automobile Registrations - 1931 to 1971* (and Indices - 1961= 100)

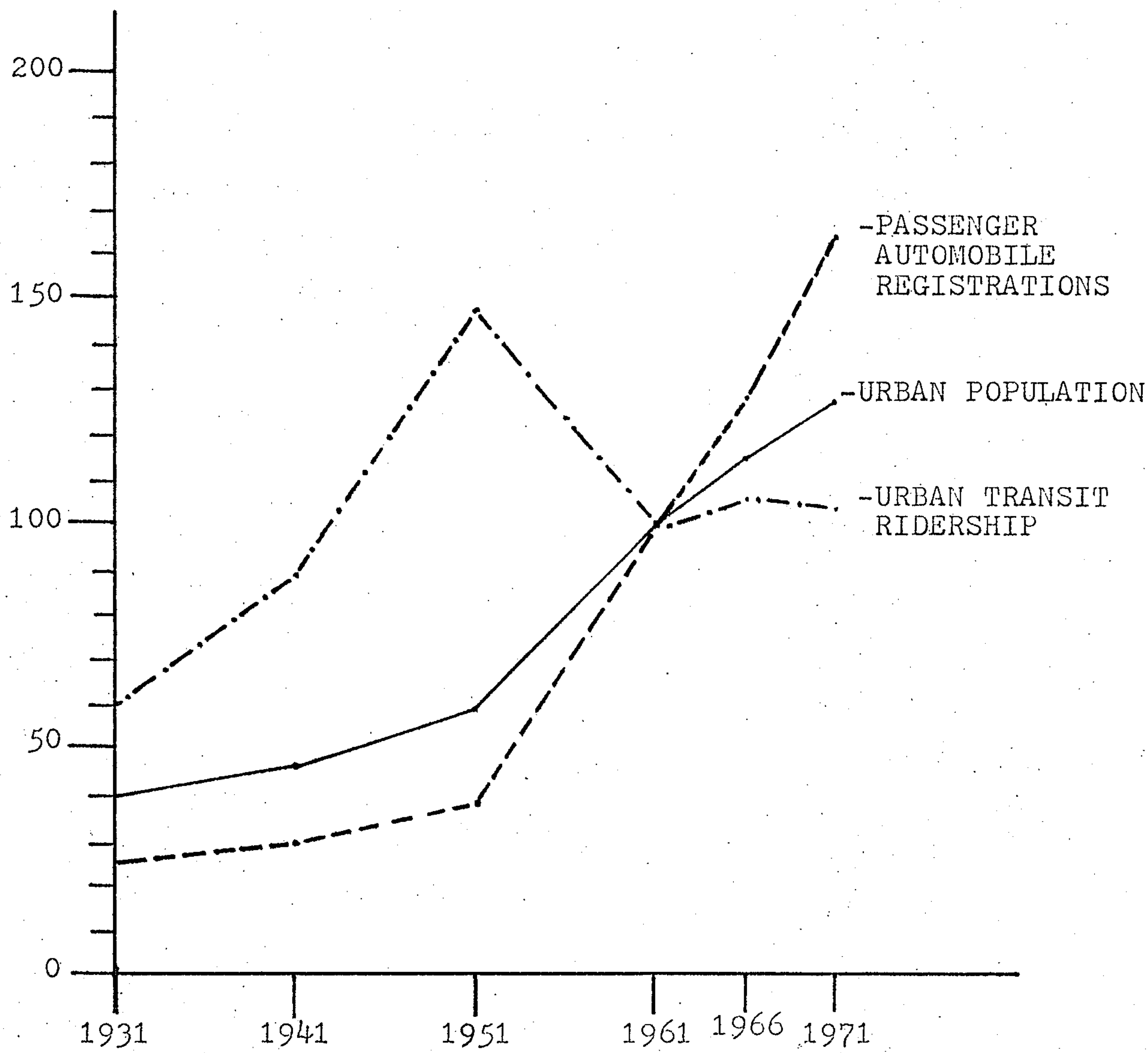
YEAR	URBAN POPULATION (INDEX)	PUBLIC TRANSIT RIDERSHIP (INDEX)	PASSENGER AUTOMOBILE REGISTRATIONS (INDEX)
1931	5,160,901 (39.8)	579,096,250 (59.4)	1,028,100 (23.8)
1941	5,853,603 (45.1)	856,721,149 (87.9)	1,281,190 (29.6)
1951	7,511,539 (57.9)	1,428,121,328 (146.5)	2,105,869 (48.68)
1961	12,971,927 (100.0)	974,786,702 (100.0)	4,325,682 (100.0)
1966	14,726,759 (113.6)	1,011,031,701 (103.7)	5,480,724 (126.7)
1971	16,410,785 (126.5)	1,000,010,476 (102.6)	6,967,247 (161.1)

* Sources: (a) Population: See Table 1.1

(b) Public Transit Ridership: Urban Transit, Statistics Canada 53 - 003, Ottawa Canada, 1971.

(c) Passenger Automobile Registration: The Motor Vehicle: Part II Registrations, Statistics Canada 53 - 219, Ottawa, Canada, 1970 and 1971.

Figure 1.2: Trends in Canadian Urban Population, Urban Transit Ridership, and Passenger Vehicle Registrations (Indexed 1931 to 1971 - 1961 = 100)*



*Source: See Table 1.2

that resources including fuel and landspace (and others including those resources required to produce motorbuses and automobiles) are becoming less plentiful and it is certainly time to place more emphasis on the mode of transport which can put these resources to their best use. Furthermore, there are circumstances under which (without the necessity of Canadian involvement in another major war) the trend toward the increased utilization of the private automobile in urban areas might be reversed.

Further to illustrate trends in Canadian urban transportation, the behaviour of population; transit ridership, and automobile registrations in seventeen major Canadian cities is examined. The seventeen cities in question have been divided into three different groups based upon the 1975 metropolitan area population of these cities. As shown in Table 1.3, Category I cities are those of 1975 population of over 1 million, Category II cities are those of population between 300,000 and 1 million and Category III cities are those less than 300,000.[13] Arbitrary

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[13]For all intents and purposes Category III cities considered here are between 100,000 and 300,000 population and a fourth Category could be introduced to consider those cities of less than 100,000 1975 population. However the development of public transit in these small cities greatly lacks in uniformity so as to make predictions or analyses of questionable meaning.

as these divisions may seem, there is some reason for grouping these cities in the manner they have been. Chiefly if one reconsiders Figure 1.1 it becomes apparent that cities of population over 1 million are different from cities between 300,000 and 1 million, are different than cities of less than 300,000 population, and especially so in an urban transportation sense.

Detailed populations, urban transit riderships and vehicle registrations for each individual city in each Category are given in Appendix I for the years 1940 to 1975 (every five years). Table 1.4 and accompanying Figure 1.3 summarize the data for cities in each Category and show Category trends in per capita transit ridership and passenger automobile registrations per thousand population. As shown in Figure 1.3 the gap in 1975 between the per capita transit and automobiles per thousand curves is narrowest for Category I cities. This gap increases as population of cities (as represented in the Categories) becomes smaller.

Such results are somewhat consistent with the earlier discussion on urban development and urban transport. Smaller cities rely heavily on the use of

Table 1.3 CATEGORIZATION OF CITIES ACCORDING TO 1975 POPULATION

1. CATEGORY I - Cities of 1975 Population Over 1 Million

CITY		1975 POPULATION (Thousands)
1. Montreal		3,164.8
2. Toronto		2,791.2
3. Vancouver		1,289.7
	Category I Total	7,245.7
	Category I Average	2,415.2

2. CATEGORY II - Cities of 1975 Population From 300,000 To 1 Million

4. Ottawa		592.5
5. Winnipeg		583.7
6. Edmonton		536.4
7. Quebec		516.9
8. Calagary		477.6
9. Hamilton		369.9
	Category II Total	3,072.0
	Category II Average	512.0

3. CATEGORY III - Cities of 1975 Population Less Than 300,000

10. London		247.3
11. Windsor		240.2
12. Halifax/Dartmouth		235.6
13. Victoria		210.8
14. Kitchener/Waterloo		164.8
15. Regina		153.9
16. Saskatoon		141.4
17. Thunder Bay		122.8
	Category III Total	1,516.8
	Category III Average	189.6

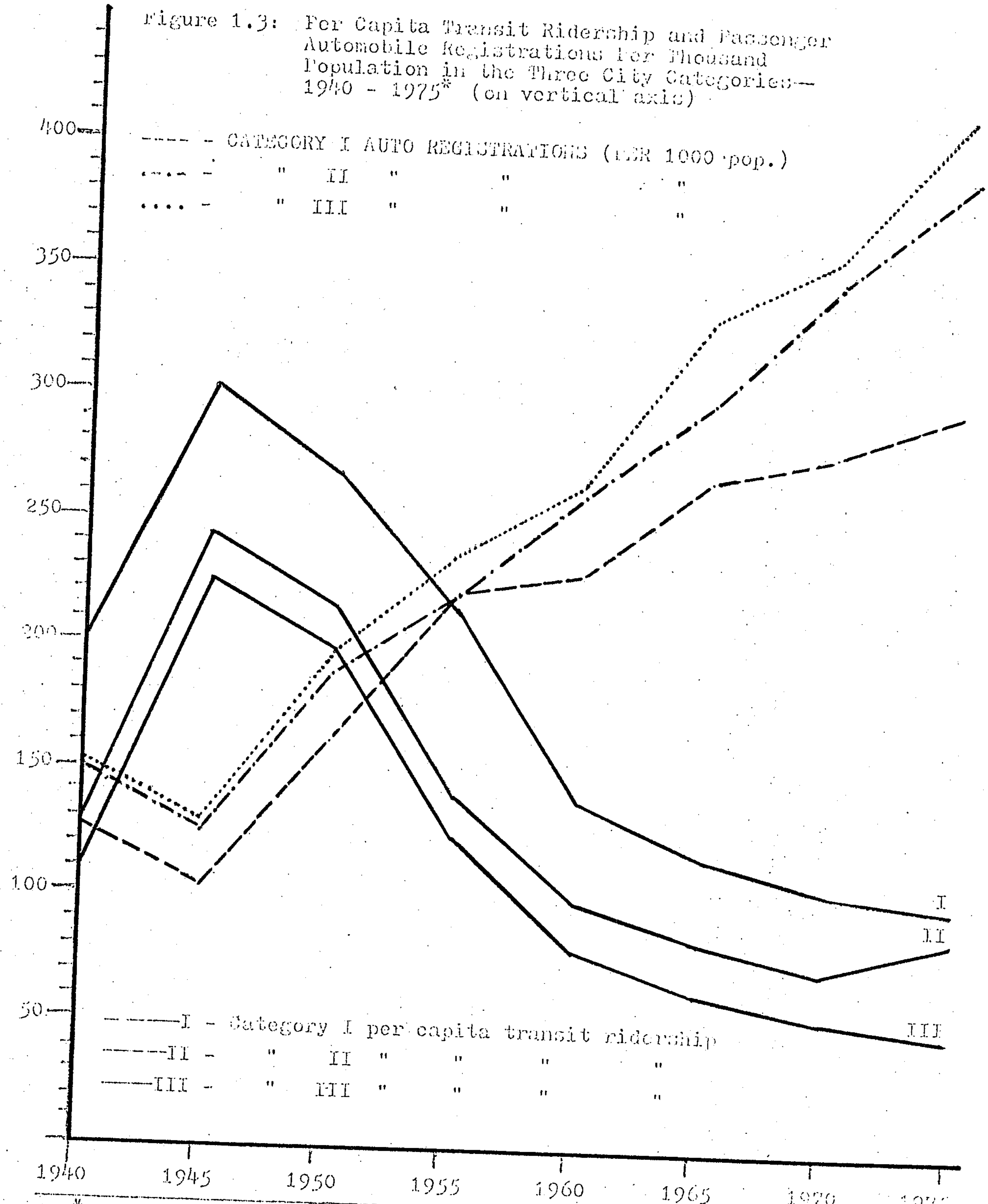
Source: Appendix I

automobiles relative to public transit. In the middle-sized Category II cities, the forces of competing land uses become visible and such cities attempt to achieve a better balance between the public transit and private automobile modes. Finally in the largest cities (Category I), the competition for space between cars and people has visibly resulted in a lower proportional difference between transit ridership and vehicle ownership. While Figure 1.3 does not illustrate the extreme case of urban blight (it is not intended to) it does show Category III cities as having the highest growth of passenger automobile registrations and the lowest level of transit ridership. This might indicate that the smallest cities are least cognizant of the urban land "people use" versus "vehicle use" problem but perhaps this is so because in this early stage of urban development, the problem has not yet reached crisis proportions. Also, it would appear at first glance that the trend of decline in transit ridership is "bottoming out". However, when compared with the rapid growth of private automobile registrations (except in the two largest cities where this growth appears to levelling) the "bottoming out" of the

Table 1.4: City Category Populations (in thousands), Transit Riderships (in millions) and Per Capita Transit Riderships, Passenger Automobile Registrations (in thousands) and Passenger Automobile Registrations Per Thousand Population - 1940 to 1975.

	1940	1945	1950	1955	1960	1965	1970	1975
CATEGORY I								
Population	2,356.5	2,699.5	2,958.0	3,440.1	4,598.5	5,237.0	6,184.4	7,245.7
Transit Ridership	470.3	840.0	794.1	731.0	643.5	610.5	651.9	711.2
Per Capita Ridership	199.6	311.2	268.5	212.5	139.9	116.6	105.4	98.2
Auto Registrations	299.2	278.7	477.2	760.2	1,056.4	1,406.9	1,727.6	2,155.7
Auto Regs. Per 1,000 Pop.	127.0	103.2	161.3	221.0	229.7	268.6	279.3	297.5
CATEGORY II								
Population	1,061.8	1,218.2	1,390.4	1,750.8	2,066.2	2.365.4	2,701.9	3,072.0
Transit Ridership	134.9	294.6	299.3	246.7	205.3	196.0	198.6	265.6
Per Capita Ridership	127.0	241.8	215.2	140.9	99.4	82.9	73.5	86.5
Auto Registrations	161.2	152.4	248.3	386.2	538.4	704.3	941.1	1,194.6
Auto Regs. Per 1,000 Pop.	151.8	125.1	178.6	220.6	260.6	297.8	348.3	388.9
CATEGORY III								
Population	571.0	653.0	730.0	883.9	1,059.7	1,214.1	1,362.0	1,516.8
Transit Ridership	61.3	147.5	145.3	110.8	84.4	74.1	70.9	75.0
Per Capita Ridership	107.4	225.9	199.0	125.4	79.6	61.0	52.1	49.4
Auto Registrations	87.5	83.8	144.0	210.0	280.8	403.5	489.0	631.2
Auto Regs. Per 1,000 Pop.	153.2	128.3	197.3	237.6	265.0	332.3	359.0	416.1

Figure 1.3: Per Capita Transit Ridership and Passenger Automobile Registrations Per Thousand Population in the Three City Categories— 1940 - 1975* (on vertical axis)



*Source: See Appendix I

transit ridership decline offers little encouragement for the prospects of reversing the private automobile trend.

If the private automobile trend is to be reversed, action is required that will change long ingrained patterns of consumer behaviour. Before those factors that are relevant to the modal choice decision-making process are examined the forecasted future of urban transportation problems in Canada's major cities will be discussed.

The Future Urban Canada - The Demand and Supply of Transport Facilities

A. The Demand for Transport

In a study prepared in 1971 for the Honourable R. K. Andras, Minister responsible for housing, D. J. Reynolds states: "The most basic variable in the future demand for transport in Canada is population."[14] On the basis of population forecasts made for the Economic Council of Canada[15] Reynolds

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[14] D. J. Reynolds, The Urban Transport Problem in Canada, 1970-2000, (Ottawa: Central Housing and Mortgage Corporation, 1971).

[15] W. T. Illing, Y. Kasahara, F. T. Denton and M. V. George, Population, Family, Household and Labour Force Growth to 1980, (Ottawa: Economic Council of Canada, 1967).

predicts that the population of Canada in the year 2000 is likely to range between 30 and 40 million so that under the assumption of medium fertility and immigration the Canadian population in the year 2000 seems most likely to be around 35,000,000 ± 5,000,000 or ± 15%.

In terms of population and the severity of transport problems, pressures are expected to be most concentrated in the nine major cities of Quebec, Montreal, Ottawa, Toronto, Hamilton, Winnipeg, Edmonton, Calgary and Vancouver. These cities will almost double their combined populations by the end of the century, thus comprising half of the future Canadian population. N. D. Lea & Associates state that there are other factors which will cause urban transport problems to be more severe in these nine cities aside from simple population growth, namely: (1) due to higher average population densities in these larger cities per capita road mileage tends to be low; (2) internal trips tend to be lengthy because of the cities' size; and, (3) because of these factors, traffic will likely exhaust and exceed the capacity of highways (especially those main arteries carrying the bulk of vehicle mileage)--the problem is compounded by the fact that the network and its capacity cannot be easily expanded due to severe physical difficulties and high capital costs.[16]

Reynolds further states that while some 46 smaller urban centres are likely to have a population of at least 50,000 by the year 2000 and encounter similar population and urban transport pressures, in national terms their problem will not be as serious and important as those in the nine major cities. Also the cities expected to exceed 50,000 population by the year 2000 are principally located in Ontario and Quebec and some 21 of these cities are located within a 700 mile corridor between Quebec City and Windsor. These 21 cities will account for 43% of Canada's population in the year 2000. The population growth of cities less than 50,000 will be nearly static with those cities' combined populations rising from about 8,000,000 in 1970 to approximately 10,000,000 in the year 2000.

Regarding car ownership and use in Canada in the future Reynolds expects Canadians to own 0.33 cars

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[16] N. D. Lea and Associates, Urban Transportation Developments in 11 Canadian Metropolitan Areas, (Ottawa: Canadian Good Roads Association, 1967).

per capita of total 1970 population rising to a saturation level (all other things including roadways remaining constant) of 0.45 cars per capita in most of Canada excepting Quebec (including the cities of Montreal and Quebec) and the Atlantic provinces which will probably achieve this level by 1990. This so-called saturation level in Ottawa, Toronto, Hamilton, Winnipeg, Calgary and Vancouver will probably be reached by 1980.

Since automobile traffic accounts for the increasingly larger portion of road traffic these population and car ownership increases will be closely reflected in a corresponding increase in road traffic. From a growth rate of approximately 100% in the decade 1960 to 1970, road traffic will likely increase by about 50 to 60% from 1970 to 1980 and by about 20% from 1980 to 1990 and again in the last 10 years to 2000. Furthermore, because of the nature of road traffic, highways, and the distribution of traffic over them, it is estimated that nearly half of total vehicle mileage will take place in urban areas (defined as places of 1000 population and over and rural townships of over 10,000 people). Both rural and urban traffic can be expected to increase at the rates mentioned above and similar rates of increase can be expected in the nine major cities.

In analyzing the demand and the market trends for the various intercity rural and urban passenger transport modes, Reynolds suggests that the most significant changes (other than the increase in car ownership) are that there will be a decline in rail passenger transport, and an increase in the intercity bus transport, and urban transit will continue to have a difficult and doubtful future.[17]

B. The Supply of Transport Facilities

Having discussed the demand for the various transport modes at current price and cost levels and existing technology Reynolds turns to a discussion of how costs, prices, technology and the whole supply side of the problem might change in the future.

Similar to other economic activities, the change in price and cost levels of urban transport will principally be the outcome of two sets of forces (1) price increases in the factors of production employed in transport; and, (2) productivity improvements possibly resulting from steady and expected

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[17] D. J. Reynolds, op. cit., p. 22-24.

changes in technology, higher load factors, or other improvements in organization.

Respecting future changes in costs and prices, the major change expected by Reynolds is a possible relative increase in real wages (in terms of $1970) of up to 2% per year. It is expected that most transport modes should be able to increase their productivity per unit of labour in order to offset this, a significant exception being urban motorbus transit for which current problems will be further aggravated by this trend.

Regarding new technology, Reynolds states that most of the new innovative technologies in transport have problems and defects that cause their future development to be uncertain. For example, small cars and/or electric cars for urban use appear to offer no obvious overall advantages over present cars while on the other hand the technical development of new transit systems is inhibited by the problem of frequent stops within relatively short journey lengths. Disregarding problems and risks perhaps the most promising development in major cities would be the possibility of developing mass rapid transit on inexpensive existing rights-of-way (as is currently being done in Edmonton and being studied in Winnipeg[18]), that is, the development of systems which attempt to combine the advantages of cars and transit and the study of the urban passenger market and behaviour in an attempt to fill gaps, to tailor transit systems to make them more demand-responsive and to devise and develop optimum transit systems.

With respect to the supply of highways to meet the demand Reynolds concludes that present levels of road expenditure in Canada (or a small increase) would adequately meet future Canadian demand. However, due to the present distribution of expenditures there would be a deficit in meeting urban transport investment needs and a surplus over rural needs. Therefore a diversion of future road expenditure from rural to urban seems to be required. Moreover, such a diversion of funds would likely not be suitable in a province such as Manitoba where there is a firm commitment to a rural stay option and the improvement or at least preservation of the equality of the human condition and the general quality of life. Given low population

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[18]This study is being undertaken by De Lieuw Cather and Co. on behalf of the governments of Winnipeg, Manitoba and Canada and is still in process.

densities and greater distances between communities of interest in rural areas, highway transport infrastructure investment funds should not be diverted from rural areas which are captive to the highway system. Rather, new priorities should be given to the allocation of urban transport infrastructure dollars diverting funds away from the random route automobile-freeway system to the development of more demand-responsive and viable public transit systems.

C. Plans of the Major Cities

As can be seen from Table 1.5 on the following page the major urban transport infrastructure investment that has been planned on the major cities is devoted to freeways. During the periods from 1970 up to 1976-1991 (an average planning period of about 12 years), estimated freeway mileage expansion is expected to be from about 440 miles to about 990 miles (an increase of over 100%). Table 1.5 also shows only an approximate 10% increase in arterial street mileage (those main highways usually carrying less than 10,000 vehicles per day). The estimated capital costs of these plans will be in the neighborhood of $3.9 billion 85% of which will be devoted to

TABLE 1.5: URBAN TRANSPORT PLANS FOR THE MAJOR CITIES *

CITY	POPULATION		CURRENT (1970) URBAN TRANSPORT SYSTEMS				PROPOSED URBAN TRANSPORT SYSTEMS				
	1970 (1,000's)	2000 (1,000's)	FREEWAY MILES	ARTERIAL MILES	RAPID TRANSIT MILES	PER CAPITA TRANSIT RIDERSHIP	PLANS TO YEAR	EXTRA FREEWAY MILES	EXTRA ARTERIAL MILES	EXTRA RAPID TRANSIT MILES	COST OF IMPROVEMENT $ 1970 (MILLIONS)
Montreal	2,780	5,170	143	785	15.5	110	1983	52	0	21	420
Toronto	2,530	5,250	100	800	21	130	1980	100	38	9	1,000
Vancouver	1,000	1,800	60	384	0	75	1976	24	38	0	200
Ottawa	560	1,050	22	260	0	80	1986	67	94	?	250
Winnipeg	540	730	48	280	0	120	1991	74	313	?	770
Hamilton	500	900	35	290	0	60	1985	23	0	0	135
Edmonton	470	1,000	?	20	0	100	1980	30	88	14	148
Quebec	470	880	20	157	0	95	1987	50	20	0	525
Calgary	390	820	?	?	0	?	?	100	0	?	530

* Source: D.J. Reynolds, *The Urban Transport Problem*.

highways and only 15% to transit development.

While Montreal and Toronto were planning to expand their existing rapid transit systems by 21 miles and 9 miles respectively the only other city to engage in rapid transit appears to be Edmonton. The rapid transit approach is under planning consideration in Ottawa, Winnipeg and Calgary.

Although some rough calculations would show that the freeway and arterial capacities of the major cities would increase by 30-40% if these plans were carried out, it is not possible to determine whether these plans will satisfactorily meet the projected traffic increases or whether there will be sufficient financial resources to carry them out.

Given the millions of dollars required to upgrade the highway/automobile system and the fact that proposed construction will simply perpetuate problems associated with urban automobile traffic congestion as relatively small amounts of capital investment are anticipated for public transit in the future, Reynolds poses the question: "...with such wide car ownership and low transit use, and having gone so far in accommodating the car in Canadian cities and in their layout and density, is it worthwhile or possible to reverse the process?"[19]

As has been stated earlier, the inherent functional limitations of the automobile/highway system outline the basic argument against its perpetuation in its present form. The discussion of the urban transportation and urban land use interface demonstrates that the reversal of the private automobile trend is worthwhile.

Analysis of the reversibility of the trend towards private automobile use in urban centres requires the study of modal choice on both an individual and social basis. First, however, it will be helpful to examine the nature of the urban travel modes under study. Some of the deficiencies of urban public transit which have led to its decline and some of the psychological factors favouring the continued increased use of private automobiles in metropolitan areas will be discussed.

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[19] D. J. Reynolds, op. cit., p.73.

CHAPTER II

TWO URBAN TRAVEL MODES IN CONFLICT

1. Transit Industry Deficiencies

For several years the public has expressed concern over the problem of urban public transit.[1] It is common opinion that urban public transit is a sick industry as evidenced by its need to rely heavily on large doses of subsidy aid. Table 1.1 below summarizes the financial performance of Canada's transit industry over the past forty years. Since 1970 Canadian urban transit systems have been suffering increasingly large operating losses annually as public transit continues to lose riders and fare box revenues fail to cover system costs.

A phenomenon that has contributed to the decline in profitability in the transit industry is that the population of urban areas has been and continues to be less densely concentrated at the centre and more diffused over the surrounding area. This trend of course has been coupled with an increasing reliance on private vehicles. This redistribution of population

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[1] Barton-Aschman Associates Inc., Guidelines for New Systems of Urban Transportation, Volume 2, prepared for the United States Department of Housing and Urban Development, April 1968.

Table 2.1: CANADIAN TRANSIT FINANCIAL OPERATING RESULTS ($,000'S) - 1935 to 1975*

YEAR	NO.OF PROPERTIES	OPERATING REVENUE	OPERATING EXPENSES	NET INCOME (LOSS)	ALL TAXES
1935	30	$ 37,774	$ 2,094	$ 35,680	
1940	33	40,676	28,782	11,895	
1945	35	72,119	50,964	21,156	
1950	33	85,528	75,247	10,281	
1955	32	109,247	98,784	10,463	
1960	34	132,975	116,421	16,553	
1961	35	131,671	118,549	13,022	
1962	36	132,646	121,764	10,882	
1963	36	133,825	125,821	8,004	
1964	37	139,143	127,556	11,587	$ 8,692
1965	39	154,780	139,994	14,786	9,417
1966	39	167,680	158,926	8,754	10,403
1967	46	206,848	188,619	18,229	11,357
1968	48	209,015	203,675	5,340	11,494
1969	48	231,207	214,675	16,532	11,437
1970	49	239,525	231,066	8,459	11,730
1971	47	242,410	249,193	(6,783)	10,576
1972	54	263,205	284,414	(21,209)	12,044
1973	57	274,847	326,954	(52,107)	12,834
1974	57	285,268	396,443	(111,175)	13,503
1975	61	326,790	495,620	(168,830)	15,321

* Source: Canadian Urban Transit Association, <u>Transit Fact Book 1975 - 76</u>.

has been a fundamental cause of "many of the social and economic difficulties of our large, mature, central cities: loss of middle and upper income to the suburbs, declining retail sales in downtown areas, erosion of the tax base, shift of manufacturing and service establishments to suburban areas, decline of mass transit service and patronage, and increased traffic congestion."[2] It is difficult to offer mass transit service to a thinly spread population. For instance, there are important economies of scale to be realized with the use of larger buses (for example in terms of per seat driver and fuel cost). However, the larger the vehicle the harder it is to obtain enough passengers in order to offer a frequently operating service with a reasonable level of occupancy. The "size of vehicle" economies have been pushing in one direction and the diffusion of urban populations in the other to the distress of the transit industry trapped between the two.

Perhaps the most troublesome problem faced by the transit industry is meeting the demand peaks of

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[2]L. M. Moses, and H. F. Williamson, Jr., "Value of Time, Choice of Mode, and the Subsidy Issue in Urban Transportation", Journal of Political Economy, (Volume 1. June 1968, pp. 247-264), p. 247.

the journey to and from work in the huge metropolitan area. "Typically, over a rapid transit system, one peak hour out of 24 accounts for 15% or more of the daily traffic while almost half of the day's total traffic moves in four peak hours. Peak hours require about four times as much equipment as can be used at other times. Hence, average cost per ride tends to be much higher than if demand were evenly distributed over time."[3] Unfortunately, the demand peak problem has been becoming more acute and the most apparent reason for this trend is the shift toward private automobile transportation in the off-peak periods when the thoroughfares are not congested. Figure 2.1 shows a typical hourly traffic flow comparison for public transit and automobile in a sampled composite of North American cities.

Some of the primary manifestations of the deficiencies of mass transit systems in and around our large metropolitan centres are discomfort, inconvenience, low average speed, and obsolescence of equipment. The most immediate cause of discomfort

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[3] J. B. Lansing, <u>Transportation and Economic Policy</u> (New York: The Free Press, 1966). p. 269.

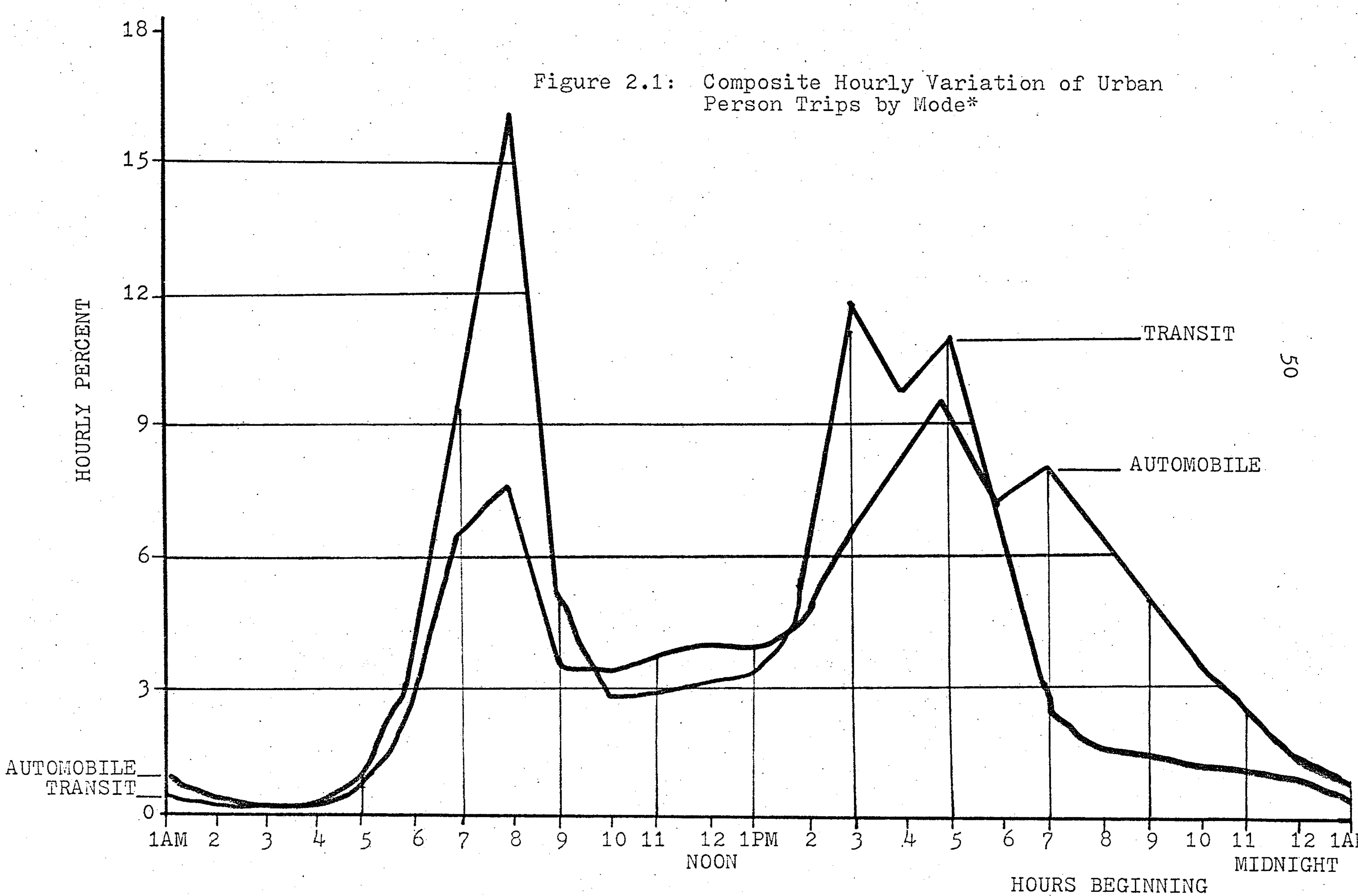

Figure 2.1: Composite Hourly Variation of Urban Person Trips by Mode*

*SOURCE: Tom E. Parkinson, Passenger Transport in Canadian Urban Areas is the overcrowding of buses, particularly during journey-to-work peak hours. Furthermore, heat, noise, unattractive or unprotected way stations and terminals, together with lengthy standing and waiting periods are common disadvantages of bus or transit travel and the transit industry has make little technological progress in the way of bettering comfort standards. The user is told: If you don't have an automobile or want to use our service you'll do so on our terms. Make your choice. Would you rather endure traffic jams on expressways, or suffer overcrowding in dirty, unsafe, uncomfortable stations or vehicles? Or, perhaps, you'd rather not make the trip?"[4]

In many urban mass transportation systems a high proportion of depreciated and obsolete equipment is being used. Poor location and shortage of stations or stops, the necessity of transfers, and the frequency of service, all contribute to the inconvenience of most urban public transit systems.

Another problem, particularly within and near

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[4]Lewis M. Schneider, "Marketing Urban Transit," Highway Research Record, No. 318, (Mass Transportation), Washington: Highway Research Board, 1970). p. 16.

central cities and their central business districts is low average speed. The only mode competitive in speed with the automobile is rapid rail transit and the greatest speed differentials are between buses and automobiles moving on urban thoroughfares[5] causing further difficulty in attempting to divert urban travellers from private automobiles to mass transit.

Also important is the often observed fact that increases in fares have accelerated loss of patronage. The most predominant general statistic available in this regard is due to a study by Simpson and Curtin[6] which examines 77 urban bus fare changes over a period of 20 years. They found what may be called a "shrinkage ratio" (an approximation to elasticity) of 0.36.[7] "Indeed the results have been so consistent that the transit industry has almost adopted the so-called "Simpson-Curtin formula" which states that for each 1% increase in fares you will get a 1/3%

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[5]Lyle C. Fitch and Associates, op. cit., p. 13.

[6]John F. Curtin, "Effect of Fares on Transit Riding, "Highway Research Record, No. 213, (Passenger Transportation), (Washington: Highway Research Board, 1968), pp. 8-20.

[7]with a standard deviation of only 0.09.

decrease in ridership."[8] However, it is clear that non-peak hour travel is much more sensitive to fare changes than is rush hour travel where the journey to and from work predominates.[9]

Aside from the simple physical and aesthetic difficulties in urban public transit, one must consider the problems besetting transit management which arise primarily from the economics of the industry, especially under recent conditions. The short-run demand for transit service is such that fare increases will usually produce more short-run total revenues, despite decreases in patronage.[10] Therefore, transit operators have no short-run economic incentives to keep fares down in order to maintain or increase passenger volume. Rather, they are under continuous pressure to increase fares. This is especially true in the United States where public

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[8]Gerald Kraft, "The Potential of Free Transit in Transportation Planning", in Unorthodox Approaches To Urban Transportation, Andrew Hamer, ed., Proceedings of a conference held at Georgia State University November 16 and 17, 1972, p. 9.

[9]Lyle Fitch and Associates, *op. cit.*, p.37.

[10]*Ibid*. p. 42.

ownership of public transit properties was not the prevailing organization of the industry. In Canada however, where public ownership of public transit has been dominant, fares have been kept relatively low over the years as is shown in Table 2.2.

This same pressure is reflected in the deterioration of service for in the short run, route abandonment and less frequent service may result in monetary savings for transit management. Moreover, operators cannot usually afford to take the temporary losses involved in building up new routes through developing suburban neighborhoods for by the time the neighborhood has reached the density sufficient to support a transit route its travel patterns, most often including the use of automobiles, will be well established and it is too late for a transit company to gain the new market.

Aside from the points raised in the first chapter of this thesis in connection with the histor-ical aspects of urban development leading to the decline of urban public transit, the factors mentioned above have been important problems in impeding the attraction of an ever increasing amount of urban public transit riders. Undoubtedly the single most

Table 2.2: HISTORICAL RECORD OF TRANSIT FARES IN CANADA - 1935 TO 1975*

YEAR	PROPERTIES	RANGE	CASH FARES (¢)	TICKET FARES (¢)
1935	30	High	10	8.33
		Low	05	4.16
		Average	06	6.24
1940	33	High	10	8.25
		Low	05	4.16
		Average	07.5	6.07
1945	35	High	10	8.25
		Low	05	4.25
		Average	08.6	6.18
1950	33	High	13	10.00
		Low	05	6.25
		Average	09.2	8.05
1955	32	High	15	15.00
		Low	10	9.00
		Average	11	10.50
1960	34	High	20	18.00
		Low	10	8.33
		Average	15	13.00
1965	39	High	25	20.00
		Low	15	11.11
		Average	20	18.00
1970	49	High	35	30.00
		Low	15	12.50
1971	47	High	35	30.00
		Low	15	14.28
		Average	25	22.50
1972	54	High	35	30.00
		Low	10	16.66
		Average	25	23.33
1973	57	High	35	30.00
		Low	15	16.66
		Average	25	23.33
1974	57	High	40	35.00
		Low	15	16.66
		Average	25	24.00
1975	61	High	50	38.60
		Low	15	20.00
		Average	29	28.90

* Source: Canadian Urban Transit Association, Transit Fact Book 1975 - 76.

important reason for the decline in public transit ridership has been the private automobile.

2. <u>Aspects of Individuals' Preferences for Automobiles</u>

As discussed earlier, since its introduction at the beginning of the century the highway/automobile system has played a dominant role in shaping the urban environment as we know it. Some of the things made possible through the mass ownership of automobiles and the vast and growing network of roadways were: (1) the physical separation by long distances of an individual's places of work, residence, shopping, entertainment, etc.; (2) the chance to reside in spread-out low density housing developments; and, (3) the horizontal growth of land space devoted to urban activities to the extent that what was once known as the city must now be called a metropolitan area due to its engulfing of many smaller formerly outlying communities.

The turn of the century pre-automobile city was characterized by high density living and working facilities and therefore most typical personal transportation requirements were satisfied by the pedestrian mode. The city was basically designed and constructed for pedestrians. The only range extenders available then were the horse and buggy and the public transit system of the day--the trolley bus and in certain cities, the subway. Of course, there was a suburb which was primarily occupied by those wealthy enough to afford the necessary mobility. Perhaps it was these suburbs which inspired cramped and crowded city dwellers with images of lifestyles that the automobile later allowed them to seek. Basically however, the pre-automobile city was a relatively motionless environment. Transit patrons were usually moving from high density living areas to high density working areas, residing at a distance not usually because of choice but rather because, in those pre-high rise days, the high density housing areas within pedestrian range of work places would have been quite fully occupied. Another characteristic of the area was the fully developed neighbourhood typified by bottom floor shops with residences above. Every neighborhood had a distinct identity since most of the people in the neighborhood not only lived there but worked there, were entertained there, shopped there, were schooled there, and usually never had any reason for leaving there. What is left of these neighborhood areas still exists in our older cities mostly housing the impoverished, the illiterate, and the racially oppressed.[11] There is however, little about the turn of the century pre-automobile city that calls for nostalgia. Since the limitations of travel range prohibited horizontal expansion, these cities were forced to absorb population growth simply by increasing their physical densities. Then the automobile appeared on the scene at a time when the crowding of the city in conjunction with the alleged wholesomeness of rural life, made it valuable as an escape device. Suburban living which for so long had been an option only available to the wealthy became an option for the masses, or at least the middle class and the flexibility of the random route system dramatically extended the range of life patterns of urban dwellers.

Indeed the automobile has satisfied more than the simple desire to travel between residences and work places. Earlier it was stated that on strictly social and economic grounds, the choice of many urban travellers to use the private automobile for the journey to work is certainly not the best one. Quite apart from social and economic considerations, however,

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[11] T. R. Stone, *op. cit.*, p. 41.

it would seem that a very important reason for the automobile being the most often preferred mode of travel is the fact that "men move through, build around them and carry about with them certain structural volumes of psychologically differentiated space."[12] While there is doubt as to how these spatial volumes are best understood and while economists normally ignore their existence or at least their importance, there should be no doubt that the contraction or expansion of these distinct spaces, or conflicts between them, or even ambiguities as to their boundaries, can cause uneasiness and stress.

"This idea of man living within a range of simultaneous spatial domains graded from the intimately personal to the plainly public, should explain more satisfactorily than any of the familiar psychiatric or sociological cliches, the attraction of the automobile."[13] Stated simply, the private automobile permits one to travel practically at will anywhere in the public domain while remaining in a completely private world unequivocally defined by physical

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[12] Ibid., p. 95.

[13] Ibid.

boundaries. To maintain the existence of this intensely personal space no longer requires explanation by psychological adaptation or cultural understanding or ritual for it is marked off structurally clearly and solidly. Perhaps this concern with the definition of personal space is primarily a North American phenomenon and it may well be that the vast continual changes in the North American social and cultural setting over the last 50 or 60 years have produced great uncertainty, unease and stress upon individuals thereby making the protection and clear definition of the private personal realm more valuable and important. While traditional Utopian dreams have been centered around a communal structure, modern Canadians and Americans continually attempt to build very personal or at least familial Utopias structured around single detached homes, television, and cars. At any rate there is a basic distinction that must be understood--that is, the distinction between public and private transportation not in the sense of titular ownership or financing or even trip scheduling, but in the sense of the personal perception of space patterns.

It has been stated that the ability to move through public space without suffering readjustment of, or impingements upon, one's own personal space could explain a good deal more than the urban travellers attachment to his private automobile. It could even partly explain the success of the automobile rental companies since a rented car allows one to travel in a strange, foreign, and often confusing public world in a kind of instant privacy and encapsulated security.[14]

The emotional importance of the automobile must not be contemptuously discussed as some psychological aberration for the automobile is much more to many individuals than a more or less efficient competitor with public transit. It was stated earlier that in certain parts of our major cities the external effects caused by the private automobile such as the over-consumption of space and time and the production of environmental nuisances necessitate restrictions on the automobile's use. Perhaps though, the only way of increasing the acceptability of public transportation is to incorporate as much spatial quality of the automobile as is possible into its design.

However transportation problems of our major

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[14] Ibid.

cities cannot be solved until the very special spatial features of the private automobile are understood for in all likelihood the consumer appeal of the automobile is just not a trivial habit which can easily be removed but rather, a means of fulfilling deeply rooted concepts of human territoriality.[15]

More functional analysis reveals that the automobile/freeway system has distinct quality advantages in four important areas:
(1) privacy, (2) comfort, (3) orientation, and
(4) convenience.[16]

(1) Privacy - Since there is no physical or social contact with people travelling in other automobiles, the great mix of economic and ethnic backgrounds represented in a city's travel patterns is made tolerable for many people by the physical isolations provided to them by their automobile. An important option that exists in the random route system which cannot be underrated is the ability to select one's fellow passengers.

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[15] J. B. Jackson, Landscape, Volume 17 (Spring 1968) page 2, as quoted in T. R. Stone op. cit., p. 96.

[16] T. R. Stone, op. cit., p.98.

(2) Comfort - Automobiles offer a number of personal comfort amenities such as adjustable seats, individual temperature controls, radio etc., restricted only by one's ability to pay for them. The motorist can actually seal himself off from contact with the outside world and be entertained besides. Also important is the fact that each automobile rider has a seat and none is forced to stand.

(3) Orientation - Due to the fact that the motorist must navigate his vehicle he rarely has disorientation problems since he is supposed to be continually aware of his routing and the distance to his destination.

(4) Conveniences - Since the suburban resident always has his vehicle parked close at hand and can drive anywhere on the roadway system without having to transfer vehicles, the random route system is actually a door-to-door transit system. Of course when the urban traveller is employed in a high density centre such as the central business district his chances of parking close to his job are becoming increasingly small. However, for those who both live and work in low density areas, the

automobile/roadway system is the optimum one.

Given the advantages of the random route system in the four areas discussed above, the public transit system needs consideration in the same categories. With regard to privacy, two types are relevant to a discussion of the design and improvement of public transit systems. The first is physical privacy by which we refer to the need of human beings to be separated spatially from each other. The actual physical distance by which a person wishes to be removed from another varies in relation to the situation in which both are involved and the social characteristics of each. The standards for public transit are interesting because it is felt that the relationship between passengers is such that each should be far removed from each other when in fact they are often forced into unnecessary physical contact by the exigencies of peak-period public transit. This is particularly true on lengthier more crowded journeys when the stress induced by unavoidably close proximity often exceeds the capacity of a passenger to cope with it resulting in a feeling of discomfort which contributes to the general aversion for public transportation.

Secondly, cultural privacy refers to the desire and need of people to be among other individuals who share the same values, norms, and beliefs and standards of behaviour and to exclude from their midst individuals with different norms and standards. This need and desire is physically expressed in all the rules established for membership in groups, that is, in the manner in which people attempt to limit the entry of strangers or newcomers to social functions, professions, neighborhoods, decision-making groups, etc. It is obviously difficult for passengers to establish any sort of cultural privacy in a public transport environment for the simple reason that public transit systems are accessible to all and any who have the small amount of money required for the fare. There is no simple method of aligning physical environments in a public transit sense with these complex sociological needs and therefore individual privacy requirements are found to be at odds with potential carrying capacities.

The comfort amenities demanded or required of public transportation are closely related to the length of trips involved. For example, a five minute dial-a-bus ride to a nearby transit terminal would not require the same extent of comfort facilities for passengers as would say, a 40 minute ride on a medium speed transit vehicle. Similarly this medium speed trip would not call for the same degree of amenities as would the two hour high-speed train trip. On high-speed trains (or commuter aircraft) bars, lounges, reading lights, enroute meals, rest rooms, and other comforts are expected. On low to medium speed transit systems however, due to the short travel times involved, users demand little more than shelter from the weather, temperature control, smooth and silent operation, and reasonable seating accommodations.

The problem of orientation is not severe for urban motorbus operations but when related to high-speed rail transit systems can cause problems as seen in both vehicle and terminal design, as well as all related graphics. Since the high-speed rail passenger is not actually navigating the vehicle and manoeuvering through the landscape by following signs and landmarks, but rather, is riding, he can experience a significant amount of anxiety if he ever has reason to suspect that he has boarded the wrong train or has missed his station. Such problems can easily be appreciated in dark subway systems for example where the onus is on passengers to know exactly where their train is going and when to get off.

Perhaps the best tool for measuring the public transport system's convenience is a -30^{o}C windy winter day when any gaps in what should be a comprehensive service become brutally apparent. Waiting in line at an unsheltered bus stop in this type of weather is certainly a cause for desiring a truly door-to-door transport system. The automobile/roadway system of course can offer this easily provided that the doors involved are each located in low to medium density areas. However, as city size and travel demand increase, fewer areas are able to provide close-proximity parking. In the case of taxi service the automobile can serve high density areas on a door-to-door basis as there is no parking involved, but the limitations of this type of service for handling commuter movement on any scale are obvious when one attempts to hire a taxicab during the peak period on any bad weather day. Convenience, however, really means more than the fact that the private vehicle is handy at both the departure and destination points but also that the trip is accomplished without having to switch vehicles enroute. Unfortunately, bus stops are not very convenient, at least in most low density areas, and the greater portion of trips cannot be made without switching vehicles and, increasing the number of stops invariably complicates overall routing then creates a greater number of necessary transfers.

Stated simply, the primary convenience requirement is to be picked up near the origin and to be let off close to the destination with a minimum of inconvenience--that is; the least possible exposure to inclement weather and the least possible confusion and discomfort caused by necessary transfers.

To provide a convenient urban transport service means to provide a comprehensive one. Of course, contemporary public transit systems do not provide this standard of service as they are not able to. However, unfavourable comparisons between public transit and private vehicle convenience factors could be eliminated or at least minimized should the overall commitment to public transit systems be expanded as proposed, provided that: (1) collection points are allotted in greater numbers so that no point in any residential area would be more than two or three blocks from a pickup point; (2) collection points are sheltered, even with only a rain and shine roof, but preferably with some wind breaking panels with a bench for the elderly, the disabled, and those who do not know when the bus is coming; and , (3) transfers occur in sheltered areas so that vehicle to vehicle exchanges are not necessarily pneumonia-inducing experiences.[17]

A comprehensively laid out urban public transit system combined with appropriate enroute amenities could be conceivably more attractive than the automobile in terms of convenience in any medium to high density areas where door-to-door automobile transport can be more accurately called door-to-parking-lot-to-door transport.

Upgrading public transit system standards so that they are at least equivalent to those of the private automobile system at least in the four areas just discussed are a necessary step in improving urban transportation systems via the public transit solution. Urban transportation planners must never lose sight of the fact that transportation systems are constructed to serve people and to respect the dignity of people; current vehicle orientations which characterize most of our urban transport systems are not acceptable.

Having said that quality of service is an important area in which to seek solutions to the urban transportation problem in our major cities

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[17] *Ibid*. p. 107.

the urban transport problem will be examined in terms of some economic theory which takes qualitative aspects of urban travel into consideration.

CHAPTER III

MODAL CHOICE ECONOMICS AND MODAL SPLIT ANALYSIS

1. Modal Choice and Value of Time

Integration of the economics of modal choice in urban transport with modal split analysis may be approached in several ways. It is now appropriate to present some of the more pertinent approaches and techniques. Such studies involve "sophisticated tools of analysis required to perceive individual and community preferences and formulate goals and policy objectives in the light of evolving technology and changing habits and values..."[1]

The method of analysis chosen by Donald M. Hill and Hans G. von Cube develops "diversion curves".[2] The authors brought together data from surveys in three metropolitan areas, studying the destination of trips (based on home interviews). For purposes of analysis, the data were grouped into zones with

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[1] The Urban Transportation Planning Process, in Search of Improved Strategy, Report of a Panel of Experts, Organization for Economic Cooperation and Development, December 1969.

[2] D. M. Hill and H. G. von Cube, "Development of a Model for Forecasting Travel Mode Choice in Urban Areas", Highway Research Record No. 38 (Travel Forecasting), Highway Research Board, 1963.

the unit of analysis being the traffic between a pair of zones. The transit share of work trips was measured for each line of travel, and variations in this share were the object of explanation. Hill and von Cube's technique is based on aggregated data as opposed to an analysis of individual's choices. However, as Guy Orcutt[3] explains, from a statistical point of view, the use of aggregated observations is a risky expedient due to the probability of introducing aggregation bias.

In a second method of analysis, Stanley Warner[4] relied upon multivariate statistical analysis of choices by individual travellers for particular trips. Warner discovered that relative time and relative cost were consistently important, and he also found it helpful to distinguish trips according to their purpose.

Ruben Gronau has considered another aspect of modal alternative analysis in transportation. In his book he considers "consumer preferences as they are influenced by the relationship of speed (or time) and

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[3]Guy Orcutt et al., Microanalysis of Socioeconomic Systems: A Simulation Study, (New York: Harpers, 1961).

[4]Stanley L. Warner, Stochastic Choice of Mode in Urban Travel: A Study in Binary Choice, (Evanston, Illinois: Northwestern University Press and Transportation Center, 1962).

price."[5] By developing and applying Gary Becker's model[6], and by utilizing data which the Port of New York Authority had made available to the National Bureau of Economic Research, he obtained some very interesting empirical results. Gronau's first major finding concerned the way the price of time affects the choice between certain modes of travel. With his theoretical model, he predicted the logical passenger choice among air, bus and rail transportation for intercity travel, given the price of time and the distance travelled. A second more tentative discovery indicated that business travellers consider the price of their time as being approximately equal to their hourly earnings, whereas personal travellers appear to assign a lower price to the value of their time. In order to reach this conclusion, Gronau estimated income and price elasticities of demand for air travel and provided some new information on the relation between family income and hourly earnings.

A fourth approach is that taken by Leon Moses and Harold Williamson who claim that "the diversion

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[5]Ruben Gronau, The Value of Time in Passenger Transportation: The Demand for Air Travel, (New York: National Bureau of Economic Research, 1970), p. 1.

[6]Gary S. Becker, "A Theory of the Allocation of Time," Economic Journal, (September 1965).

issue is central to much of the argument that is taking place on the need to subsidize public transportation as a way of reducing automobile congestion in central cities."[7] On this basis the authors have estimated a price structure that would divert automobile commuters to other modes. The analysis and empirical work are presented first under the assumption that workers have the freedom to choose the combination of income and leisure which appears optimal to them, and secondly under the assumption that commuters must conform to a standard number of hours of work. Unfortunately, when a restriction on hours is imposed, it is impossible to measure diversion prices in the choice of mode because of a lack of knowledge about the preference systems of the individuals involved. Moreover, if the leisure-preferring individual who is free to choose an optimum combination of income and leisure is discussed, something can be said about the diversion prices involved in the choice of mode.

Before diversion prices are discussed it will be helpful to examine individuals' behaviour or preferences toward money and time (income and leisure) in the context of a single mode of travel.

Consider Figure 3.1[8] whereby leisure time is

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[7]Moses and Williamson, op. cit., p. 248.

[8]Ibid., p. 250.

measured on the horizontal axis and income on the vertical axis. This diagram is a description of the preferences of a number of individuals each viewing work and travel time as equally necessary evils. The wage rate facing each individual is equal to the negative slope of the line AB and the stock of time for each individual is OA. Combinations of income and leisure available to each individual when zero time and money outlay are associated with commuting are thus shown by income line AB.

By shifting AB, various money, time and cost combinations can be introduced. If the particular mode in question involves merely transit time, but no monetary outlay then AB can be shifted downward parallel to, say, CD. Then the wage rate remains the same (ie., -slope AB = -slope CD) and travel time equals AC.

Therefore CD represents the particular mode's net income line. If the individual who chooses this mode has the freedom to choose hours of work, then any combination of leisure and income along CD, or zero income as represented by point A, may be chosen. Moreover, CD could also represent the net income line for a mode entailing zero travel time but involving an expenditure equal to BD. Then once again the individual leisure and income choices for individuals

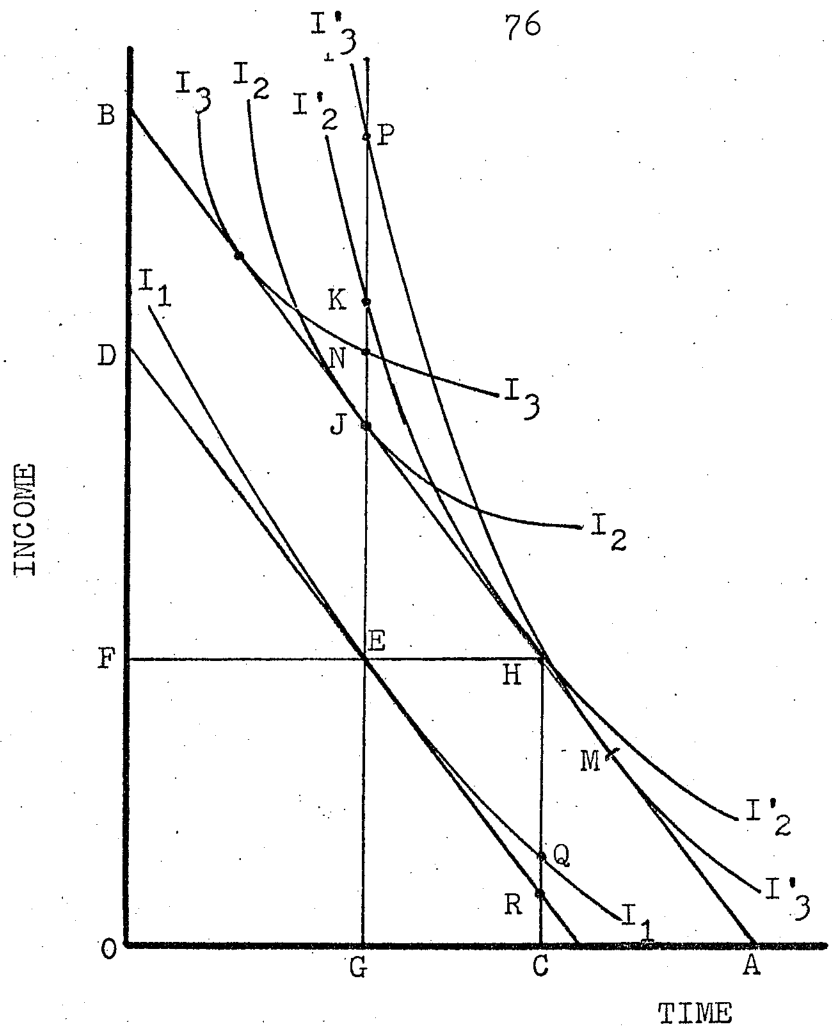

Figure 3.1: Income-Leisure Approach to Modal Choice

choosing this mode of travel are represented by CD.

Figure 3.1 can be further viewed as a representation of the net income lines of two distinct modes of travel. The income line AB would be representative of both modes of travel for some individual making the choice between them. The net income line for each mode would then be CD which represents the parallel downward shifting of AB taking into account the time and money costs for that mode. Therefore AB could be said to represent combinations of income and leisure available to the individual choosing the first mode while CD would represent available income and leisure combinations available to the individual choosing the second mode.

Now suppose AB is the net income line for one mode--say private automobile--and CD represents the net income line for the second mode--say mass transit. Then if variations in disutility of travel over time and by mode are ignored, and if individuals have the freedom to select an optimal combination of leisure and income, then all individuals facing the above budget lines would travel by car (AB). (This statement is made on the basis of modal choices being all-or-nothing choices for clarity's sake.) This is due to the simple fact that no matter what preference system between income and leisure the individual may have, AB is above CD and is tangent to a higher indifference curve. However, it is important to point out that this result is dependent upon the slope of the budget lines--that is, upon the wage rate and modal time and money characteristics. If a different group of individuals with a very different wage rate was considered then CD might lie above AB and mass transit would be the superior choice of mode for that group.

This logic becomes more evident with the simple algebra which leads to the development of diversion prices. Assume for convenience, that the consumer has two alternative modes of travel to choose from. The equation for the individual's net income for mode (1) gives income Y_1, as a function of some given level of leisure $\bar{L}$, as being:

$$Y_1 = w(s - \bar{L} - t_1) - c_1$$

where

w = individual's wage rate per unit of time

s = individual's stock of time

t_1 = travel time by mode (1)

c_1 = money cost by mode (1)

Similarly, for mode (2) the net income is described by the equation:

$$Y_2 = w(s - \bar{L} - t_2) - c_2$$

The difference in net income between the alternative modes, Z, is then:

$$Z = Y_1 - Y_2 = w(t_2 - t_1) + (c_2 - c_1)$$

> If workers are free to pick any combination of income and leisure and if the effect of disutility is ignored, Z indicates which mode they will take and what the diversion price will be. Thus, a worker will take the first mode if Z is positive, the second mode if it is negative, and be indifferent between them if it is zero. In addition, Z is the amount by which a commuter must either be compensated for taking the "wrong" mode or the minimum charge that must be imposed in order to make him switch from the "right" one. That is, if the worker were charged an additional amount equal to Z when he used the alternative mode, the two net income lines would coincide and he would be indifferent between them.[9]

The basic aim of Moses and Willwamson's paper is to reveal the kinds of price changes that would be necessary to induce shifts from automobile commuting to public transportation, if such a policy is deemed necessary. In this end the authors come to a most striking conclusion: "It is evident...that negative prices would be necessary on all modes of public transportation to divert at least 50 per cent of those currently making the trip by car."[10] Furthermore, the

[9] Ibid., p.257

[10] Ibid., p. 262.

results of their study suggest that if the reduction of public transit fares to zero were carried out, less than one fifth of the automobile commuters would be diverted.

In Moses and Williamson's paper, neither the belief that many of the problems of cities are due to the automobile, nor the policy conclusions based on that belief has been at issue. Rather, they have developed a measure which they feel sheds light on the nature of price changes involved in diverting people from the automobile mode in the work trip. This measure (Z) is a function of the time and money costs of a commuter's modal alternatives and his wage rate. Having made estimates for the city of Chicago, the authors believe that the results they obtained warrant the collection of similar data for other urban areas. Furthermore, other analyses, they claim, could profitably examine and determine the level of investment that would be required to reduce travel time by public transportation systems. "The cost of a diversion program based on price changes might then be compared with one based on improvements in this very significant aspect of quality of service."[11]

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[11] Ibid., p. 264.

2. Characteristics Approach to Modal Choice

While the studies discussed above attempt to explain the modal-choice decision-making process, they fail to achieve this result, not because of their lack of recognition but, because of their lack of incorporation into their models, of very relevant factors other than price (or cost) and time. Modal choice models must be reconciled with the fact (as stated in Chapter II) that a necessary step in improving urban transportation systems via the public transit solution requires the upgrading of urban public transit standards so that they are at least equivalent to those of the private automobile system at least in the areas of privacy, comfort and convenience. This statement leads us to the conclusion that if urban travel is to be diverted away from the automobile then a transit-improvement approach must be taken and that therefore models which analyze the modal choice decision-making process must go beyond price and time factors.

In the work of Moses and Williamson as in most of the literature on modal choice, the analytical framework is based upon utility-maximizing individuals who choose between modes in light of their particular preferences regarding income and leisure. Individuals go about their normal business of choosing an optimal combination of leisure and income, in consideration of the fact that they have to spend time, which they value, and money on fares or operating costs so that they may travel about to and from work. The point is not that income and leisure choices are irrelevant to individuals but rather that there are other factors that are important in the determination of modal choice and should therefore be considered.

In response to the question: "What is it that causes individuals to prefer one mode of urban transport over another?"--the income-leisure approach (as discussed by Moses and Williamson) replies that utility--maximizing individuals prefer the mode which leads them to an optimal income and leisure combination in respect of the costs associated with urban travel and individuals' valuations of time. It is submitted that while there can be no doubt as to the importance of costs in individuals' modal choice decision making criteria, the assumed consumer objective of choosing an optimal income-leisure combination is inadequate and perhaps even insufficient in attempting to explain the choice of mode.

Now if the selection of a mode of travel is not primarily based on the selection of an optimal income-leisure combination then a new answer must be found to the question: what is it that causes one mode of travel to be preferred over another? It is submitted, following Lancaster,[12] that it is the characteristics of the goods, or in this case the modes of travel, that give rise to utility and hence the preference of one mode over another. That is, "we assume that consumption is an activity in which goods, singly or in combination are inputs and in which the output is a collection of characteristics. Utility or preference orderings are assumed to rank collections of goods indirectly through the characteristics they possess."[13] It is by no means implied that urban travel and time costs are to be ignored for these cost criteria are vital to the analysis of modal choice. The introduction of modal characteristics in the analysis is simply intended to provide a more comprehensive and realistic approach.

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[12] Kelvin J. Lancaster, "A New Approach to Consumer Theory", Journal of Political Economy, (April, 1966), p. 132-157.

[13] Ibid., p. 133.

The essence of this approach then is that travel on either mode of transport, per se, does not give utility to the individual. Rather, each mode possesses certain characteristics which give rise to utility. Lancaster states that many of the intrinsic qualities of individual goods can be incorporated only by moving to multiple characteristics. However, it is assumed that the analysis of modal choice can be fairly accurately represented in a two-characteristics, two-goods world, and that other seemingly important characteristics such as time in transit can be quantified, priced and considered as direct costs attributable to each mode of travel.

Furthermore, two distinct groups of decision-makers can be identified: (a) the urban transportation planners (acting in the interests of the community) who view mass bus transit as the solution to urban congestion, energy, and pollution problems, and, (b) all the other individuals who make the actual decision to use a mode of travel. Let it be said for now, that each decision-making group views costs and characteristics in a different manner thus giving rise to different Lancastrian predictions about modal choice due to different interpretations of the nature of the goods (or modes).

Following Lancaster, it is firstly assumed that the utility of urban travel depends upon the characteristics possessed by each mode, that is,

$$U = U(C_1; C_2)$$

where C_1 and C_2 are the quantities of each characteristic consumed. Each characteristic must be measurable on a cardinal scale. Assume that the two most important characteristics which give rise to utility and hence the selection of a mode of travel are "transportationness" and "comfort-convenience quality."[14] What might be called transportationness is perhaps the most important characteristic as it is not only highly price and income inelastic but is also the principle identifier of goods relevant to our travel activities. For example, even though a sofa has some comfort-convenience quality, it does not (normally) possess any transportationness.

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[14]The selection of these two particular characteristics does not preclude the possibility of defining other characteristics which might more accurately explain the nature of the two goods (modes) in question. However, the purpose of this exercise does not call for such accuracy as much as it calls for the introduction of characteristics into the modal choice decision-making process itself.

Hence individuals will not consider a sofa as a relevant good in the selection of a mode of travel.

The second characteristic, comfort-convenience quality, is measured in terms of the number of dollars spent on initial vehicle outlay per seat in excess of the price of the least expensive vehicle capable of carrying the number of passengers usually carried on the typical vehicle and is actually a measure of the degree to which extra expenditure on a vehicle provides a more luxurious pleasing atmosphere to individual travellers.

To summarize briefly in terms of a response to the question pertaining to the causality of modal choices then, the factors which are important to a consumer of urban travel are:

(1) transportationness - the capability of carrying an individual from one point to another; and,

(2) comfort-convenience quality - travelling conveniently in a pleasant or comfortable atmosphere.

Goods or, in this case, modes of travel as agents for the production of characteristics, each mode providing certain characteristics in fixed proportions and in proportion to its consumption.

Thus:

$$c_1 = a_{11}g_1 + a_{12}g_2 \quad \text{and}$$
$$c_2 = a_{21}g_1 + a_{22}g_2 \quad \text{or}$$
$$c = Ag \quad \text{in matrix notation.}$$

Here, c_i is the amount of the i-th characteristic, a_{ij} is the amount of the i-th characteristic produced by one unit of the j-th good and g_j is the quantity of the j-th good. If all possible goods in the economy (including sofas) were considered, many zero elements in the A matrix would be found.

Regarding the form of the utility function it is assumed that the set of points in characteristics space with utility greater than or equal to some level is strictly convex. The possibility that utility may be reduced with the increment of some characteristics beyond a point is explicitly allowed for. It is highly possible that some characteristics confer disutility with any amount consumed, while others have to be consumed beyond a "satiation point" before they confer disutility. Characteristics are "satiable" when they have a satiation point and are "satiated" when consumed at or beyond this point. The possibility of negative marginal utility is vital to the analysis for when goods produce characteristics these may have negative imputed prices even though all goods have positive prices.

Now, in addition to the law of the "diminishing marginal rate of substitution" along an indifference curve, convexity means that we can also speak of "increasing marginal rate of compensation". Indifference curves have an increasing positive slope when one characteristic is satiated and the other is not.[15] That is, moving along an indifference curve, successively large increments of a desired characteristic must be given to the household to make up or compensate for the increasing disutility conferred by increments of the satiated characteristic.

Furthermore, as an important additional restriction on the utility function it is assumed that a non-satiated characteristic cannot be inferior, or, cannot have a negative income demand elasticity. From this assumption follows the "non-Giffenness" of non-satiated characteristics. The purpose of this

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[15]Richard Lipsey and Gideon Rosenbluth, "A Contribution to the New Theory of Demand: A Rehabilitation of the Giffen Good", Canadian Journal of Economics, IV (May, 1971), p. 135.

assumption is to assist in showing how the technical relationship between characteristics and goods can produce inferior and Giffen goods although the utility function is set up to rule out inferior and Giffen characteristics. Except in the special case of additive utility functions which are of no concern here,[16] the above assumption does not restrict the nature of the demand for satiated characteristics.

Regarding the shape of indifference curves in two-characteristics space the assumption about the non-inferiority of non-satiated characteristics implies that where neither characteristic is satiated, indifference curves are downward sloping and means that proceeding out along any horizontal line, successive indifference curves cannot get steeper, whereas proceeding upwards along any vertical line, the indifference curves cannot get flatter.

In the case where the characteristic on the horizontal axis is satiated with the vertically plotted characteristic not being satiated, indifference

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[16]Although this particular problem is of no concern here, Lipsey and Rosenbluth discuss the matter of additive utility functions briefly.

curves are upward sloping and the non-inferiority assumption means that proceeding out along a horizontal line, successive indifference curves cannot get flatter. In this case no restriction is implied about the slope of indifference curves along a vertical line (except in the case of additive utility). Lipsey and Rosenbluth call this assumption that of "non-increasing marginal rate of substitution--ceteris paribus" or NIMRS--CP.[17] It can be asserted that diminishing marginal utility is a sufficient condition for NIMRS--CP as long as the characteristics are not "excessively substitutable", meaning that an increase in one will decrease the marginal utility of the other proportionately more than its own. This result holds for non-satiated characteristics. That is, when one characteristic is satiated, diminishing marginal utility of the one will ensure the non-inferiority of the other and thus NIMRS--CP, unless the characteristics are "excessively complementary", meaning an increase in the satiated characteristic will increase the marginal utility of the other proportionately more than it raises its own

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[17]Lipsey and Rosenbluth, <u>op</u>. <u>cit</u>., p. 136.

marginal utility.

In order to set the stage for discussing the predictive abilities of the characteristics model some numerical values can be assigned to the concepts and variables involved in the modal-choice decision-making process as envisaged by the urban transportation planners who would like to for various reasons reverse the private automobile trend.

The various costs and values of characteristics have been fully derived and explained in Appendix II, therefore in order to not detract from the present analysis assume that the urban transport planners perceive the following cost elements as being important in the choice of mode:

(1) vehicle operation, maintenance and parking;

(2) depreciation of vehicle and right of way;

(3) maintenance of right of way and system; and,

(4) congestion costs imposed by each vehicle on others.

All of these costs apply to both private automobile and bus.

Secondly, regarding characteristics, society views each mode as producing "transportationness" in terms of its average occupancy and "comfort-convenience quality" as the difference between the price of the vehicle in use and that of the least expensive alternative capable of carrying the number of passengers usually carried on the vehicle in use, divided by the number of people sharing the vehicle (or, its average occupancy).

From a social point of view then the relevant decision-making costs and characteristics' values are as described in Table 3.1 below.

The costs and characteristics pertinent to the allocation of transportation infrastructure investment dollars ideally should lead to the appropriate modal split when viewed from a social perspective. That is, while day-to-day travel experience may dictate an outcome at variance from such a result, the relative costs of the provision and operation of public transit versus private urban travel infrastructure (freeways, bridges, signals, etc...) should control modal split.

Consider now how society views the choice between bus (good 1) and private automobile (good 2). Quantities c_1 of characteristic 1 (transportationness) are measured horizontally and quantities of c_2 of characteristic 2 (comfort-convenience quality) vertically. The quantity of a mode yielding both

Table 3.1: Costs and Characteristics as Viewed by Society

I Cost Categories (costs in cents)	Private Automobile	Bus
1. Vehicle operation, maintenance and parking	12.0	75.0
2. Depreciation of vehicle and way	8.5	20.0
3. Maintenance cost of way system	0.5	20.0
4. Congestion cost imposed on other vehicle	26.7	160.0
5. Total cost in cents per vehicle mile	47.7	275.0
II Characteristics (in units)		
1. Transportationness	1.6	30.0
2. Comfort-convenience quality	1,563.0	333.0

characteristics is now represented as the length of a ray through the origin whereby the ray's slope measures the ratio of quantities c_2 to c_1 produced by each mode. Mode 1 is said to have a comparative advantage over mode 2 in the production of the first characteristic when the quantities of the two modes producing equal quantities of the second characteristic yield unequal quantities of the first characteristic with the higher quantity of the first characteristic being produced by the first mode.

Figure 3.2 shows motorbus transit as having a comparative advantage in the production of "transportationness" while the private automobile has a comparative advantage in the production of "comfort-convenience quality". As explained in Appendix II, an expenditure of 47.7 cents on good 2 - car - yields 1.6 units of c_1 and 1563 units of c_2 while an expenditure of 275 cents on good 1 - bus - yields 30 units of c_1 and 333 units of c_2. Using an arbitrary budget constraint of 82.75, an expenditure of this amount on bus gives 30 units of c_1 and 333 units of c_2 while an expenditure of the same amount on car gives 9.2 units of c_1 and 9,011 units of c_2. Thus, given a set of money prices and, an income or budget constraint, society's perceived market opportunity line (MOL) can be drawn. If society's hypothetical consumers spend all of their money on bus rides then they can move out along the g_1 vector to a and if only car rides are consumed, then consumers can move out along the g_2 vector to b. a and b are called the "maximum attainable points" along g_1 and g_2. The line joining ab is the MOL in characteristics space. Indifference curves can be drawn in this space in order to locate the equilibrium position of society's consumers on the MOL. Note that since the MOL is confined to the interval between goods vectors, the position of equilibrium may easily be (as will be seen later) a corner solution rather than a point of tangency.

Society's MOL depicted in Figure 3.2 shows a given expenditure on good 1 producing more transportationness and less comfort-convenience quality than the same expenditure on private automobile. It now can be determined whether the urban transport planners' interest in promoting bus travel is an uneconomic goal, or more simply, whether or not bus travel is an inferior good. To do this an imaginary "unconstrained income-consumption line" (UICL) is constructed and line ab is projected to the two axes. Letting income change and shifting this extended budget line to all possible positions, points of tangency with indifference curves trace out an income-consumption line (Engel curve) which is unconstrained by the possible non-existence of goods that might permit the consumption of the two characteristics in the required proportions. Due to the assumption regarding the non-inferiority of non-satiated characteristics, such a UICL is upward sloping. It is assumed that it passes through ab in Figure 3.2 cutting it at x.

Before proceeding further the quantities consumed of the two modes must be shown by means of a construction. This can be done by drawing a line parallel to g_2 cutting g_1 at m. Thus society's hypothetical decision-makers can be thought of as arriving at x by first buying enough "bus" to get from o to m and then enough "car" to get from m to x. The quantities consumed of bus and car are thus om and mx respectively.[18]

Beginning at z, a rise in income - ceteris parebis - shifts the MOL away parallel to itself to, say, cd. Now a horizontal line is drawn from x to cut cd at e as well as a vertical line to cut the new MOL at f. The assumption of non-inferiority of non-satiated characteristics means that society's consumers' new equilibrium consumption position must be on segment ef.

Now project a line through x parallel to g_2 cutting cd at j. If the new consumption point

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[18]Lipsey and Rosenbluth op. cit., p. 136.

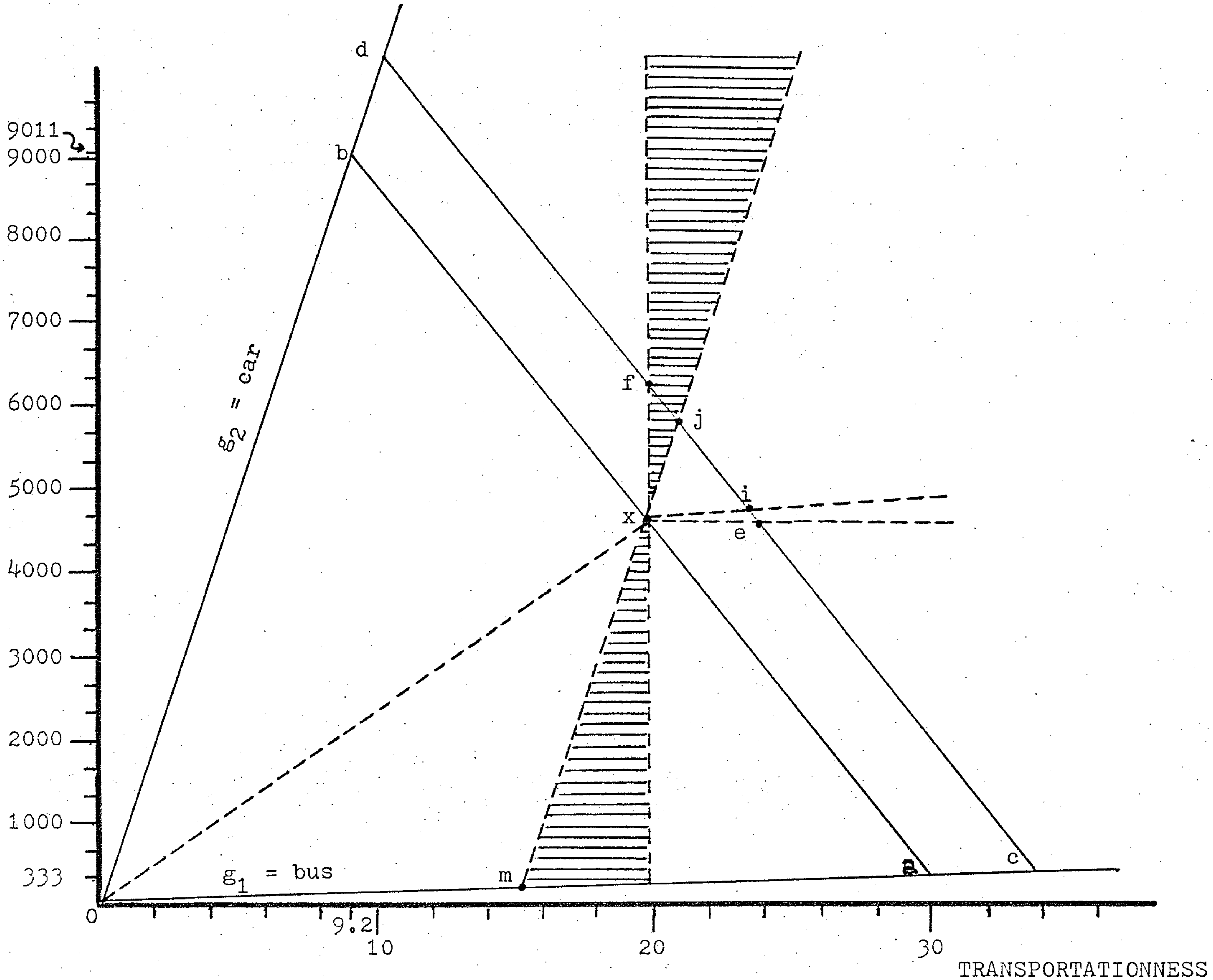

Figure 3.2: Characteristics Model of Modal Choice as Viewed by Society

is at j, when society's consumers move from x to j, the increase in the consumption of characteristics is in the ratio of characteristics as produced by private automobile, and therefore, all of the additional consumption is of private automobile. This implies the zero income elasticity of demand for bus. Project a line through x parallel to g_1 cutting cd at i. If the new consumption equilibrium turns out to be i then all of the extra consumption must necessarily be of bus, so that the income elasticity of demand for private automobile must be zero. From this it follows that if the final equilibrium is on ei below i or on jf above j then either private automobile or bus respectively will have a negative income demand elasticity--that is, it will be an inferior good. For variations in income the shaded area in Figure 3.2 is the area of negative income demand elasticity. If the UICL at x exceeds the slope of g_2 or if the income elasticity of demand for transportationness is low enough (or conversely if the income elasticity of demand for comfort-convenience quality is high enough), then bus is the inferior mode of travel for society's consumers.

A question of interest here would pertain to the likelihood of the above result. The answer lies in an examination of the technical similarities of the modes. Suppose the modes were to be made technically alike by reducing the angle between vectors g_1 and g_2 assuming that to keep the slope of the MOL constant, prices of the modes change appropriately. Then the angle formed by the intersection of xj and xi is accordingly reduced resulting in the shortening of segment ji. Now considering the set of all utility functions having UICLs passing through x, the subset with UICLs cutting fj or ei is now greater which means the subset containing UICLs cutting ji is now smaller. Thus in making the modes more technically similar the likelihood of the inferiority of either of the modes has been increased. That is: "the more similar are the technical characteristics of the two commodities the more likely it is that one of them (the one that has a comparative advantage in the production of the characteristic with the lower income elasticity of demand) will be an inferior good."[19]

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[19]It is obvious that the line through x could have been drawn parallel to g_1 cutting g_2 at a corresponding n (not shown). The quantities on of mode 2 and nx of mode 1 would have been consumed. The

In terms of questioning society's judgemental bases, considering the set of all utility functions with UICLs passing through x, the subset with UICLs cutting segments fj or ie is substantially smaller than the subset having UICLs passing through ji. In conclusion, therefore, the two goods, or modes, are not so technically alike as to present a high likelihood of inferiority of either of them--that is, bus and private automobile are quite probably both normal goods in relation to one another.

The implication that this result holds for the urban transport planners is that in actual situations of modal selection by individuals there is no reason to believe that private automobile should drastically or even marginally be preferred to bus. However it is! It now remains to examine the perception of costs and characteristics by the second decision-making group--the individuals who actually make the modal selections.

Again, the various costs and values of characteristics from an individual's point of view

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geometric laws of parallelograms ensure that the same results would come from either procedure.

have been derived and explained in Appendix II. It is most important to note here (because of the results which will emerge) that the individual decision-making costs and characteristics apply only to those individuals who have the private automobile as an alternative. Table 3.2 below as compared to Table 3.1 shows that individual decision-makers view these costs and characteristics quite differently than does society's hypothetical decision-makers. For example individuals do not take into account such cost items as the operation, depreciation and maintenance of urban transport systems (public or private) and the right of way, or even the depreciation of their own vehicles. As concerns the conceptualization of characteristics, while individuals are assumed to view comfort-convenience quality in the same way as does society, individuals only assign a value of one for the transportationness characteristic of both car and bus.

Table 3.2 below, shows the costs of travel and values of characteristics as viewed by individual decision-makers. As explained in Appendix II, from an individual's point of view, an expenditure of 78.6 cents on bus produces 333 units of comfort-convenience quality and 1 unit of transportationness while an expenditure of 38.8 cents on car produces again 1 unit of transportationness but 1,563 units of comfort-convenience quality.

Again an arbitrary budget constraint of 78.6 cents if spent on bus gives 1 unit of transportationness and 333 units of comfort-convenience quality, or, if spent solely on car, gives 2 units of transportationness and 3166 units of comfort-convenience quality.

Table 3.2: Costs and Characteristics as Viewed by Individuals

		Private Automobile	Bus
I	Costs		
1.	Vehicle operation, maintenance and parking (in cents per mile)	12.0	0.0
2.	Fare (flat rate in cents)	0.0	25.0
3.	Value of travel time at 6.7 cents per minute with car trip = 4 min. and bus trip = 8 min.	26.8	53.6
4.	Total cost for a journey of one mile length as viewed by individuals	38.8	78.6
II	Characteristics		
1.	Transportationness	1.0	1.0
2.	Comfort-convenience quality	1,563.0	333.0

Figure 3.3 shows private automobile as having the absolute advantage in the production of both characteristics for a given expenditure (here 78.6 cents). This results in an upward sloping MOL and points of tangency with indifference curves would require these to be oddly-shaped indeed. Since it was assumed that the characteristics are not inferior, the indifference curves are expected to behave normally and if this is the case, then the point of consumption equilibrium will not be one of tangency but rather, a corner solution. That is, with the exception of a few irrational, but persistent, bus riders, the private automobile will be the mode of travel always selected.

The implications are obvious for the urban transportation planners who must now realize that because of the way individuals perceive costs and characteristics, the private automobile is the overwhelmingly preferred mode of travel. Looking at Figure 3.3 in a practical sense one could hardly accept the implications contained therein for the car/transit balance. However, the important condition that this model is only applicable to individuals for which the private automobile is an alternative should be recalled. Since ridership studies in various cities

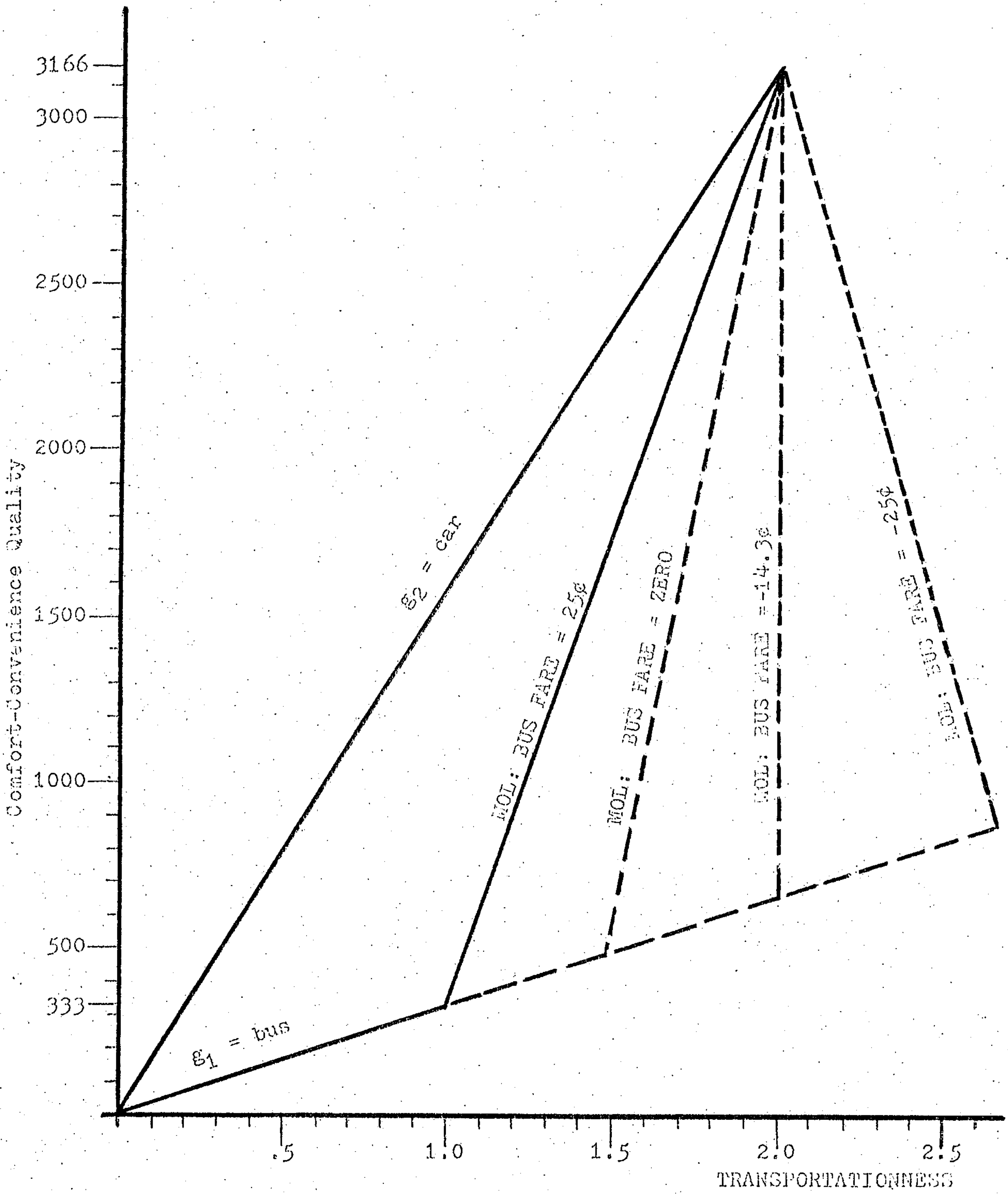

Figure 3.3: Characteristics Model of Modal Choice as Viewed by Individuals

show that by far the greatest portion of public transit traffic consists of people for whom the automobile is not a realistic (or possible) alternative, the individuals' modal choice model is likely not an inaccurate conceptualization of the modal choice decision-making process for the market with which it attempts to deal.

Figure 3.3 also shows various Market Opportunity Lines resulting from changes in individuals' bus costs. An examination of the various MOL's shows that potential transit riders must be compensated by at least 14.3 cents before there will be a tangency between the MOL and probable indifference curves at points other than corners. In fact, it would appear that to make bus more or less competitive with private automobile, individuals, rather than paying 25¢ upon boarding a bus, would have to be paid this amount by the bus driver instead.

Such results do not warrant much optimism on the part of urban transit planners as regards an improvement (from a social perspective) in the car/transit modal split, or indeed the very future of public transit. The results presented here lead us to the same conclusion as that of Moses and Williamson mentioned earlier--that is, diversion programs based on price reductions are most often unrewarding. There is no need to discuss the implications that the model has in terms of much needed fare increases on the part of transit management in order to meet operating expenses out of farebox revenues.

Returning to the attempt to plan urban transport systems with the aim of reaching a socially optimal allocation of urban transportation infrastructure investment dollars (as would be evidenced by a modal split that would be based upon society's modal choice decision-making criteria), it is obvious that because of the way in which individuals view the modal choice decision-making process, such an optimal position will not be reached, all other things equal. The degree to which there is a misallocation of urban transport dollars, and an estimation of the amount, is not discussed in this thesis. Moreover, the differences in conceptualization of costs and characteristics by society and individuals, or the variance in the modal choice decision-making criteria between the individuals who actually choose modes and the planners (whose estimates are assumed per force to be truly reflective of the actual situation) who are supposed to ensure the provision of the modes in the proper proportions, is of such a magnitude that it can be asserted that any change in individuals' decision-making criteria which causes them to choose bus as a normal good, in a manner similar to that in which they would if they perceived costs and characteristics from a societal point of view, would certainly be worthwhile for society's urban transport dollar spending as a whole.

Having made a case for the reversal of the private automobile trend, the predictive abilities of the modal choice model are discussed before the analysis of reversal strategies is undertaken.

3. Predictive Ability of the Characteristics Model

In the second chapter of this thesis, it was argued that if the objective is to shift the car/transit modal split in the transit direction, attention must be given to ensuring that the quality of the urban travel experiences are equally good for passengers using either mode. Presently the random route or automobile/roadway system has distinct advantages in four important areas:

(1) privacy; (2) comfort; (3) orientation; and, (4) convenience. Since there is no simple method of aligning physical environments in a public transit sense with individuals' complex sociological needs resulting in individual privacy requirements being at odds with potential carrying capacities and since the orientation problem is not quite so grave (or at least much more easily resolvable) in the case of urban public motorbus transit, there remain only two principal areas in which improvements to public transit can be made--namely comfort and convenience. For the above reasons the aesthetic or psychological characteristic has been labelled as comfort-convenience quality.

Since empirical investigations have demonstrated that diversion programs based on price reductions are not very rewarding, upgrading public transit system standards so that they approach equivalency with private automobile standards in the areas of comfort and convenience is a necessary step in improving urban passenger transportation systems via the public transit solution.

Returning to the individual's characteristics model it can readily be seen that an increase in comfort-convenience quality by means of an appropriate increase in initial dollar outlay on bus (the increased expenditure of course to be reflective of some comfort or convenience improvement such as air conditioning etc...) would not do much to favour public transit because of the relative costs (and speeds) of automobile and bus and the assumptions regarding transportationness. For example, suppose that the comfort-convenience quality of bus was doubled, all other things equal, and that the doubling of this characteristic was compared to a reduction in bus fares of some amount.

Figure 3.4 shows the initial Market Opportunity Line, with costs and characteristics as perceived by individuals as in the previous section, as being represented by line ab. The amount of transportationness is T, and comfort-convenience quality, q. Suppose bus fares were to be reduced by an amount resulting in the MOL's shifting to ad. Because of the reduced price of bus, individuals would now be able to consume transportationness in the amount T_2 and comfort-convenience quality in the amount q_2. On the other hand, if an appropriate expenditure on buses were made so as to increase comfort-convenience quality to q_2, transportationness

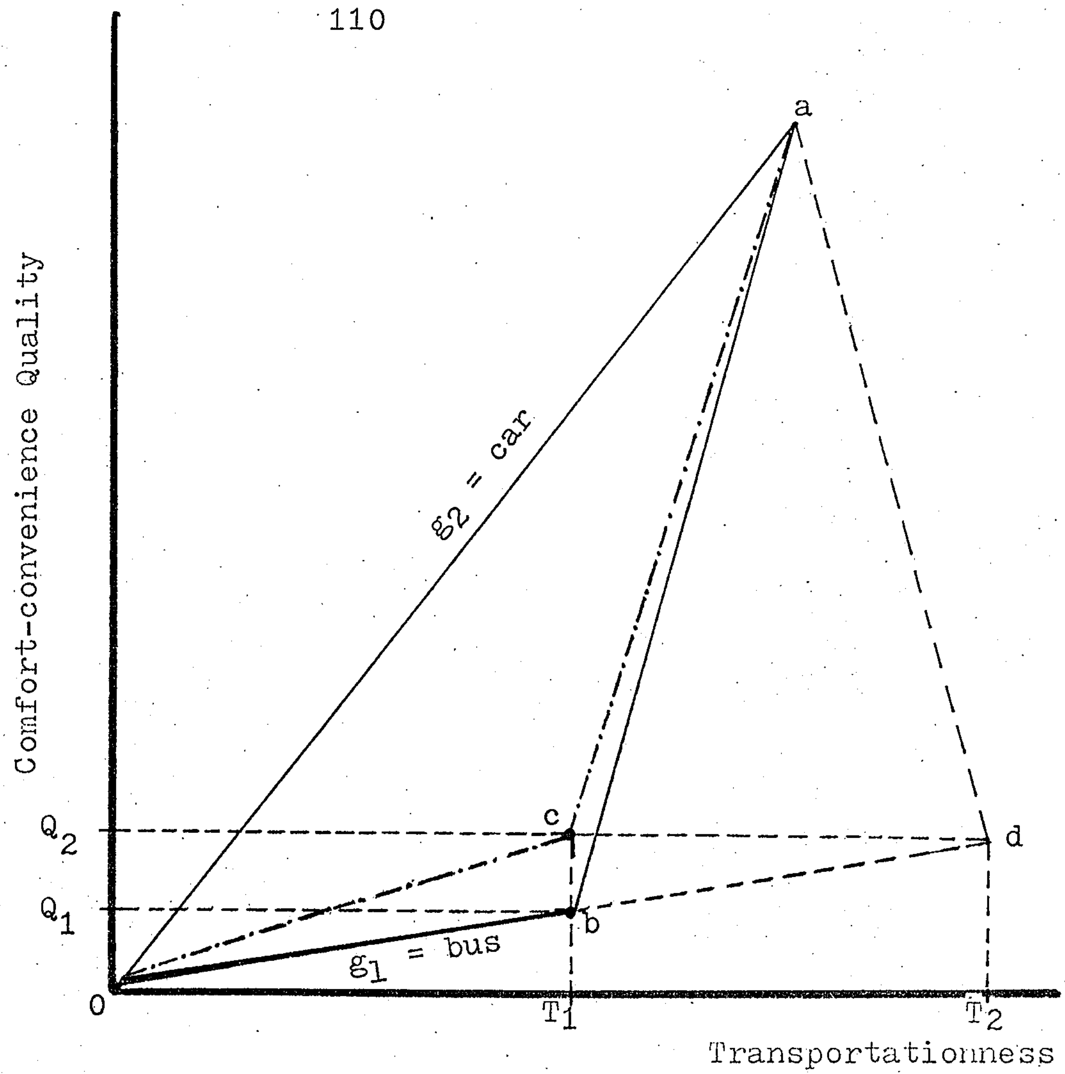

Figure 3.4: Comparison of a Reduction in Bus Fare with an Increase in Comfort-Convenience Quality.

remains constant at T_1 and the MOL shifts to ac; one would be reluctant to say that individuals with MOL ac are better off than individuals facing MOL ab. If this is the case then, the increase in comfort-convenience quality, which cost money to society because of an increased expenditure on bus was probably all for naught.

Two possibilities arise from the above:

(a) either the whole characteristics approach to the modal choice problem is inappropriate; or,

(b) there is more to a change in comfort-convenience quality than was shown. Results obtained thus far help to show that there is a strong case to be made for the introduction of characteristics into the explanation of modal choice. Assuming then that this approach is plausible an important assumption is required--an assumption which will allow for some positive predictions about changes in comfort-convenience quality.

A fundamental issue in the present discussion of the urban transportation problem has been that price factors alone do not influence the choice of mode. In the second chapter it was argued that people are willing to pay dearly (from a social economic point of view) for urban travel in order to enjoy aesthetic comforts, convenience, privacy etc. and tend to keep away from buses because these lack terribly in what has been represented here as comfort-convenience quality. It does not seem inappropriate to assume then that individuals would respond favourably to improvements in the bus mode in the areas of comfort and convenience.

On this basis then it is assumed that for a given increase in comfort-convenience quality, there is a proportional increase in transportationness.[20] This means that a given increase in comfort-convenience quality will have exactly the same effect on the Market Opportunity Line as would a fare reduction which would result in individuals being able to obtain the level of comfort-convenience quality (via an income effect) as was made available by increasing initial expenditures on buses. In terms of Figure 3.4, this really means that an increase in comfort-convenience quality in the amount $oq_2 - oq_1$ results in transportationness's not remaining constant but increasing

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[20]A certain amount of arbitrariness in assuming a one-to-one proportional increase in transportationness for an increase in comfort-convenience quality is admitted. However, a strong case exists for some assumption to be made in this area and perhaps some sensitivity analysis on the assumption of such a one-to-one correspondence could be made. For example, one could attempt to determine how the final analysis of public policy intervention strategies might be affected if the assumed relationship varied by twenty per cent either way. The estimation of the exact nature of this relationship has not been included in this exercise, however, it is likely that detailed empirical studies of travel demand could yield an appropriate numerical relationship regarding the effect on transportationness of an increase in comfort-convenience quality. For the purposes of this thesis then, the unitary relationship described above is assumed to be reflective of the actual situation.

by the amount ot_2 - ot_1 all of which is exactly the same as a bus fare reduction resulting in the production of characteristics in the amounts t_2 and q_2. Stated even more simply, both strategies would result in the new Market Opportunity Line ad.

Given this assumption it would be possible to investigate a number of types of public policy interventions in the areas of speed, price and characteristics relationships and to draw some conclusions on the merits of possible strategies for improving the urban transport problem and the urban public transit situation. Before any of this can be done however, it is necessary to introduce yet another concept which will allow us to evaluate changes in the above mentioned relationships.

While it is claimed that the characteristics approach is superior to the classical income-leisure approach to modal choice, because statements about diversion programs involving factors other than price or cost can be made, both methods are deficient inasmuch as little can be said about the exact nature and value of the relevant utility functions involved. Therefore no predictions can be made about changes in preferences of automobile versus bus (or any other set of goods for that matter) other than that as a result of a specific public policy intervention, consumers will either prefer, not prefer or be indifferent between modes of travel (or consumer goods). Therefore in order to make any predictions about changes in the car/transit balance, we must turn to "modal split analysis". This technique will allow for the translation of cost and characteristics modification strategies into quantifiable changes in modal split given an initial situation or starting point.

4. Modal Split Analysis and Application to the Characteristics Model

Quite simply stated, a modal split model determines the change in mass transit ridership given changes in the relative costs, travel time and comfort of automobiles versus mass transit. The diversion of passengers to or away from public transit can then be transformed into estimates of total trips between specified zones (such as the Central Business District and residential areas). It is important to reiterate that the type of passenger of concern in this analysis is the passenger for whom both automobile and bus are possible alternatives.

In the relatively short history of urban transport planning, a rather large number of modal split models have been developed for different cities--such models of course embodying the special characteristics of the urban settings for which they were developed. As concerns the more general type of modal split model, most seem to work equally well. Therefore this analysis will make use of a shortcut modal split formula which has been devised to measure the number of motorists in large and middle-sized cities who would switch to public transit if fares were reduced and/or if transit travel time (including waiting) was reduced by given amounts.

This modal split formula applies only to car owners working in the CBD as this group usually constitutes the only significant concentration of urban travellers who can exercise a practical choice between private automobile and public transit. This shortcut modal split formula can be applied when two specific pieces of information are known: (a) the number of CBD workers owning their own cars; and, (b) the percentage of car-owning CBD workers using public transit in the journey to work.[21] This model

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[21] F. Houston Wynn, "Shortcut Modal Split Formula", Highway Research Record, No. 283, (Travel Factors and Travel Modes), (Washington: Highway Research Board, 1969), p. 48.

is general enough to allow for the evaluation of data for an entire city or for specific zones and zone clusters.

The shortcut modal split formula was developed by Wilbur Smith and Associates,[22] under the authority of the United States Department of Transportation, Bureau of Public Roads. One aspect of the terms of reference called for the development of a "shortcut" method for quickly estimating general magnitudes of change in modal split resulting from changes in cost or travel time. The formula was derived from data representative of trip-making behaviour in large cities but is intended to be able to estimate the impact of cost and travel time changes on any community's car/transit modal split.

The formula relates only to the journey to and from work in the CBD as was developed from data on this type of urban travel in the cities of Philadelphia, Boston, Baltimore, Seattle, Milwaukee, Springfield Massachussetts, and Columbia South Carolina, and while it was developed for a somewhat small and specialized

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[22] Wilbur Smith and Associates, A Method for Estimating the Impact of Travel Time or Cost Changes on Diversion of Car Drivers to Transit: Work Travel to Central Business District, Prepared for U. S. Dept. of Transportation, Bureau of Public Roads, Feb. 1968.

segment of urban travel, there appears to be no basic reason (other than data constraints) why the shortcut formula cannot be applied to the work journey to any concentration of urban employment. This modal split technique however is not intended to forecast induced or wholly new urban travel possibly resulting from an improvement in an urban environment's general level of mobility.[23] Rather it is designed to measure only the expected change in modal split resulting from modifications in the relative cost or quality of urban travel by public transit versus private automobile. Furthermore since this formula only applies to the reapportionment of given amounts of travel, it deals only with individual decision-makers having the choice between public transit and private automobile.

The shortcut modal split formula is illustrated in Figure 3.5 where the use of public transit in the work journey to and from the CBD is expressed as a percentage of any particular trip movement in accordance with calculated differences in costs between public transit and private automobile. When

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[23]eg. as in the case of the construction of a new network of freeways, or the introduction of a subway.

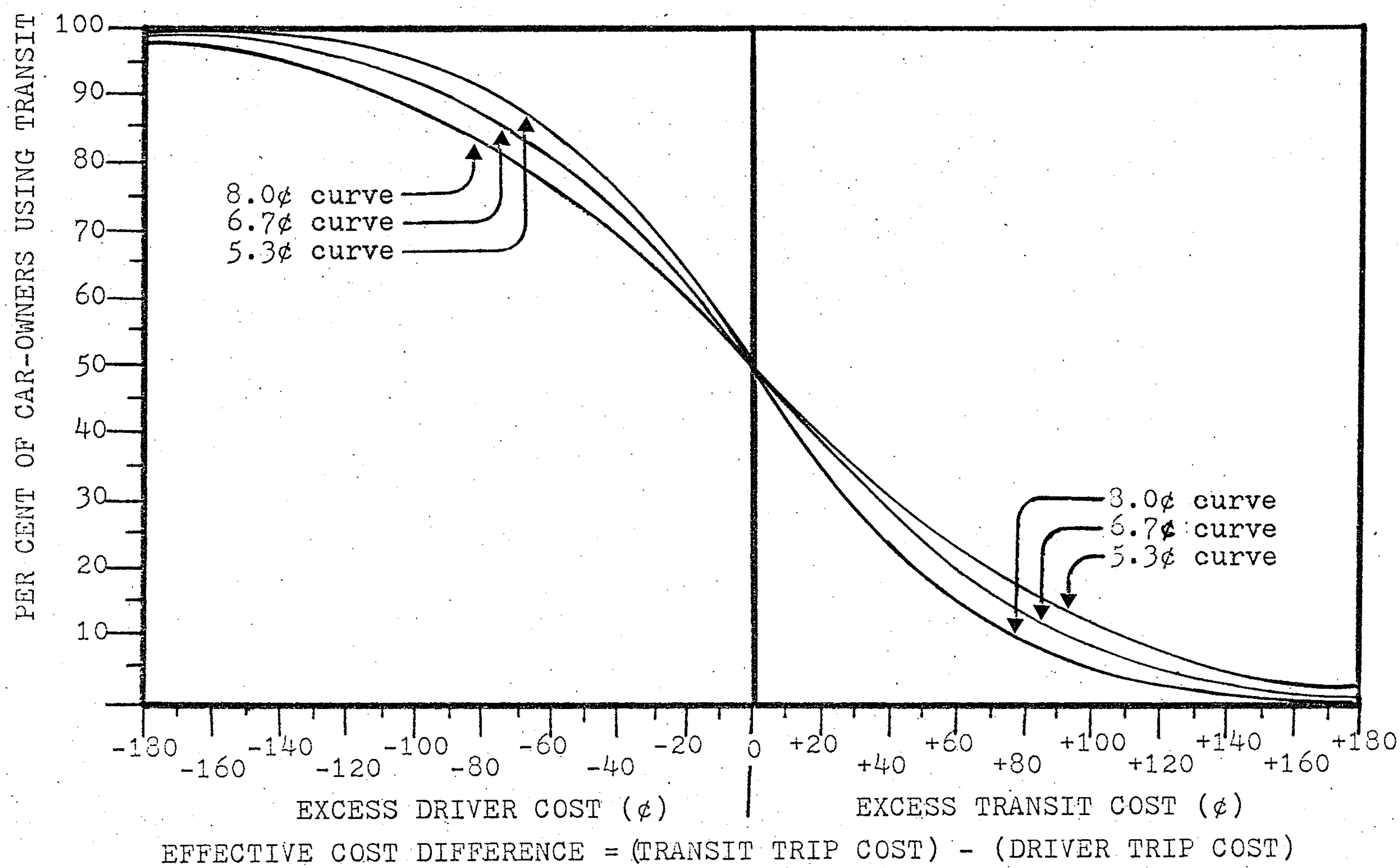

Figure 3.5: Shortcut Formula to Estimate the Effect of Changes in Travel Time or Trip Cost on the Use of Transit for Central Business District Work Trips by Car-Owners

the cost difference is equal to zero (i.e., costs on either mode are equal) individuals are expected to be indifferent between the modes and therefore half of the automobile-owning CBD workers would use their cars while the other half would be expected to use transit. In the case where transit costs are higher than those by car, transit would carry less than half of the journey to work travel to and from the Central Business District.

The shortcut formula consists of a logarithmic growth curve calibrated to show the percentage of car-owning CBD workers who might choose public transit under a wide range of transit/automobile cost differentials. The Wilbur Smith and Associates shortcut modal split formula is[23]

$$P = (1/1 + e^{.16x/c})\ 100$$

where

P = percent of car-owning CBD workers using public transit;

e = base of natural logs = 2.71828;

c = value of time in cents per minute; and

x = net trip cost differential = (transit trip cost) - (automobile trip cost)

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[23]F. Houston Wynn, *op. cit.*, p. 51.

Figure 3.5 shows three curves which have been calculated applying different values for time in the formula. The value of 6.7 cents is that which was assumed in the previous characteristics analysis. Rates of 5.4 cents and 8 cents for value of time were calculated and drawn in Figure 3.5 to illustrate a range within which an estimate of the change in modal split would be affected by different assumptions about the value of time. This range can be thought of as a twenty per cent error margin. Based on the above rates for value of time the three equations mapped out in Figure 3.5 are:

(a) for value of time = 8 cents per minute,

$$P = (1/1 = e^{0.02x})\ 100;$$

(b) for value of time = 6.7 cents per minute,

$$P = (1/1 + e^{0.0239x})\ 100;\ \text{and,}$$

(c) for value of time = 5.4 cents per minute,

$$P = (1/1 + e^{0.0296x})\ 100.$$

The three curves considered together show the effect of different assumptions about the value of travel time on estimates of changes in modal split, ranging from low (8 cent curve) to high (5.3 cent curve) transit use potentials.

Figure 3.6 shows how the shortcut modal split

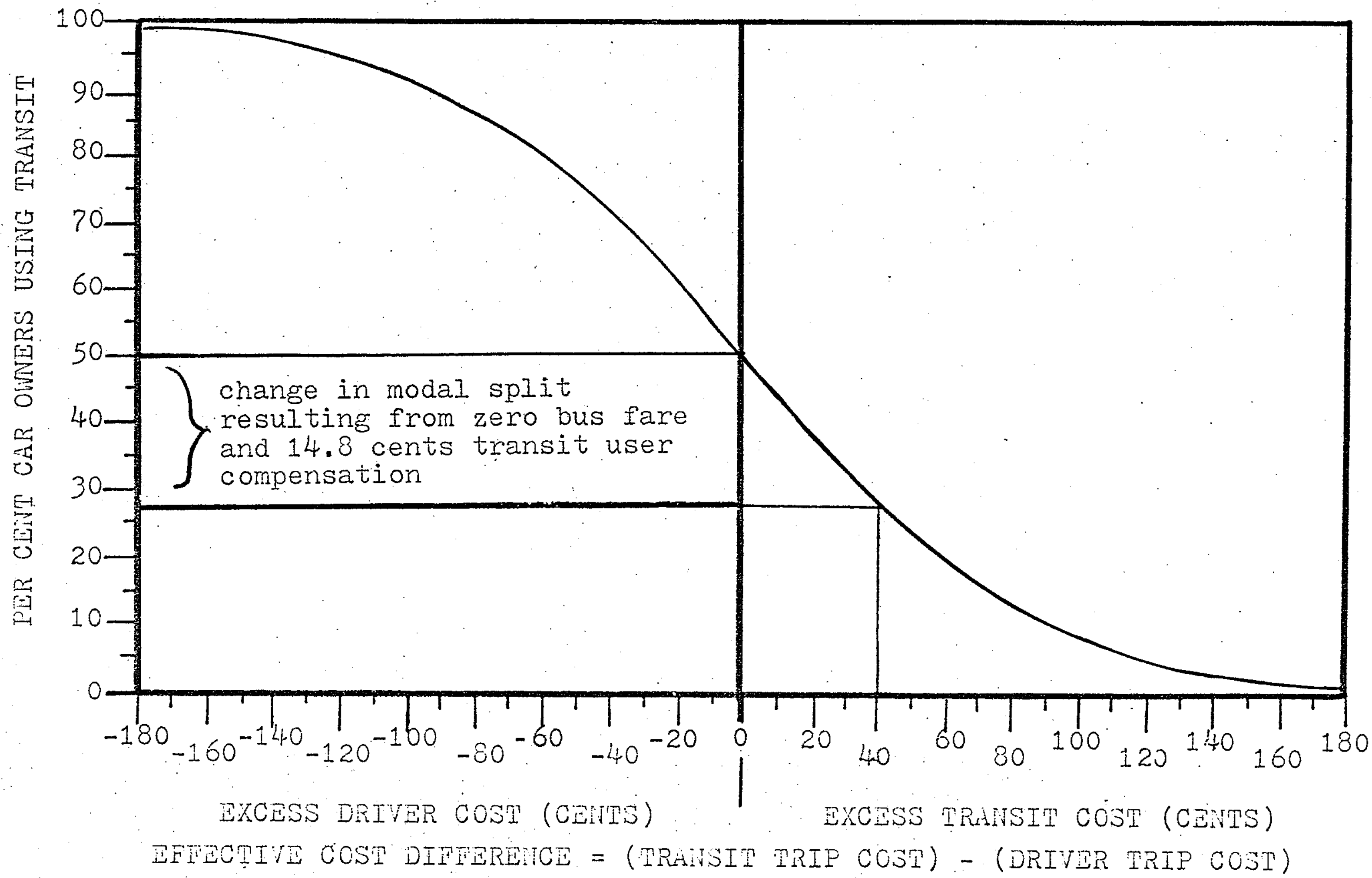

FIGURE 3.6: APPLYING THE SHORTCUT MODAL SPLIT FORMULA (6.7¢ curve)

curve can be used to estimate, for example, the effect of a reduction in transit trip costs relative to private automobile trip costs. Of course it is necessary to know the proportion of car-owning CBD workers who use transit in the journey to work. However since this value is not known (at this point in time), it is assumed that this proportion can be derived from the known cost differential between transit and car. Earlier, we established that from an individual's point of view, the costs of a one mile journey by transit and by car were 78.6 cents and 38.8 cents respectively, or, a differential of 39.8 cents. This means that the proportion of car owners using transit (according to individuals' decision-making criteria) should be:

$$P = 1/1 + e^{0.0239x}$$

where

$$x = 39.8 \text{ cents, therefore,}$$

$$P = 1/\ 1 + e^{0.0239(39.8)}$$

$$= 27.86\%$$

Given the workings of the modal split model as demonstrated above and the characteristics model of modal choice and the assumptions relating thereto, it appears that the techniques for analyzing and evaluating public policy intervention strategies, aimed at reversing the private automobile trend, are in place. That is to say, if modal choice decision-making criteria are known and can be translated into accurate reflections of the actual car/transit balance, then it is relatively simple to determine the usefulness of public policy interventions favouring urban public transit. The next chapter will analyze alternative interventions.

CHAPTER IV

REVERSAL OF THE PRIVATE AUTOMOBILE TREND: AN ANALYSIS OF SOLUTIONS

In the previous chapter the differences in the modal choice decision-making criteria of individuals and communities (or society) were noted and the way in which these criteria led to a substantial variance between society's predicted or desired choices of mode and individuals' actual choices was discussed. At the end of Chapter III it was suggested that the sum of individuals' choices according to their respective decision-making criteria might lead to a car/transit modal split of 27.9% of car-owning CBD workers using transit.

In the context of attempting to arrive at solutions to the urban public transit problem by reversing the private automobile trend it would be helpful to determine society's perception of the car-owning CBD worker modal split. Table 3.1 showed that society views an expenditure of 47.7 cents on private automobile as producing 1.6 units of transportationness and 1,563 units of comfort-convenience quality while an expenditure of 275 cents on bus is considered to produce 30 units of transportationness and 333 units of comfort-convenience quality. These costs and characteristics as viewed by society, however, must be reduced to values which reflect the production of one unit of transportationness by each mode because the individual decision-maker views either mode as producing only a single unit of transportationness and society's decision-makers who wish to influence the modal choices of individuals in favour of public transit will necessarily have to base their diversion strategies upon the values of costs and characteristics as viewed by individuals.

Reduced to terms of a single unit of transportationness then, an expenditure of 29.8 cents on private automobile or 9.2 cents on public transit will, according to society's cost calculations, produce one unit of this characteristic. The "Effective Cost Difference" between the two modes for the purposes of the shortcut modal split formula ('Transit Trip Cost' minus 'Driver Trip Cost') is -20.6 cents. In terms of Figure 3.6 this "Excess Driver Cost" of 20.6 cents would indicate that 62.1% of car-owning CBD workers should use transit. This result indicates a much higher socially desirable modal split than that arising from individuals' decision-making criteria and which may be considered as the "observed" or "actual" modal split.

In some sense the 62.1 per cent transit/automobile balance may be considered as a "socially optimal" modal split because it is determined on the basis of all (as defined in Chapter III) costs rather than only out of pocket costs. If this 62.1 per cent modal split can be considered as some sort of optimum, then clearly it is quite distant from the "observed" modal split. An appropriate goal is therefore to develop strategies or public policy interventions which will favour urban public transit (thereby reversing the private automobile trend) and allow for the attainment of such an optimum in a developmental (and possibly sequential) manner.

As is evident from the workings of the characteristics model of modal choice developed in Chapter III, there are essentially three areas in which public policy interventions can be made in order to reverse the private automobile trend. These are of course the areas of:

(1) price of urban travel;

(2) speed of urban travel; and,

(3) improvements in the characteristics of the public transit mode.

Several public policy interventions which fall under these three areas will now be discussed in an attempt to determine their effectiveness in meeting the objective of modal split improvement. Such interventions will be discussed in terms of their rationale for implementation, their effect upon the choice of mode, and finally their effect upon the modal split for car-owning CBD workers. Impediments to the implementation of these solutions or interventions will be the subject of the next chapter. The examination of solutions begins with perhaps two of the most controversial issues in urban public transportation--road pricing and free transit.

Interventions Affecting the Price of Urban Travel

Road Pricing versus Free Transit

It was shown in Chapter I that the nine major Canadian cities were planning to spend over $3 billion in freeway and arterial highway construction and doubt was expressed as to whether or not funds would be available for such construction. The question arises then--who is to pay for all these highways which supposedly must be built? For one school of thought in this area, the answer obviously appears to be that the users should pay for these facilities. Currently such users are paying nothing for the use of such roadway facilities other than the small amounts paid in the form of gasoline taxes (which we shall discuss later). If any market economy price is set at a level below that which reflects supply and demand conditions there is likely to be excess demand. "The signs of excess demand are well known--long queues, shortages of goods and arbitrary rationing (and even first come first served is a form of rationing)."[1]

Such manifestations of excess demand are experienced every day by private automobile users in the form of peak period congestion. "In the absence of pricing arrangements which equate demand for road space with its supply, congestion is the only means of allocating space, but it is an inefficient means."[2]

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[1]R. J. Burns, P. D. Love, and Ralph Hedlin, "Economic and Financial Aspects of Urban Transportation", Canadian Urban Transportation Conference February 9-12, 1969 Toronto, in *First Canadian Urban Transportation Conference Study Papers*, (Ottawa: Canadian Federation of Mayors and Municipalities, 1969), p. 289.

[2]*Ibid.*

In addition to the fact that congestion seriously reduces the capacity of the road system, other difficulties are caused by the lack of a pricing system. For example, there is no accurate way of determining how much road space should be built and as long as the demand for road space exceeds the supply there is no way of truly relieving congestion. As a form of space allocation congestion operates indiscriminately and does not even allow those who could and would pay to save time to do so. Moreover, by impeding and slowing down public transportation (also competing for road space) congestion is an important factor causing the decline of transit patronage.

In strict economic terms the solution to the problem of congestion is to replace congestion as a space allocator by a pricing system whereby drivers would be levied charges for driving during the rush hour, thereby excluding those people to whom driving in peak periods is least important. In response to objections that road pricing would discriminate against the less well to do it could be argued that that it would do so is inescapable but that is the way the price system works. After all, income rather than need determines the allocation of many of our goods and services. "Is public transportation a social good that is incapable of being left to the operation of market forces for an optimum solution?"[3]

In discussing the use of tolls in controlling urban traffic congestion William Vickrey offers some interesting observations.[4] The author states that on the basis of a million dollars capital investment for the construction of one lane-mile, an 8% annual rate for interest amortization, maintenance, etc. means that this one lane-mile of road is going to cost $80,000 a year.[5] Vickrey assumes that the peak hour conditions occur in the neighborhood of 16 hours a week allowing 3 hours every day for the rush hour. Now if the $80,000

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[3] Ibid., p. 290.

[4] William Vickrey, "The Use of Tolls in Controlling Urban Traffic Congestion," in Unorthodox Approaches To Urban Transportation: The Emerging Challenge To Conventional Planning, Proceedings of a Conference Held at Georgia State University, November 16 and 17, 1972, Andrew Hamer editor, (Atlanta: Georgia State University Publishing Services, 1972), p. 22.

[5] In 1972 dollars.

a year lane-mile cost is divided by 16 hours per week (50 weeks per year) the weekly cost is $1600 and the hourly cost $100. Since the usual maximum design capacity per lane-mile is 1700 cars this results in a cost of 6¢ per car per lane-mile for what was originally a $1 million facility. In some cases the facilities cost between $5 and $10 million per lane-mile or 30¢ to 50¢ per car mile. If on this basis, a 10 mile commuting trip (for example) were to be priced, the cost would easily be from $2 to $3 for the roadway exclusively--that is, parking space, depreciation charges or anything else are not included. While this analysis is somewhat simplistic it shows that the peak hour users must be subsidized to a considerable extent because, at best, such users are probably paying about one cent per mile in gasoline taxes and registration charges. The extent to which peak hour motorists are subsidized is not generally a matter of common public knowledge. "We sweep the whole business into an overall average and assume that the highway funds that are coming out of the federal gasoline tax and the state highway funds are enough to cover the costs."[6,7] Motorists and

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[6]Vickrey, op. cit., p. 23.

[7]While highway financing is somewhat different in Canada, motorist psychology is much the same.

urban transport planners alike seem to forget the fact that city streets are maintained, policed and traffic-controlled from funds that have absolutely nothing to do with motorists.

One possible solution would be to offer free transit in the hope of both relieving congestion and in terms of making things even between the highly subsidized motorist and the transit rider. However, this is not quite equitable for even if transit riders are subsidized 30¢ to 50¢ or even $1.00 this is still not really close to giving the user a subsidy equal to that being given to the automobile driver. If the objective was to give a person a real choice between a transit ride and driving a private automobile in a way that would truly reflect the real social cost of his choice, the only way to do it would be to give the user a dollar bill every time he boarded the bus. Since for a number of reasons (including municipal finances) this is not really possible, the more plausible alternative might be to make motorists aware of the direct costs of peak hour driving. There is no merit in proposing higher gasoline taxes because these are also paid by people who drive during non-rush hour periods as well as in rural areas which is something which is not necessarily to be discouraged (at least for the present). "We therefore need a method of charging which is specific as to time and place. Then we tell the person, 'If you want to drive into town at 9:00 in the morning you've got to pay $2.00 for that. You can come in at 11:00 a.m. for a nominal 20¢.'"[8]

To look at the congestion problem in a more analytical manner a diagram relating speed to the density of traffic is useful.

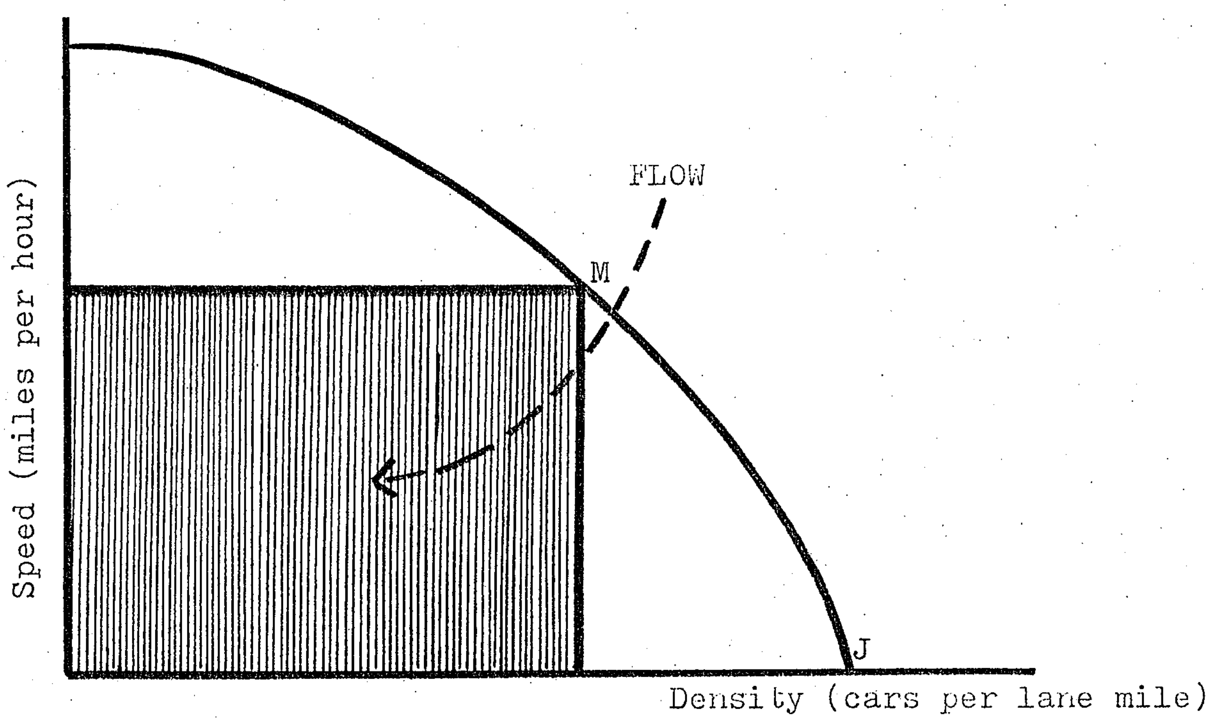

Figure 4.1: Relationship Between Speed and Traffic Density

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[8]Vickrey, op. cit., p. 23.

At higher speeds traffic density on roadways is low. However, as traffic density increases corresponding speeds drop until we arrive at the traffic jam density at J where everybody is stopped. The flow of cars per hour per lane-mile is the product of the number of cars per lane-mile and the prevailing speeds. At a point where both density and speed are moderate (as at M) traffic flow is maximized.

In order to determine the relationship between dollar costs and traffic flow, speed-volume curves (as in Figure 4.1) are transformed into a time-volume relationship which indicates the required amount of time to travel one mile on a roadway at a given volume. To obtain a dollar cost the amount of time spent travelling is multiplied by an estimate of the value of time to the commuter. This is added to the other operating vehicle costs to determine the total cost of travel by private automobile on the roadway. With an increased volume of vehicles congesting the road this cost will increase. This time-volume relationship can be transformed into a price-volume relationship where price is expressed in cents per vehicle mile of travel and volume in terms of vehicle per lane per hour as in Figure 4.2.

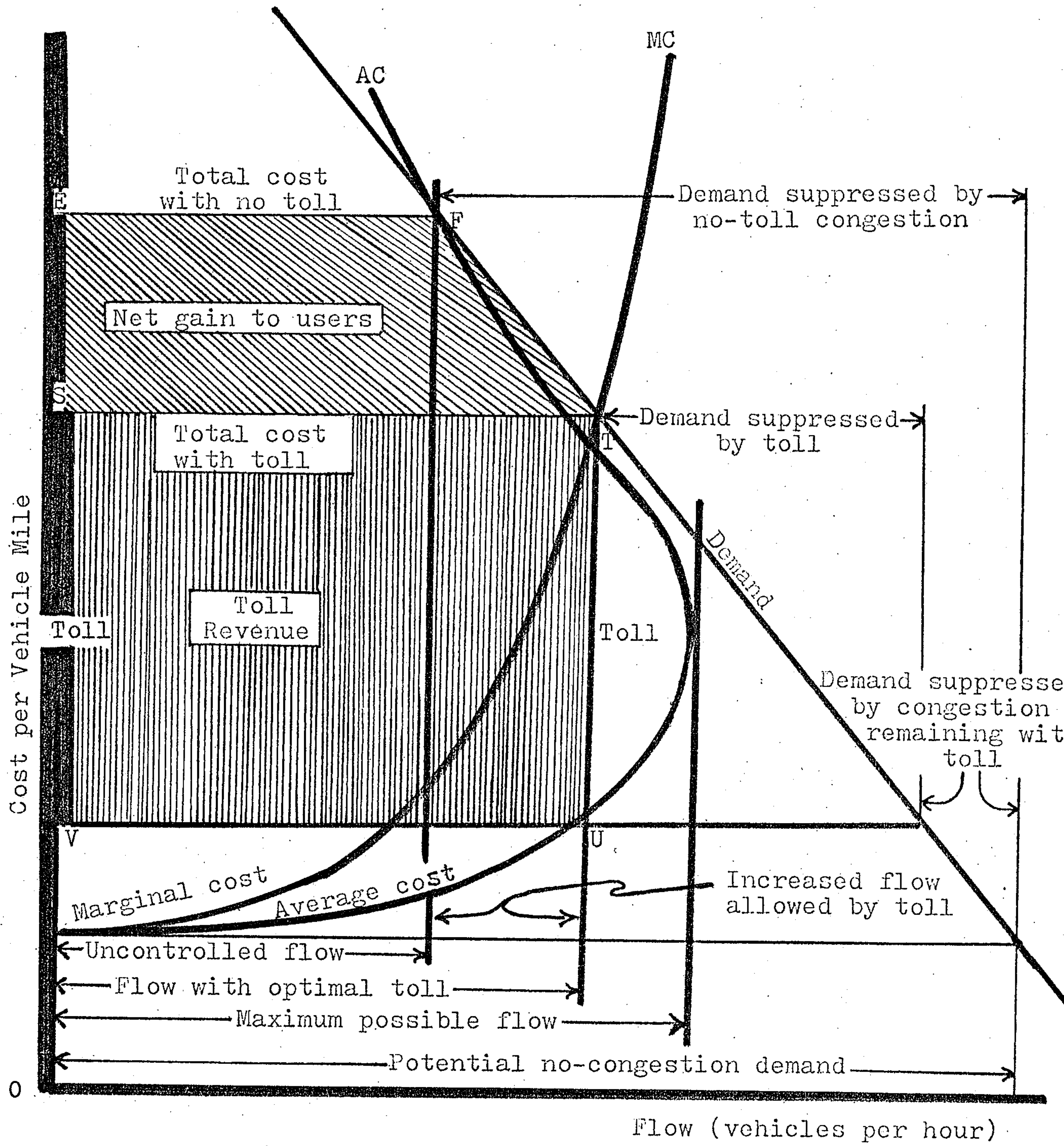

Figure 4.2: Relationship Between Per Vehicle-Mile Travel Costs and Traffic Flow

"There exists in fact, two relevant price-volume curves, one representing the price perceived by the individual driver and another reflective of the costs paid by society as a whole."[9] The price-volume relationship is the average per vehicle mile cost of travel relevant for each given roadway volume. The social price-volume relationship is the additional total cost of travel resulting from a unit increase in vehicle miles travelled. The change in total cost that occurs when a new car enters the roadway system is reflected in the social cost or price which takes into account the effect of added congestion on all cars--that is, each individual car is considered to be the marginal car. The actual level of use of a roadway depends on the intersection of such price-volume curves with a roadway demand curve. Of course, the demand for roadway use declines with increasing roadway travel price given a constant price of urban public transit.

The unusual nature of the backward bending average cost curve can be explained quite easily.

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[9] Richard O. Zerbe and Kevin Croke, Urban Transportation For The Environment, (Cambridge Massachussetts: Ballinger Publishing Company, 1975), p. 77.

As average roadway volume per lane increases, average speed decreases until capacity is reached. These relationships show travel time increasing with volume until "hypercongestion" conditions occur. "Hypercongestion is reached at capacity when the relationship between flow and speed reverse and both traffic flow and speed decrease."[10] Therefore as congestion worsens, not only do fewer vehicles flow on the roadway, but the per mile travel costs actually increase due to lower speeds. The reversal of the flow and speed relationship thus gives rise to the backward bending average cost curve as shown in Figure 4.2.

In the absence of roadway pricing the flow of traffic is restrained by minimum operating costs and time costs as would exist without congestion in addition to the costs created by the congestion itself. In order to make optimal use of the roadway under such conditions, the individual motorist should pay a toll that causes him to realize the costs he imposes on others by using the roadway during the peak period. The toll is simply the difference between the average cost of operating the vehicle

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[10] Ibid.

and the marginal cost imposed by that vehicle on all others. Marginal costs are equal to the "price" that consumer-drivers should pay for their vehicle's being allowed to use the facility. During congested periods instead of the usage pattern with traffic flow decreasing drastically under conditions of excessive congestion, as at F, the level of traffic is controlled as at T. More cars, therefore, can flow through a given portion of roadway than before. "Since the total number of vehicles using the facility and the congestion related costs are cut by the imposition of the toll, users actually save money; the total cost of travel inclusive of average congestion costs and tolls, is reduced from OE to OS.[11] These benefits, represented in Figure 4.2 by the shaded SETF, are known as "consumer surplus". What is effectively happening is that a tax is being levied which makes taxpayers better off--a result not encountered very often. By imposing a tax amounting to the rectangle STUV, the efficiency of the system which formerly cost VUTFE is actually improved by reducing the system cost by the amount SEFT.

To express the cost of congestion as simply as

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[11]Vickrey, <u>op</u>. <u>cit</u>., p. 29.

possible [12] in a mathematical manner, assume average traffic speed on a given road to be a linear function of traffic flow of the form:

$$s = a - bq \qquad (1)$$

where s = average speed in miles per hour,

a = average speed at very low traffic volumes,

b = some road constant expressing the effect of one vehicle per hour on average speed.

The average costs per vehicle mile can be expressed as follows:

$$x = m + c/s \qquad (2)$$

where m = average operating costs per mile (net of tax) at speed a,

c = cost of vehicle's time consisting primarily of occupant's value of time, and partly of increased operating costs attributable to starting and stopping.

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[12] J. C. Tanner, "Pricing the Use of the Roads-Mathematical and Numerical Study", in Proceedings of the Second International Symposium on the Theory of Traffic Flow (London 1963), Joyce Almond editor, (Paris: The Organization for Economic Cooperation and Development, 1965).

and,

q = traffic flow in vehicles per hour

It is necessary to postulate a relationship for the use of the road as a function of the cost. This demand function is of the form

$$q = f(x)$$

where q and x are as previously defined and f is a decreasing function which we need not specify.

The total cost to society therefore is simply the flow of vehicles per hour, q, multiplied by the average cost per vehicle mile, x. Total cost X is therefore:

$$X = qx$$

or $$qm + cq/s$$

or, since

$$s = a - bq$$

$$X = qm + cq/a - bq$$

The marginal cost, or additional total cost of travel resulting from a unit increase in venicle miles travelled is therefore

$$dX/dq = m + [c(a - bq) + bcq]/(a - bq)^2$$

or, since

$$q = (a - s)/b,$$

$$dX/dq = m + [cs + bc(a - s)/b]/s^2$$
$$= m + cs/s^2 + c(a - s)/s^2$$
$$= m + c/s + c(a - s)/s^2 \qquad (4)$$

Now since the average cost of road travel per vehicle mile, $m + c/s$ will be paid by the individual vehicle, all that remains is to determine the difference between marginal and average congestion costs, $c(a - s)/s^2$[13] and to express it in terms of a devised price system.

Perhaps the most difficult value to estimate is 'c', the value of vehicle time because the major part of urban traffic consists of private automobiles whose occupants are normally travelling in their non-working time. While the value of time is controversial and difficult to estimate, most research done on this topic analyzes modal choice under the assumption that individuals can trade off extra costs for the benefit of saving time.[14]

Again, following Reynolds,[15] suppose the average value of time, c, were established at $1.50

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[13]Equation (4) minus Equation (2)

[14]See Chapter III

[15]D. J. Reynolds, op. cit., p. 72.

per hour. "In view of the difficulties and nature of this problem, however, this must be regarded as an order of magnitude; for no degree of precision is possible without very considerable research. The solution to the question of the value of time probably demands nothing less than the full integration of persons' time into economic analysis,[16] a massive task with an uncertain outcome."[17] Surprisingly enough, but fortunately, it has been established that road pricing charges are not very sensitive to the value of time assumed.[18]

Using a 'c' value of $1.50 per vehicle hour on a typical urban roadway susceptible to congestion and an average speed of 30 miles per hour at low traffic volume Reynolds estimates the marginal and average costs per mile at various speeds and the resultant congestion costs imposed by the "marginal" vehicle on the other vehicles as shown on the following page.

Chiefly because, at high traffic volumes and

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[16]See Gary S. Becker, op. cit.

[17]D. J. Reynolds, op. cit., p. 72.

[18]See J. C. Tanner, op. cit.

Table 4-1: Average Costs, Congestion Costs Imposed on Other Traffic, and Marginal Costs in Cents Per Vehicle Mile*

Actual Average Speed(s) - including stops	Average Cost per vehicle mile (cents)	Congestion Costs imposed on other traffic per vehicle mile (cents)	Marginal Costs per vehicle mile (cents)
5 (m.p.h.)	$m + c/s$	$c\ (a - s)/s^2$	$m + c/s + c\ (a - s)s^2$
30	10.0	0.00	10.00
25	11.0	1.20	12.20
20	12.5	3.75	16.25
15	15.0	10.00	25.00
10	20.0	30.00	50.00
5	35.0	150.00	185.00
0	∞	∞	∞

* Reynolds, <u>The Urban Transport Problem</u>, p. 72.

corresponding low speeds, individual vehicles impose serious delays on other vehicles, congestion costs (as shown in the third column of Figure 4.1) are highly sensitive to actual average journey speed. In the extreme cases, such costs can be as high as several dollars per vehicle mile and can be almost infinite when an additional vehicle causes the whole system to become paralyzed.

Regarding the level of charges which would practically express the marginal costs of vehicle use, clearly there is little advantage in charging for road use where speeds are 25 miles per hour or more. In particular the more important and predominant case where average speeds are in the neighborhood of 15 miles per hour, at which the congestion costs imposed ny one additional vehicle on others are in the order of 10 cents per vehicle mile, must be considered. It should also be recalled that traffic and the marginal costs of congestion will be reduced by the imposition of a charge. A price that will have an effect equal to the marginal costs of congestion imposed on other vehicles at a traffic volume of drivers willing to pay that charge must therefore be determined.

Tanner has found that the optimum charge is neither very critical or sensitive to the demand elasticity and that 80% of the benefits from road use pricing can be obtained from a charge within approximately 50% of the optimum.[19] It appears then that the optimal charge for the usual case where speeds are around 15 miles per hour (prior to road pricing) will be around 5 cents per mile. Tanner estimates that such a charge will probably reduce traffic by approximately 15 per cent until an average speed (all other things equal)of around 18 miles an hour is reached.[20] The objective here is to obtain a significant increase in speed for a large remaining volume of traffic by pricing off that small volume of road users who are either unable or unwilling to pay the true full costs of urban travel which includes the congestion costs they impose on others. Furthermore, road pricing should be applied to all vehicles including buses and trucks which have three times the congestion impact on other vehicles because of their size and power/weight ratios.[21] However, the incidence per passenger mile of road pricing charges would be

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[19]J. C. Tanner, op. cit.

[20]Ibid.

[21]Road Research Laboratory, Research on Road Traffic, (London, England: Her Majesty's Stationery Office, 1965).

much less for buses than for cars because of their respective average occupancies and therefore road pricing would tend to operate in favour of public transit.

On the other hand to apply such tolls to public transit vehicles would mean little more than an interdepartmental transfer in a municipal financing sense. Suppose then that as a public policy intervention, a five cent per mile toll is imposed on private automobiles only. In the context of the characteristics model of modal choice described in Chapter III, if a five cent per mile road use charge were imposed, individual decision-makers (whose decision-making cost and characteristics criteria are shown in Table 3.2) would perceive the cost of a mile of automobile travel rising to 43.8 cents (from 38.8 cents) while the per mile cost of bus travel would remain constant at 78.6 cents.

In terms of the shortcut modal split formula, the new decision-making urban travel costs would result in an "Effect Cost Difference" of 34.8 cents in "Excess Transit Cost" further resulting in an observed modal split of 30.3 per cent. However since these results are based on Reynolds' assumption about the value of time being $1.50 an hour, the

6.7 cent per minute (or $4.02 per hour) value of time assumption used in this thesis would justify a proportionate increase in the proposed user charge from 5 cents to 18.7 cents per mile. This of course would mean that the per mile cost of urban travel by automobile would increase to 57.5 cents. The new "Excess Transit Cost" of 21.1 cents would result in a new modal split of 37.7 per cent which represents a 35 per cent increase in the initial modal split.

On the other side of the road pricing argument is the question of free transit. There is much merit in the oft-stated opinion that, while private automobiles make use of urban roads free of specific charge, transit must pay for itself from farebox revenues. The diminishing returns aspect of the automobile and the increasing returns aspect of public transit, warrant a special examination of the pricing relationship between them. Finally there is the paradox that while public transit vehicles are struggling to make their way through congested cities, there is no doubt that, under some circumstances, the total journey time of all travellers could be reduced if they were all forced to travel by bus rather than car.[22]

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[22]F. V. Webster, "A Theoretical Estimate of the

In terms of economic principles, if private vehicles and public transit are close substitutes for at least a proportion of travellers, a given volume of urban travel will be undertaken at minimum total cost when the marginal costs of travelling by each mode are equal, for otherwise total costs will be reduced by the constant transferal of travellers from one mode to the other. Perhaps the best way to ensure that the marginal costs of the two modes are equal is to charge the relevant marginal costs for each of the two modes allowing people to choose freely between them. The marginal costs of automobile use under urban conditions have been discussed earlier and it will be shown in Chapter V that it is very difficult in practice to charge them. In order to determine how to improve the car/transit modal split, the matter is now discussed in a public transit sense.

It would appear that given a small amount of excess capacity (in the form of empty seats) in the system and specific frequency of starting and

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Effect of London Car Commuters Transferring to Bus Travel", Road Research Laboratory Report LR 165, (London, England: Her Majesty's Stationery Office, 1968).

stopping, the marginal costs of public transit use involve little more then the cost of walking, waiting, and time spent in the vehicle. "This marginal cost will diminish with increased transit usage, because as usage increases a rational system will spread routes more widely and operate buses over them more frequently and thus reduce walking and waiting. Since the costs of walking and waiting and the time spent in the vehicle are already borne subjectively by the user, the proposal to charge marginal cost for buses amounts to giving the user free use of transit. It may be noted that purely by chance, the values are closely symmetrical with the possible changes for car use; instead of charging the car five cents per vehicle-mile, we are considering subsidizing the bus at four and a half cents per passenger-mile."[23] Of course this is only true if the value of time is assumed to be $1.50 per hour.

Speaking strictly in terms of improvements to the modal split, when the probability of car users transferring to free transit is considered, it is obvious that two separate margins are affected:

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[23]D. J. Reynolds, Urban Theory and Practice, 1969 Convention, Canadian Good Roads Association.

(1) car users' income and ultimately their valuations of time; and, (2) their nearness of actual or potential bus routes and the actual or potential frequency of bus service over them.[24]

For example, consider urban travellers in Ottawa who perform journeys of similar length whether by car or by bus. The average bus user pays 25 cents and takes 30.5 minutes on his journey while the average automobile user takes 12.4 minutes on his journey and incurs various other objective and subjective costs of car use.[25] The question of importance then is what effect will there be on car users' behaviour resulting from the abolition of the 25 cent fare?

In addressing this problem, D. J. Reynolds states that assuming that the car users' valuations of time are linearly distributed about a mean of $1.50 an hour (ranging from $0.00 to $3.00) and assuming that automobile users are randomly distributed between bus routes, it would be expected that

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[24] D. J. Reynolds, The Urban Transport Problem, p.77.

[25] De Lieuw Cather and Co. of Canada, Ottawa-Hull Area Transportation Study, 1965.

car users would be attracted by a fare reduction of 25 cents if they valued their time at less than 83 cents per hour. This apparently would account for about 28 per cent of car users if public transit was to penetrate to the edges of the urbanized area. Therefore, it would seem that a reduction in automobile traffic density of the order of twenty per cent could be attained by offering a system of free transit operating to the limits of the urbanized area. However, this result is initial and highly speculative requiring verification by practical experiment. On the surface however, it does seem that such a system of free transit could have similar effects on the modal split as would road pricing by achieving a reduction in traffic volume in the order of 15 to 20 per cent.[26]

Again, the assumed value of time of $1.50 per hour by Reynolds differs greatly from the time value of $4.02 per hour assumed in Appendix II. However the fare still cannot be reduced by more than 25 cents unless society wished to pay passengers a dollar each time they boarded the bus (as discussed earlier). This

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[26] D. J. Reynolds, The Urban Transport Problem, p. 77.

public policy intervention is therefore restricted to reducing the bus fare by 25 cents which causes the cost of a mile of urban travel to become only 53.6 cents (as compared to the previous 78.6 cents) while the per mile cost of automobile travel (without road user charges) remains constant at 38.8 cents.

In terms of the shortcut modal split model then the "Effective Cost Difference" is 14.8 cents in "Excess Transit Cost". Such a cost difference should result in a new modal split of 41.2 per cent of car-owning CBD workers using transit. This represents an increase of 47.7 per cent over the initial modal split.

Now without, at this time, discussing some of the impediments to the implementation of road pricing and free transit, another type of public policy intervention will be analyzed in the context of the modal choice and modal split models.

Interventions Affecting the Speed of Urban Travel

As it is senseless (and contrary to objectives embodied in the goal of reducing traffic congestion) to initiate public policy interventions which attempt to reverse the private automobile trend by reducing automobile speed, the only types of interventions which will be considered here are those which might improve the speed of public transit or at least reduce urban travel time.

Express Transit and Reserved Bus Lanes

In Chapter I it was noted that historically, the streetcar had the right of way over other forms of urban transportation. However as technological improvements brought upon the introduction of trolley buses and motor buses, urban public transit lost those special right-of-way privileges and has had to compete for space on urban roadways. "As the level of service becomes lower due to increased traffic density, the operating speed of transit will be reduced. This reduction in speed will mean that in order to maintain the same frequency of service, more buses will be required. In other words the productivity of transit is reduced at a time when costs are increasing greatly and the potential demand is the highest. To overcome this problem, the solution of providing exclusive right-of-way to transit or to give priority treatment to transit should be considered."[27]

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[27] J. J. Bakker, Public Transit Right-of-Way, (Prepared for the 1974 Annual Meeting of the Canadian Urban Transit Association in Calgary, June 20, 1974), p. 1.

This solution can be implemented in a number of ways including exclusive bus operations in curb lanes or median lanes, reverse-flow operations on one-way streets or on the wrong side of the median, or through exclusive approach lanes and transit signals, etc. Whatever approach or combination of approaches is taken, the fact is that "local bus systems operating on streets with other traffic simply fail to provide service adequate to attract a large number of automobile users. Systems operating on their own rights-of-way where high speeds can be attained for a major portion of each trip are necessary to provide required service."[28] Some of the potential advantages of exclusive bus right-of-way include "the possibilities of feeder-trunk service, better tailoring of service to reduce the number of seat-miles, and reduced capital costs resulting from no requirements for signal or power distribution."[29]

Perhaps the most fundamental statement of rationale for reserved bus lanes however has been

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[28]Thomas B. Deen, "Mass Transportation Research: The Basic Issues", in Highway Research Record #318, Mass Transportation, (Washington: Highway Research Board, 1970), p. 6.

[29]*Ibid.*, p. 10.

made R. M Topp who says that "very simply, when you realize that automobiles average between one and two persons per vehicle even during rush hours and contrast this with buses having a peak hour capacity of up to say one hundred per vehicle, then it is only reasonable that the public vehicle should warrant special consideration on heavy transit arteries."[30]

In order to discuss this public policy intervention in terms of the modal choice and modal split models, some data relating to expected time savings resulting from the introduction of express transit and reserved bus lanes is required. The City of Winnipeg has made some estimates of express bus and rapid bus travel times which would result from the implementation of a proposed five year transportation program drawn up in 1974.[31] The modal choice decision-making criteria described in Chapter III contain the assumption that a car travels twice as fast as a bus. If a comprehensive system of express transit and

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[30] R. M. Topp, Reserved Transit Lanes, A Brief Address to the Annual Meeting of the Canadian Transit Association (Ottawa, June 17-20, 1973), p. 3.

[31] City of Winnipeg Public Transit Study, Progress Report, 5 Year Program, January 1974.

reserved bus lanes were implemented, this relationship would change from 2:1 to 1.2:1. This means that a mile of automobile travel (at 15 miles per hour) would still take 4 minutes, but whereas a one mile transit trip (at 7.5 miles per hour) took eight minutes, the same average transit trip would only take 4.8 minutes (at 12.5 miles per hour) on a transit system with express and reserved bus lanes.[32]

In terms of the modal choice decision-making criteria of individuals as described in Table 3.2, the cost of automobile travel time valued at 6.7 cents per minute would remain at 26.8 cents for the 4 minute journey. However, if the transit travel time can be reduced from 8 minutes (with trip travel time having a value of 53.6 cents) to only 4.8 minutes with the implementation of this public policy intervention, the value of the time expended on a mile of transit travel would be reduced to 32.2 cents. This amounts to reducing the individual's total transit travel cost from 78.6 cents 57.2 cents. In terms of the car/transit modal split, the new "Effective

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[32]These figures have been derived by the author and are not to be considered as demonstrative of the City of Winnipeg's transit system, but are merely illustrative of the possible results of the introduction of an effective system of express transit and reserved bus lanes.

Cost Difference" would be 18.4 cents in "Excess Transit Cost" with the result that 39.2 per cent of car-owning CBD workers would now use transit. This result represents a 40.5 per cent improvement over the initial car/transit balance.

Signal Preemption for Transit Vehicles

For much the same rationale as introducing reserved bus lanes, an argument can be made for the designing of traffic signal priority systems for public transit. "Any system which alters the phasing, split, cycle time or offset of traffic signals on a fixed or real-time basis for the purpose of reducing transit delays is a traffic signal priority system."[33] Allen states that travel time by transit can be considered as consisting of three components: (1) loading and unloading of passengers (passenger service time); (2) stops at signals (signal delay time); and, (3) actual travel along the route (run time). The relative importance of these three components in total travel time can vary widely on different routes in different urban areas. However

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[33]Duncan W. Allen, Signal Priority For Transit Vehicles, Research Report Nol 34, (Toronto: University of Toronto/York University Joint Program in Transportation, May 1976), p. 1.

traffic signal delay time commonly accounts for 10 to 20 percent of total transit trip time.[34]

There are essentially two basic approaches to signal preemption. Active preemption systems require a positive indication of the presence or status (i.e., whether the bus driver wishes priority or not) of a transit vehicle in order to make a real-time adjustment to signals. "Passive" systems require no such indication and can be considered as permanent changes to a traffic signal system in aid of transit vehicle movement.

In his study and review of signal priorization Allen found that: transit signal priority can be implemented and can reduce transit travel time; detection of electric streetcars via overhead contacts has been in practise for some time (especially in Europe); and, detection of buses and manipulation of signals by radio has proved to be successful. Furthermore "both theoretical and experimental results indicate that transit delay reductions of as much as seventy per cent are possible. This means

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[34] Westinghouse Air Brake Co., Wilbur Smith and Assoc., Institute of Public Administration, Study of Evolutionary Transportation, February, 1968.

that up to fifteen per cent of total transit route time could be eliminated in some cases."[35]

If such time savings were applied to the individual's decision-making model, the transit trip time cost would be reduced from 53.6 cents for a one mile (8 minute) journey to 45.6 cents for a journey of the same length taking only 6.8 minutes because of signal preemption for transit vehicles. Reducing the individual's travel time cost by 8 cents reduces his total transit trip cost to 70.6 cents from 78.6 cents for an "Effective Cost Difference" of 31.8 cents in "Excess Transit Cost". The resultant modal split would be 31.9 per cent of car-owning CBD workers using transit, representing a 14.3 per cent improvement over the initial modal split.

Again, problems associated with the implementation of public policy interventions affecting the speed of public transit vehicles will be the topic of the next chapter. A final type of urban transit solution remains to be considered here.

Improvements in the Characteristics of the Urban Transit Mode

In the type of public policy intervention to be discussed here, the usefulness of the character-

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[35]Duncan W. Allen, *op. cit.*, p. 51.

istics model of modal choice in analyzing public transit solutions which cannot be related to individuals' urban travel time and costs is demonstrated. Two solutions will be discussed. While only the first pertains explicitly to the actual characteristics of the physical transit vehicles, data pertaining to the other one is easily manipulated so as to fit into the analytical context of the modal choice model.

It was assumed in Chapter III that "a given increase in comfort-convenience quality will have the same effect on the Market Opportunity Line as would a fare reduction which would result in individuals being able to obtain the level of comfort-convenience quality (via an income effect) as was made available by increasing initial expenditures on buses." Consider again individuals' modal choice decision-making criteria whereby given a budget constraint of 78.6 cents, this amount if spent solely on public transit would afford the individual 1 unit of transportationness and 333 units of comfort-convenience quality, or if spent solely on private automobile would yield 2 units of transportationness and 3166 units of comfort-convenience quality. For illustrative purposes, recall the case where free transit was offered thereby reducing individuals' urban public transit travel costs by 25 cents to 53.6 cents. It was predicted that the modal split would change from 27.9 per cent to 41.2 per cent of car-owning CBD workers using transit. However, while nothing was said of this in considering the free transit intervention, a certain number of individuals will change to the public transit mode because with a budget constraint of 78.6 cents and transit costs having been reduced to 53.6 cents, whereas the individual could obtain 1 unit of transportationness and 333 units of comfort-convenience quality, he can now obtain 1.5 units of transportationness and 488 units, or an increase of 155 units, of comfort-convenience quality.[36]

Now reconsider the definition of this characteristic. "Comfort-convenience quality is measured in terms of the number of dollars spent on initial vehicle outlay per seat in excess of the price of the least expensive vehicle capable of carrying the number of passengers usually carried on the typical

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[36]For more precision in this analysis, empirical studies of the elasticity of demand (especially in the case of fare reductions as opposed to increases) would be required so that the substitution effects may be taken into account.

vehicle." Suppose, for example it was decided that each transit vehicle would be equipped with air-conditioning at a cost of, say, $4,650 per bus. This would work out to a per passenger vehicle outlay increase of $155. Such an expenditure would result in the comfort-convenience quality characteristic being raised from 333 units to 488 units (again an increase of 155 units). This it may be recognized yields the same result as was the case with the implementation of free transit. Therefore one would expect that the effect of the air-conditioning solution would result in the same change in modal split as the free transit intervention. On this basis then two interventions affecting the characteristics of the public transit mode which can, therefore, be analyzed in the characteristics context, are considered below.

The Improved Motorbus

The question of improving transit buses in the interest of attracting increased ridership has received much attention in recent years and prototypes of what have been called the "world's most advanced city transit buses" have been designed, built, and even tested in actual revenue service.[37] TRANSBUS is the name which has been given to this new bus which incorporates the first basic changes in urban transit buses in almost twenty years. The design and construction of three prototypes by American General Corporation, GMC Truck and Coach Division, and Rohr Industries was funded by a $25 million grant from the United States Department of Transportation's Urban Mass Transportation Administration (UMTA). The project evolved from recommendations of the National Academy of Engineering in 1967. In 1971 sub-contracts were let to the three above-mentioned manufacturers to develop their individual designs and produced three prototypes by mid-1973. Evaluation tests were conducted in mid-1974 and while UMTA did not place any orders for these buses, two of the companies--GMC Truck and Coach Division and Rohr Industries (Flxible)--have received a number of options orders for these. The special features of the TRANSBUS are described below in an UMTA news release.

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[37]Transport Development Agency, "World's Most Advanced City Transit Buses", in Transport Development News, vol. 4, no. 10, 1974, p. 9-10.

TRANSBUS is not a remake of buses now operating in America's transit systems. From its sleek exterior and low profile to its many passenger comforts, it is an all-new bus, capable of speeds up to 70 miles per hour for high speed operations on exclusive bus lanes.

From the moment the rider boards via low steps, he will discover comforts heretofore unknown on transit buses. The first step will be only six inches up from the curb, with the next riser no more than seven inches high, like the steps in a house. At night, doorways will be well illuminated, as will the adjacent street and curb areas where passengers enter and leave the bus. Even the destination signs will be better illuminated by means of a special film coating.

Two of the prototype buses will have incorporated a "kneeling" feature into their designs. Through the use of an air bag suspension system, these buses will actually lower three inches for receiving and discharging passengers. As the bus starts to move, the system inflates, raising the bus. As it slows down, the system deflates lowering the bus.

One model of each of the companies' three buses will be fitted with such experimental devices as electrically controlled ramps and lifts that will enable passengers in wheelchairs to board. Other improved features include a 25 per cent wider front door than those on today's buses. Passengers will board and leave the buses more quickly for faster service. Seats will be wider and spaced farther apart, allowing more leg room. The rear of the bus may be transformed into a

U-shaped lounge area, comparable to jet air travel accommodations.

Operators will be given options in choosing the type of interior and seating arrangements that best suit their services. The seats may be large, plush and padded, or constructed of heavily resistant plastic materials. Even the bus operator's seat will be adjustable to the individual requirements of the driver.

Speakers, inside and out, will enable the driver to assist passengers with current route and stop information. Temperatures in the bus will be kept uniform and fume-free in summer and winter through improved air-conditioning, heating and exhaust systems. Broad, tinted windows will provide a glare-proof view. Individual wheel suspension will smooth out the ride.

The new bus will accommodate about 45 comfortably seated persons, but up to 50 seats will be available for high density runs. The seats will be supported on a cantilever to facilitate faster cleaning and more foot room.

TRANSBUS will be safer than other buses. Its windows will be resistant to the high impact of thrown or falling objects. Handholds of pliable materials have been designed for maximum use and safety. Strategically placed and padded bulkheads will help protect passengers from falling. Bumpers and extra-strong body construction will minimize damage in traffic accidents. The windows, which will not open under normal conditions, will have emergency releases. All of the materials inside the bus will be splinterproof, and the windows will be made of shatterproof

> glass. Escape hatches in the roof will provide exits if the bus should roll over.
>
> TRANSBUS will also incorporate environmental advances. Plans call for a 75-per cent reduction in the internal noise level and a 50-per cent reduction in external noise. The new bus also will have a reduced level of emissions, below the 1975 California heavy duty vehicles standards. AM General and Rohr designs will have improved diesel engines and GMC will have a gas turbine. All buses will be designed so that transit operators will be able to select any of these engines or even future advanced power plants such as steam and Stirling-cycle engines now under development.
>
> From the three designs now being built will come a final design destined to become the next generation of urban transportation buses. The Department of Transportation will make the design available to all manufacturers bidding to build future fleets for city transit operators.[38]

It would seem then that this "Bus of the Future" contains a very comprehensive number of special changes and improvements of the sort that might be successful in attracting new transit ridership. To determine the magnitude of the

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[38]Joseph W. Marshall, "Bus of the Future" in Highway and Urban Mass Transportation, U.S. Department of Transportation - Urban Mass Transportation Administration, Spring-Summer 1973, pp. 4-5.

change in ridership to be achieved by the introduction of such a vehicle in urban public transit systems, or more fundamentally the effect of this solution on individuals' modal choice decision-making criteria, the price of the improved vehicle must be known. Discussions between the present author and the various developers of TRANSBUS prototypes indicate that for applications to the Canadian market, the price of this bus would have to be in the order of thirty per cent higher than that of conventional vehicles in use today.

On the basis of the assumed price of the conventional bus being $45,000, the improved bus would cost $58,000. This means also that comfort-convenience quality will increase, by definition, from 333 units to 783 units. Then, for an expenditure 78.6 cents on a mile of bus travel, whereby with old buses individuals could obtain 1 unit of transportationness and 333 units of comfort-convenience quality, on the new improved buses individuals could obtain 2.35 units of transportationness and 783 units of comfort-convenience quality.

In order to determine the modal split which would result from the introduction of such buses, it is necessary to determine the "Effective Cost Difference" in modes which would result from a change in the costs of urban travel which, through an income effect, would result in individuals being able to obtain characteristics in the above-mentioned amounts. As it turns out, if through some strategy the actual cost of a mile of urban travel by transit had been reduced to 33.5 cents, then this cost reduction would have resulted in individuals being able to obtain 2.35 units of transportationness and 783 units of comfort-convenience quality--the same results which would occur with the introduction of TRANSBUS. Given this relationship then the "Pseudo Effective Cost Difference" would be 5.3 cents in "Excess Driver Cost". The resultant modal split would be 53.2 per cent--a 90.7 per cent improvement over the initial modal split.

Improved Complementary Transit System Components

The previous solution to the private automobile trend demonstrated how expenditures on substantial improvements to transit vehicles could result in a substantial improvement in the percentage of car-owning CBD workers using transit. Another transit system improvement that could have a significant effect on the modal split in an area important to individuals even before they board the buses deals with transit shelter improvements.

In Chapter II we stated that "perhaps the best tool for measuring a public transit system's convenience is a -30°C windy winter day when any gaps in what should be a comprehensive service become brutally apparent." Also, it was stated that unfavourable comparisons between public transit and private vehicle convenience factors could be minimized if, among other things, collection points are sheltered, and if transfers occur in sheltered areas so that vehicle to vehicle exchanges are more pleasant experiences. Unfortunately however transit shelters are usually not only few and far between but inadequate in a weather protection sense and unattractive in a public transit image sense.

In order to improve this situation the City of Winnipeg, in recognition of the fact that better transit shelters can act as a marketing instrument in enhancing transit's image and increasing ridership, has committed funds to the development of new shelters. The program which was initiated in 1974 consists of two components: (a) the development of a new attractive transit passenger shelter to serve as the prototype for the ongoing replacement of shelters throughout the city; and, (b) the development, design and construction of special passenger shelter facilities at 7 major collection points having daily passenger boardings between 2,000 and 6,000. The preliminary cost estimates of these two components are $50,000 and $285,000 for a total transit system improvement expenditure of $335,000[39] exclusive of new operating and maintenance costs.

In order to determine the effect of this improvement on the modal split let us assume that the average operating fleet of Category II cities (of which Winnipeg is one) consists of 400 vehicles. In a per vehicle sense, this expenditure would amount to $838. In terms of the individual's modal choice decision-making model, comfort-convenience quality would increase from 333 units to 361 units and transportationness from 1 unit to 1.08. For the purpose of determining the change in modal split, this strategy must be related to its cost-reduction counterpart. That is, by increasing expenditures

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[39]City of Winnipeg, Innovative Transit Projects, Streets and Transportation Division of the Works and Operations Department, June 1974, pp. 1-2. Undoubtedly, certain new maintenance costs will be associated with such new facilities. Unfortunately the author has not been able to determine the nature and extent of these costs for either a transit shelter program or the improved transit vehicle program.

on shelters, 361 units of comfort-convenience quality can be obtained, and alternatively if the urban transit trip cost had been reduced to 72 cents the amounts of comfort-convenience quality and transportationness which could have been attained are 361 units and 1.08 units respectively. The "Pseudo Effective Cost Difference" for the transit shelter improvement strategy is then 33.2 cents in "Excess Transit Cost". The new modal split would therefore be 31.1 per cent--an improvement over the initial modal split of 11.6 per cent. It should be noted however that expenditures incurred for the replacement or improvement of successive transit shelters will, in the context of the characteristics model of modal choice, result in successive incremental changes in the modal split for car-owning CBD workers.

Summary of Results and Implications of Modelling Problems

The effectiveness of the six public policy interventions discussed above in reversing the private automobile trend are summarized below in Table 4.2.

Of the auto-trend-reversing public policy interventions tested, clearly the best results are

Table 4.2: Effectiveness of the Public Policy Interventions

	Description	Car Cost	Transit Cost	Cost Difference (Bus-Car)	Modal Split
1)	Initial Situation	38.8	78.6	39.8	27.9
2)	Road Pricing (charge drivers 18.7 cents per mile)	57.5	78.6	21.1	37.7
3)	Free Transit (25 cent fare eliminated)	38.8	53.6	14.8	41.2
4)	Express Transit and Reserved Bus Lanes (transit travel time reduced by 3.2 minutes: saving of 21.4 cents)	38.8	57.2	18.4	39.2
5)	Signal Preemption for Transit (transit travel time reduced by 1.2 minutes: saving of 8 cents)	38.8	70.6	31.8	31.9
6)	Improved Transit Bus (improvements per bus of $13,500)	38.8	33.5	-5.3	53.2
7)	Transit Shelter Program ($335,000 in improving shelters)	38.8	72.0	33.2	31.1

to be obtained from a comprehensive program of improvements to transit vehicles. There is reason to believe that other public policy interventions which are oriented toward improving the public transit mode as discussed in Chapter II, would also yield favorable improvements in the modal split. Unfortunately, there has been very little experimentation in this area and data has not been readily available for analysis in the characteristics modal choice and modal split models presented in this thesis. Other strategies which could usefully affect the modal split include: (1) the devotion of increased dollars to transit marketing and improving transit's public image; (2) the construction of large parking lots on the CBD periphery complemented by shuttle buses commuting between the parking lots and CBD destination (i.e., park-and-ride schemes); (3) inducement of employers to introduce staggered hours working schemes to spread out the peak hour and to reduce overcrowding of buses; and, (4) other positive solutions which offer physical and visible improvements to the public transit mode.

It has been shown that there exists a number of public policy interventions which can make a considerable contribution toward reversing the private automobile trend. However, before dealing with some of the practical or public policy problems involved with the implementation of such solutions an examination of the implications which the theoretical constructs and assumptions of the modal choice and modal split models hold for the results, is required.

The results of all of the solutions discussed here depend on the assumptions embodied in the characteristics model of modal choice and the shortcut modal split model. The first basic assumption made in relation to the choice of mode is that "it is the characteristics of the goods, or in this case the modes of travel which give rise to utility and hence the preference of one mode over another." While a number of approaches to modal choice analysis, including the income-leisure approach, are quite useful in terms of their predictive abilities, such approaches are limited by their inability to analyze the impact of qualitative changes in urban travel modes on the modal split. To overcome this shortcoming, the characteristics theory of demand has been used here because it is capable of analyzing a wider realm of public policy interventions.

Perhaps the single most important problem with the characteristics model is the selection and definition of the characteristics themselves. It is by no means claimed that the two characteristics used in this analysis are the only appropriate ones. Certainly, detailed empirical studies of individual and community preferences in urban travel are required in order to arrive at the most suitable set of relevant characteristics. That is, since it is possible to do so, it is important to determine those factors which cause individuals to select a mode of travel. Fortunately, the characteristics used in this analysis were suitable enough to at least demonstrate that the reversal of the private automobile trend is possible.

A more comprehensive approach would involve detailed statistical studies of a number of variables (or characteristics) which might "explain" modal choice. There is an abundance of statistical techniques and methodology available for such analysis. However, while this exercise would likely shed some additional light on whether or not the private automobile trend is reversible, such work would be best undertaken for city-specific applications rather than the more general approach which has been taken here. All that has been attempted in this thesis is to achieve a better explanation of those factors which cause individuals to prefer certain modes of travel and to find ways to modify decision-making criteria so as to alter the final outcome of such preferences and choices.

In order to make predictions about the effect of public policy interventions on the choice of mode, a modal split model has been used. There remains the question however of which modal split model is most appropriate. As discussed in Chapter III modal split models are usually highly complicated and pertain only to those specific cities for which they were developed. In trying to find an appropriate and general modal split model, discussions with urban transport planners in a number of cities have revealed that the general concensus regarding modal split models is that in recent years few of these models have proven to be very accurate. The principal reason for the use of the shortcut model in this thesis therefore is that while it may embody the shortcomings associated with generality, it is not biased by factors which are pertinent to specific urban areas only.

Quite apart from the conceptual issues surrounding the use of the models used herein is the question of the models' mechanical workings. It could be argued that the models' strength which allows for numerical predictions is also their weakness because if the assumed values of, say, travel time, operating or travel costs, or the constant used in the modal split model have been incorrectly estimated, then estimates of the results of the various public policy interventions will be seriously affected. The fact that such estimates would be affected is not denied, but such inaccuracies should not interfere with the determination of whether or not the private automobile trend is reversible to any serious extent unless of course one individual character was grossly misestimated. It is submitted however that the numbers used in this thesis, while not pertinent to any specific urban centre, should be reasonably reflective of urban transportation situations in general.

Also in the area of assumptions regarding data are the more specific issues surrounding the use of certain controversial characters. One such character is the value of travel time. As has been stated earlier, considerable debate surrounds the assumption of an appropriate value of time because of different assumptions relating to the nature and purpose of urban travel. The reason then that 6.7 cents per minute was assumed here is that since this thesis essentially focuses on the journey-to-work type of travel, then perhaps the most relevant assumed value of time for this type of travel is one which reflects the average hourly wage rate of the urban travellers involved rather than some average value which takes into account all travellers and all travel purposes. This latter alternative would result in a considerably lower estimate of urban travel costs on both modes.

A similar problem arises from the fact that the values of the selected characteristics (and changes therein) depend on the purchase price of vehicles. The problem emerges in trying to determine what the relevant prices were for an exact point in time and how modifications to vehicles made in other points in time might be related to the base year. A serious attempt has been made to obtain data which pertain to a common time neighborhood (circa 1973) for all variables and parameters in order to avoid discounting or revaluation problems. However where necessary revisions were required, appropriate changes were made. A problem might arise with the continuation of rising prices in times of inflation but this can be handled rather easily. If it were determined that the models, assumptions and values used here are substantially accurate in an urban transportation planning sense then the entire analytical framework could be computerized with regular revisions made to account for changes in prices, costs and other values.

In spite of the conclusion that the theoretical problems discussed above should have a limited effect on the results of solutions which were tested which can be, in any event, corrected, other totally unrelated problems will be less simple to rectify; such problems are those related to the implementation of solutions or public policy interventions.

Despite the reasonably large array of alternatives which exist for improving transit and thereby reversing the private automobile trend, it would be rather naive to think that such strategies are easily implemented. If there existed no problems of implementation most of the solutions (or variants) would be in effect in cities all over the world. The fact that they are not necessarily implies that solutions can only be successfully implemented under a set of certain institutional conditions and that there exist some serious impediments to the implementation of transit improvement strategies. The next chapter explores some of the implementational problems as well as the conditions under which public policy strategies can be applied in order to reverse the private automobile trend.

CHAPTER V

NECESSARY CONDITIONS FOR THE IMPLEMENTATION OF URBAN TRANSPORT SOLUTIONS

The public policy interventions or solutions to the urban transportation problem which were discussed and analyzed in the previous chapter test the hypothesis that "the observed tendency of the relative use of private automobiles, compared to urban public transit, to increase in a developing urban environment is a reversible phenomenon." Each of the solutions tested in the context of the characteristics model of modal choice and the short-cut modal split formula showed that public transit patronage could be increased at the expense of private automobile ridership (certain solutions being more effective, of course, than others). Unfortunately, however, while excellent results can be obtained in theory, there exist some institutional and public policy problems which are impediments to the implementation of solutions to the urban transportation problem and the reversal of the private automobile trend. Furthermore, regardless of limitations in the theoretical constructs of the models, such institutional problems will still remain and must be solved.

Road Pricing in Practice

Consider the imposition of road user charges. If the principles of road pricing as discussed in Chapter IV were to be implemented, perhaps the greatest difficulties and objections would be encountered in devising practical systems to express the necessary road pricing charge. "If the comparatively simple (but crude) gas tax is to be used, a typical urban congestion charge of 5¢ per vehicle mile implies a total gas tax of 70¢ a gallon, more than 4 times its present average level."[1] This, however, is too high a price to charge rural and suburban road users. Even if a differential urban gas tax were imposed, if it were large enough it would be worthwhile for motorists to evade this tax by travelling to nearby rural filling stations for, in a typical urban area, half the cars are based at less than 1/3 radius from the city's perimeter.[2]

British Road Research Laboratory experts

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[1] D. J. Reynolds, The Urban Transport Problem, p. 74.

[2] Ibid.

recommend the following practices for the application of road pricing:

(1) a fixed charge or license (daily, weekly, monthly, or annually) for entry into a congested area;

(2) a parking surcharge over and above those rates already being paid;

(3) systems for metering and charging more precisely for road use in congested areas.[3]

While it could be fairly simply imposed and administered, a fixed charge to enter a congested area in the form of an additional license would be rather crude in its incidence because it would not vary with vehicle mileage or traffic density. The greatest problems, however, would be the definition of boundary, the inequities of the definition, the heavy parking and congestion that would occur at the boundary and the paradox of less congested streets within the area.

A fixed parking surcharge over and above existing rates is commendable for it does not require the definition of boundary and can be varied according to the location and the estimated degree of congestion

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[3]Panel on Road Pricing, Road Pricing: The Economic and Technical Possibilities, (London England: Her Majesty's Stationery Office, 1964).

caused in reaching it. Of course parking charges can have a considerable impact on per vehicle mile operating costs that are known and borne directly by the motorist. The parking surcharge however, fails to tax non-parking through traffic which indeed causes a great portion of the congestion burden in areas which have nothing to do with the origin or destination of the journey-to-work. Moreover, since many employers, especially those in suburban locations, find it worthwhile to give their employees and clients free parking at their own expense, the parking surcharge could either be widely evaded by the motorist or constitute a serious and difficult interference in customer and/or labour relations. Therefore, while in city centres there is clearly scope for action by increasing municipal parking charges up to and above commercial rates, such action would have no deterring effect on motorists travelling from one surburban area to another via the CBD.

The last application of road pricing to be discussed here is vehicle metering systems in congested areas. Vehicle metering systems have the advantage of being able to at least roughly measure vehicle mileage and to weight journey speed or journey time by congestion thereby apparently offering a much greater degree of precision in urban road pricing. A number of metering systems are possible: on-vehicle, off-vehicle, distance-based, or time-based. The most favoured system at the British Road Research Laboratory[4] where practical research and development has been undertaken on urban road pricing systems, is a point pricing system whereby on-vehicle meters are activated by installations at a number of strategic points where relevant charges are built up. "The major weakness in these systems however is the recording, billing and subsequent collection of millions of charges (without the automatic sanctions available to utilities), but clearly it is necessary to await further development before finally evaluating them."[5]

In concluding the discussion on road pricing, whatever the controversy over the underlying principles are, the fact appears to be that the practical problems are so great that it would not be wise to rely on the development of actual functional systems, although there is certainly scope for the use of higher parking

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[4] Road Research Laboratory, op. cit.

[5] D. J. Reynolds, The Urban Transport Problem, p. 75.

charges. However, in giving an insight into the fundamental nature of the urban passenger transportation problem and the "private benefit/public nuisance" aspect of the automobile, the work on road pricing has been very valuable in an indirect way. For example, as was mentioned earlier, it has been shown that if the prices for the use of the roadway are less than optimal a road investment will tend to attract greater than optimal traffic volumes and achieve less than optimal benefits. This serves as a useful warning of the losses society endures because of the problems in achieving a simple yet precise method of pricing the use of roads.[6]

Implementation of Free Transit

On the other side of the road pricing argument is free transit. In trying to reverse the private automobile trend, much can be said (and the potential results of such a strategy have been shown) for the implementation of free transit. The initiation of free transit service however has much greater implications than the simple transferring of a small proportion of car users from private automobile to

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[6]J. C. Tanner, *op. cit.*

public transit--additional social benefits would result but very large subsidies would be required.

Again, using Ottawa as an example, a transfer of 20% of car users to public transit would in fact double transit passenger mileage and although currently low load factors (generally less than 50%) could accommodate part of this increase, it is expected that other transit patrons would increase their utilization and public pressure to extend routes and increase frequencies could involve a doubling of bus route mileage as well as transit operating costs.[7]

While the free transit argument is the extreme case of public transit subsidy the question of even the simple subsidization of annual transit deficits is perplexing. Kraft argues that subsidies may bring temporary relief to ailing transit systems but eventually the pain will become unbearable.[8] Since the demand for transportation is a derived demand, any subsidy to transport is ultimately and effectively

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[7]De Lieuw Cather and Company of Canada, op. cit.

[8]Gerald Kraft, "Economic Aspects of Urban Passenger Transportation", in Highway Research Record No. 285, Transportation Economics (Washington: Highway Research Board, 1969) p. 17.

a subsidy to other activities and the merit of using public funds to subsidize private activities must be questioned. That is not to say that subsidies are always inappropriate, but rather to suggest that thorough consideration must be given to the problem before resorting to this solution. Subsidies are often helpful in overcoming short run problems. "The subsidy may serve only to distort the natural incentives or to delay needed adjustments. Yet they may be useful supplements in the interim while the needed adjustments are taking place. Some insurance should be provided, however, that such adjustments will be made."[9] It is submitted then that the subsidy approach is inappropriate in attempting to bring about a better car/transit modal split. As has been argued earlier, in trying to approach a socially optimal car/transit balance better results can be obtained by improving and adjusting the quality of urban public transit systems. However, institutional difficulties exist with this approach as well.

Financing Urban Transport Improvements

It is well known that historically there has

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[9] Ibid.

been great pressure on municipal finances from the various sources competing for such funds. While urban transportation in general (including the construction and maintenance of right-of-way, traffic signals, grade level separations and crossings, etc....) no doubt commands a relatively large portion of any municipal budget, the question of providing new capital for transit improvements is a difficult one.

As was discussed earlier, those public policy interventions which seem most promising involve what could amount to rather large capital outlays. However, the fact that certain improvements might cause additional pressure on municipal finances does not mean that these should be necessarily dismissed. Rather the objective should be to use municipal monies wisely in order to derive greater social benefits. It is submitted that the efficient allocation of funds towards the reversal of the private automobile trend by federal, provincial, and municipal governments would be of benefit to society.

Moreover, if the funds required for the reversal of the private automobile trend are to be made available, it is of utmost importance that the role of urban public transit in meeting the demand for urban travel be evaluated seriously by governments and that new urban transportation planning priorities be developed and acted upon.

Planning for Improved Urban Transit

As was mentioned in the opening chapter of this thesis, the simple fact that the urban transportation problem has progressed to its present state implies that the "proper" planning of urban transport systems has not been taking place. It is therefore necessary to establish guidelines and goals by which approaches to urban transportation can be taken in the planning process. In relation to alleviating the urban transportation problem, George Smerk states that "the first most crucial and difficult step will be the establishment of workable objectives"[10] for urban transport.

In reference to the requirement for new approaches to urban transport planning, the Organization for Economic Cooperation and Development states: "A new approach...is emerging--one which gives increased emphasis to human values and to the social and

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[10]George M. Smerk, "The Urban Transportation Problem: A Policy Vacuum?" in Urban Transportation Policy: New Perspectives, ed. by D. R. Miller (Lexington, Massachussetts: D. C. Heath and Co., 1972), p. 5.

economic goals of urban development."[11] In terms of specific objectives for solving the urban transportation problem, the following have been cited as being important:[12] (a) the improvement of peak hour mobility, (b) reducing the requirements for additional freeways in existing urban development, (c) the contribution toward a viable solution to the long range transportation problem, (d) provision of expanded mobility for non-car users, (e) reducing environmental nuisances (air pollution, noise, and pedestrian conflicts), (f) the encouragement of desirable regional growth patterns, (g) allowing for more design flexibility for high-activity centres, and, (h) the reduction of transportation system costs.

Conclusion

In conslusion, aside from solvable implementation problems associated with the public policy interventions discussed in Chapter IV, advances toward solving the urban transport problem by means of reversing the

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[11] Organization for Economic Cooperation and Development, The Transportation Planning Process--In Search of Improved Strategy, Report of a Panel of Experts, December, 1969.

[12] T. B. Deen, *op. cit.*

private automobile trend can be made provided that: (1) goals for the systematic improvement of urban public transit are defined and acted upon; (2) commitments to new serious approaches to urban transportation research and planning be made in the hope of developing demand-responsive urban public transportation systems in support of both the social and individual urban well-being; and, (3) definite commitments on the part of governments (federal, provincial, and municipal) toward the realistic and responsible allocation of public funds for the improvement of urban transportation (and hence, the improvement of Canadian urban areas) be made so that much needed improvements can be implemented.

In brief, only if federal, provincial, and municipal governments reassess their approach to (or simply their perception of) the urban transportation problem and make realistic financial commitments toward its solution by reversing the private automobile trend, can "the war on urban immobility--and environmental decadence--" be won.[13]

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[13] George M. Smerk, op. cit., p. 18.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The central concern of this thesis in determining whether or not the private automobile trend is reversible has been the explanation of individual and social economic decision-making criteria in the selection of urban travel mode. Historically, individuals' perceptions of modal choice decision-making criteria have led to what might be considered an improper car/transit balance or mix of modes. It appears that as urban centres have developed, problems of urban mobility conflicting with the utilization of urban landspace have become increasingly acute. Furthermore, trends in major Canadian cities indicate that as urban centres continue to grow and develop, continued and increased emphasis will be placed on the use of the private automobile at the expense of urban public transit and to the general detriment of urban centres in an urban land use and development sense.

This thesis examines the hypothesis that the observed tendency of the relative use of private automobiles, compared to urban public transit to increase in a developing urban environment is a reversible phenomenon.

A number of factors which are characteristic of urban public transit have contributed to the continuing relative decline of urban transit ridership (although more recently such ridership decreases show some sign of bottoming out). Conversely, certain inherent characteristics of the private automobile mode have led to its increased utilization. The characteristics of the modes of travel have played at least as important a role in individuals' modal choices as have the cost criteria involved in the choice of mode.

The classical income-leisure approach to modal choice is therefore deficient inasmuch as it does not account for the particular characteristics of modes of travel. In order to account for the influence of non-price factors in the choice of mode, the Lancastrian characteristics theory of demand has been used to analyze individuals' perceptions of the nature of modes of travel. Furthermore a shortcut modal split model which is general enough so as not to be influenced by city-specific urban transportation problems has been employed to make numerical predictions as to the effect of certain public policy interventions on the number of car-owning Central Business District workers using public transit.

In the modal choice model, two characteristics--transportationness and comfort-convenience quality--were used in an attempt to explain modal choice. Other important decision-making factors were incorporated into the model as well. Those factors common to both social and individual choices include vehicle operation, maintenance and parking costs, bus fare, and value of time (assumed to be 6.7¢ per minute). However from a social point of view, the costs of urban travel also include depreciation of vehicles and right-of-way and the cost of maintaining the right-of-way and urban transportation system.

In terms of the modal split model used here which has as a primary determinant the effective cost difference between modes of travel, the above-noted differences between social and individual perceptions of urban travel have important implications. For example, according to socially perceived decision-making criteria, the appropriate modal split was determined to be 62.1 per cent of car-owning CBD workers using public transit. However, an examination of individually perceived decision-making criteria showed that the actual or observed modal split (that is, the modal split resulting from the sum of all choices of mode made by individuals) showed that only 27.9 per cent of car-owning CBD workers would use transit.

This substantial variance between society's predicted or desired choices and individuals' actual choices of mode is supportive of statements that the misconception of the true costs of urban travel to the community as a whole results in a modal split which is not socially optimal. Thus, in order to approach developmentally a socially optimal modal split, a number of public policy interventions were tested that affected individuals' decision-making criteria. The solutions tested were of three types: (a) those affecting the cost of urban travel (road pricing and free transit); (b) those affecting the speed of urban public transit and hence the value of the time spent in urban travel (express transit and reserved bus lanes and transit signal preemption); and, (c) solutions involving improvements in the characteristics of the public transit mode. The results of these public policy interventions are summarized in Table 4.2.

In the analysis of possible methods to reverse the private automobile trend it became apparent that none of the individual solutions is sufficient in isolation. Among the individual solutions, the most promising involve improvements to the characteristics of the public transit mode. Those solutions which affect the cost of urban travel show some promise but have serious limitations. For example, road pricing might be effective but tolls charged could only reach a moderate level before this solution became politically unacceptable. With free transit, the increased burden on taxpayers in the finance of public transit becomes acute. Finally, while solutions affecting the speed of public transit show some merit they are quite limited by the fact that while gains can be made, buses must stop to pick up passengers and the necessary amount of stopping and starting will limit the degree to which average operating speeds can be increased.

It appears that a program of constant properly planned and coordinated improvements to the public transit mode offer the best promise for reversing the private automobile trend. Such improvements include transit shelter and vehicle improvements but it is expected that others such as improved frequency, transit information systems, public transit image and marketing could play an important role.

Thus, while there is no one particular strategy which is the end-all solution to the urban transportation problem discussed, each of the public policy interventions discussed in this thesis, and various combinations of these solutions can be implemented in a developmental fashion gradually to bring about a reversal of the private automobile trend. With the implementation of such solutions urban centres might approach some socially optimal situation in which an appropriate combination of urban travel modes would exist.

However, quite apart from any technical difficulties with any of the solutions examined (or those associated with solutions not examined), there exist a number of institutional implementational factors which will independantly pose problems in the actual effectuation of solutions to the urban transportation problem. The implementation of solutions can be impeded not only by technological factors but also by financial, political, and even ideological factors. The initiation of public policy interventions in the public transit field will pose difficult problems, both in terms of financing and physical implementation, and will require more supportive urban planning and development methods generally.

In conclusion, after due consideration of the potential of the solutions examined here as well as their limitations in a technical, institutional and implementational sense, it is the conclusion of this thesis that the observed tendency of the relative use of private private automobiles, compared to urban public transit, to increase in a developing urban environment is a reversible phenomenon.

APPENDIX I

POPULATION,

TRANSIT RIDERSHIP,

AND PASSENGER VEHICLE

REGISTRATION TRENDS

IN THE 17 MAJOR

CANADIAN CITIES

1940 to 1975

Table A I. 1: Population (thousands) of 17 Major Canadian Cities By Category - 1940 to 1975 - And Indices (1960= 100)

CATEGORY I CITIES	1940	1945	1950	1955	1960	1965	1970	1975
Montreal	1,120.3 (54.5)	1,245.3 (60.6)	1,349.0 (65.6)	1,531.1 (74.5)	2,056.6 (100.0)	2,321.0 (112.9)	2,724.0 (132.5)	3,164.8 (153.9)
Toronto	899.2 (50.5)	992.9 (55.7)	1,069.4 (60.0)	1,263.9 (71.0)	1,781.0 (100.0)	2,066.0 (116.0)	2,401.4 (134.8)	2,791.2 (156.7)
Vancouver	377.0 (49.5)	461.3 (60.6)	539.6 (70.9)	645.1 (84.8)	760.9 (100.0)	850.0 (111.7)	1,059.0 (139.2)	1,289.7 (169.5)
Cat. Total	2,356.5	2,699.5	2,958.0	3,440.1	4,598.5	5,237.0	6,184.4	7,245.7
Cat. Avg.	785.5 (51.2)	899.3 (58.7)	986 (64.3)	1,146.7 (74.8)	1,532.8 (100.0)	1,745.7 (113.9)	2,061.5 (134.4)	2,415.2 (157.6)

Table A I. 1 (Continued)

CATEGORY II CITIES	1940	1945	1950	1955	1960	1965	1970	1975
Ottawa/ Hull	214.6 (53.3)	247.3 (61.5)	276.3 (68.7)	323.0 (80.3)	402.3 (100.0)	474.8 (118.0)	530.4 (131.8)	592.5 (147.3)
Winnipeg	299.8 (66.6)	314.8 (69.9)	347.0 (77.1)	398.1 (88.4)	450.2 (100.0)	494.7 (109.9)	522.0 (115.9)	583.7 (129.7)
Edmonton	90.3 (27.7)	128.1 (39.3)	166.0 (51.0)	242.3 (74.4)	325.7 (100.0)	385.0 (118.2)	484.0 (148.6)	536.4 (164.7)
Quebec	219.7 (62.6)	244.8 (69.8)	267.8 (76.4)	300.4 (85.7)	350.7 (100.0)	392.0 (111.8)	451.8 (128.8)	516.9 (147.4)
Calgary	88.3 (32.9)	104.9 (39.1)	128.7 (48.0)	240.7 (89.8)	268.1 (100.0)	323.0 (120.5)	391.0 (145.8)	472.6 (176.3)
Hamilton	149.1 (53.4)	178.3 (66.2)	204.6 (76.0)	246.3 (91.5)	269.2 (100.0)	295.9 (109.9)	322.7 (119.9)	369.9 (137.4)
Cat.Total	1,061.8	1,218.2	1,390.4	1,750.8	2,066.2	2,365.4	2,701.9	3,072.0
Cat.Avg.	177.0 (51.4)	203.0 (59.0)	231.7 (67.3)	291.8 (84.7)	344.4 (100.0)	394.2 (114.5)	450.3 (130.8)	512.0 (148.7)

Table A I. 1 (Continued)

CATEGORY III CITIES	1940	1945	1950	1955	1960	1965	1970	1975
London	87.2 (48.8)	106.2 (59.4)	123.9 (69.3)	149.1 (83.4)	178.7 (100.0)	188.7 (105.6)	215.4 (120.5)	247.3 (138.4)
Windsor	103.7 (62.2)	111.9 (67.1)	121.8 (73.0)	144.5 (86.6)	166.8 (100.0)	188.0 (112.7)	214.7 (127.2)	240.2 (144.0)
Halifax/ Dartmouth	95.1 (53.2)	112.6 (63.0)	127.9 (71.5)	160.3 (89.7)	178.8 (100.0)	207.1 (115.8)	221.0 (123.6)	235.6 (131.8)
Victoria	72.3 (48.2)	87.3 (58.2)	105.0 (70.0)	119.7 (79.9)	149.9 (100.0)	171.6 (114.5)	191.0 (127.4)	210.8 (140.6)
Kitchener/ Waterloo	43.5 (48.3)	49.6 (55.1)	52.6 (58.4)	74.4 (82.6)	90.1 (100.0)	119.4 (132.5)	137.2 (152.3)	164.8 (182.9)
Regina	56.9 (52.3)	63.5 (58.4)	67.4 (62.0)	85.3 (78.5)	108.7 (100.0)	126.0 (115.9)	139.0 (127.9)	153.9 (141.6)
Saskatoon	42.0 (45.2)	47.1 150.7	52.2 (56.2)	68.3 (73.5)	92.9 (100.0)	106.0 (1114.1)	125.0 (134.6)	141.4 (152.2)
Thunder Bay	70.3 (74.9)	74.8 (79.7)	79.2 (84.4)	82.3 (87.7)	93.8 (100.0)	107.3 (114.4)	118.7 (126.5)	122.8 (130.9)
Cat. Total Cat. Avg.	571.0 71.4 (53.9)	653.0 81.6 (61.6)	730.0 91.3 (68.9)	883.9 110.5 (83.4)	1,059.7 132.5 (100.0)	1,214.1 151.8 (114.5)	1,362.0 170.3 (128.5)	1,516.8 189.6 (143.1)

Table A I.2: Urban Transit Ridership (millions) In 17 Major Canadian Cities - 1940 To 1975 - And Indices (1960= 100)

CATEGORY I CITIES	1940	1945	1950	1955	1960	1965	1970	1975
Montreal	225.8	385.6	370.1	316.4	284.5	258.7	261.2	264.3
	(79.4)	(135.5)	(130.1)	(111.2)	(100.0)	(90.9)	(91.8)	(92.7)
Toronto	168.1	321.4	310.4	314.6	285.6	291.0	323.6	357.6
	(58.9)	(112.5)	(108.7)	(110.2)	(100.0)	(101.9)	(113.3)	(125.2)
Vancouver	76.4	133.0	113.6	100.0	73.4	60.8	67.1	89.3
	(104.1)	(181.2)	(154.8)	(136.2)	(100.0)	(82.8)	(91.4)	(121.7)
Cat. Total	470.3	840.0	794.1	731.0	643.5	610.5	651.9	711.2
Cat. Avg.	156.8	280.0	264.7	243.7	214.5	203.5	217.3	237.1
	(73.1)	(130.5)	(123.4)	(113.6)	(100.0)	(94.9)	(101.3)	(110.5)

Table A I.2 (Continued)

CATEGORY II CITIES	1940	1945	1950	1955	1960	1965	1970	1975
Ottawa/ Hull	25.8 (70.1)	60.4 (164.1)	54.1 (147.0)	42.8 (116.3)	36.8 (100.0)	32.9 (89.4)	34.1 (92.7)	54.3 (147.6)
Winnipeg	44.6 (74.8)	91.2 (153.0)	91.6 (153.7)	71.0 (119.1)	59.6 (100.0)	58.4 (97.9)	58.7 (98.5)	66.7 (111.9)
Edmonton	16.0 (56.7)	34.0 (120.6)	37.0 (131.2)	34.7 (123.1)	28.2 (100.0)	31.6 (112.1)	38.5 (136.5)	51.2 (181.6)
Quebec	18.7 (63.0)	43.3 (145.8)	46.3 (155.9)	38.2 (128.6)	29.7 (100.0)	25.5 (85.9)	18.9 (63.6)	25.9 (87.2)
Calgary	11.5 (49.6)	27.0 (116.4)	30.8 (132.8)	27.1 (116.8)	23.2 (100.0)	21.6 (93.1)	23.4 (100.9)	38.2 (164.7)
Hamilton	18.3 (65.8)	38.7 (139.2)	39.5 (142.1)	32.9 (118.3)	27.8 (100.0)	26.0 (93.5)	25.0 (89.9)	29.3 (105.4)
Cat.Total	134.9	294.6	299.3	246.7	205.3	196.0	198.6	265.6
Cat. Avg.	22.5 (65.7)	49.1 (143.6)	49.9 (145.9)	41.1 (120.2)	34.2 (100.0)	32.7 (95.5)	33.1 (96.8)	44.3 (129.4)

Table A I .2 (Continued)

CATEGORY III CITIES	1940	1945	1950	1955	1960	1965	1970	1975
London	10.1 (67.3)	21.6 (144.0)	20.3 (135.3)	15.9 (106.0)	15.0 (100.0)	15.1 (100.7)	16.1 (107.3)	13.8 (92.0)
Windsor	9.9 (96.1)	37.2 (361.2)	30.7 (298.1)	17.4 (169.9)	10.3 (100.0)	9.7 (94.2)	9.3 (90.3)	8.2 (79.6)
Halifax/ Dartmouth	13.8 (81.2)	32.6 (191.8)	26.0 (152.9)	24.9 (146.5)	17.0 (100.0)	12.5 (73.5)	9.7 (57.1)	11.5 (67.6)
Victoria	7.4 (69.8)	5.3 (50.0)	17.5 (165.1)	13.8 (130.2)	10.6 (100.0)	8.6 (81.1)	8.0 (75.5)	11.7 (110.4)
Kitchener/ Waterloo	4.0 (54.1)	13.0 (175.7)	13.1 (177.0)	8.6 (116.2)	7.4 (100.0)	6.9 (93.2)	7.2 (97.3)	6.6 (89.2)
Regina	6.6 (66.7)	13.9 (140.4)	13.9 (140.4)	11.5 (116.2)	9.9 (100.0)	7.4 (74.7)	7.8 (78.8)	8.1 (81.8)
Saskatoon	4.4 (53.7)	10.7 (130.5)	11.8 (143.9)	10.2 (124.4)	8.2 (100.0)	7.9 (96.3)	7.8 (95.1)	9.9 (120.7)
Thunder Bay	5.1 (85.0)	13.2 (220.0)	12.0 (200.0)	8.5 (141.7)	6.0 (100.0)	6.0 (100.0)	5.0 (83.3)	5.2 (86.7)
Cat. Total	61.3	147.5	145.3	110.8	84.4	74.1	70.9	75.0
Cat. Avg.	7.7 (72.6)	18.4 (173.6)	18.2 (176.3)	13.9 (130.7)	10.6 (100.0)	9.3 (87.4)	8.9 (83.6)	9.4 (88.4)

Table A 1.3: Passenger Automobile Registrations (thousands) In 17 Major Canadian Cities - 1940 To 1975 - and Indices (1960 = 100)

CATEGORY I CITIES	1940	1945	1950	1955	1960	1965	1970	1975
Montreal	86.1 (227.8)	81.7 (21.6)	144.4 (38.2)	261.9 (69.3)	377.9 (100.0)	547.1 (144.8)	625.8 (165.6)	741.5 (196.2)
Toronto	165.4 (35.3)	150.3 (32.1)	239.6 (51.1)	355.7 (75.9)	468.9 (100.0)	562.1 (119.9)	710.6 (151.5)	928.0 (197.9)
Vancouver	47.7 (22.8)	46.7 (22.3)	93.2 (44.5)	142.6 (68.0)	209.6 (100.0)	297.7 (142.0)	391.2 (186.6)	486.2 (232.0)
Cat.Total	299.2	278.7	477.2	760.2	1,056.4	1,406.9	1,727.6	2,155.7
Cat. Avg.	99.7 (28.3)	92.9 (26.4)	159.1 (45.2)	253.4 (72.0)	352.1 (100.0)	469.0 (133.2)	575.9 (163.6)	718.6 (204.1)

Table A I. 3 (Continued)

CATEGORY II CITIES	1940	1945	1950	1955	1960	1965	1970	1975
Ottawa/ Hull	37.3	34.1	55.0	84.5	115.0	140.3	177.7	347.7
	(32.4)	(29.7)	(47.8)	(73.5)	(100.0)	(122.0)	(154.5)	(206.7)
Winnipeg	38.9	36.7	58.8	86.1	112.6	146.4	171.6	188.4
	(34.5)	(32.6)	(52.2)	(76.5)	(100.0)	(130.0)	(152.4)	(167.3)
Edmonton	21.3	21.3	34.6	54.3	79.6	108.8	158.1	207.9
	(26.8)	(26.6)	(43.5)	(68.2)	(100.0)	(136.7)	(198.6)	(261.2)
Quebec	18.5	17.6	31.0	56.3	86.6	117.4	176.3	185.4
	(21.4)	(20.3)	(35.8)	(65.0)	(100.0)	(135.6)	(203.6)	(214.1)
Calgary	19.5	19.4	31.6	49.6	71.5	99.7	155.0	230.0
	(27.3)	(27.1)	(44.2)	(69.4)	(100.0)	(139.4)	(216.8)	(321.7)
Hamilton	25.7	23.4	37.3	55.4	73.1	91.7	102.4	145.2
	(35.2)	(32.0)	(51.0)	(75.8)	(100.0)	(125.4)	(140.1)	(198.6)
Cat. Total	161.2	152.4	248.3	386.2	538.4	704.3	941.1	1,194.6
Cat. Avg.	26.9	25.4	41.4	64.4	89.7	117.4	156.9	199.1
	(30.0)	(28.3)	(46.1)	(71.8)	(100.0)	(130.9)	(174.9)	(222.0)

Table A I .3 (Continued)

CATEGORY III CITIES	1940	1945	1950	1955	1960	1965	1970	1975
London	14.7	13.4	21.3	31.6	42.5	65.3	83.7	121.6
	(34.6)	(31.5)	(50.1)	(37.4)	(100.0)	(153.6)	(196.9)	(286.1)
Windsor	15.3	13.9	22.2	32.9	43.2	59.5	73.1	94.3
	(35.4)	(32.2)	(51.4)	(76.2)	(100.0)	(138.7)	(169.2)	(218.3)
Halifax/ Dartmouth	1.6	1.8	13.7	21.4	29.1	39.8	51.6	60.1
	(5.5)	(6.2)	(47.1)	(73.5)	(100.0)	(136.8)	(177.3)	(206.5)
Victoria	14.2	13.9	27.8	42.5	62.5	91.4	98.9	119.9
	(22.7)	(22.2)	(44.5)	(68.0)	(100.0)	(146.2)	(158.2)	(191.8)
Kitchener/ Waterloo	11.0	10.2	16.0	23.7	27.5	41.0	56.2	71.7
	(40.0)	(37.1)	(58.2)	(86.2)	(100.0)	(149.1)	(204.4)	(260.7)
Regina	12.1	12.5	16.8	21.7	28.9	41.8	50.2	63.2
	(41.9)	(43.3)	(53.1)	(75.1)	(100.0)	(144.6)	(173.7)	(218.7)
Saskatoon	10.3	10.6	14.2	18.4	23.4	33.0	39.8	52.6
	(43.5)	(45.3)	(60.7)	(78.6)	(100.0)	(141.0)	(170.1)	(224.8)
Thunder Bay	8.3	7.5	12.0	17.8	23.7	31.7	35.5	47.8
	(35.0)	(31.7)	(50.6)	(75.1)	(100.0)	(133.8)	(149.8)	(201.7)
Cat. Total	87.5	83.8	144.0	210.0	28.8	403.5	489.0	631.2
Cat. Avg.	10.9	10.5	18.0	26.3	35.1	50.4	61.1	78.9
	(31.2)	(29.8)	(51.3)	74.8	(100.0)	(143.7)	(174.1)	(224.8)

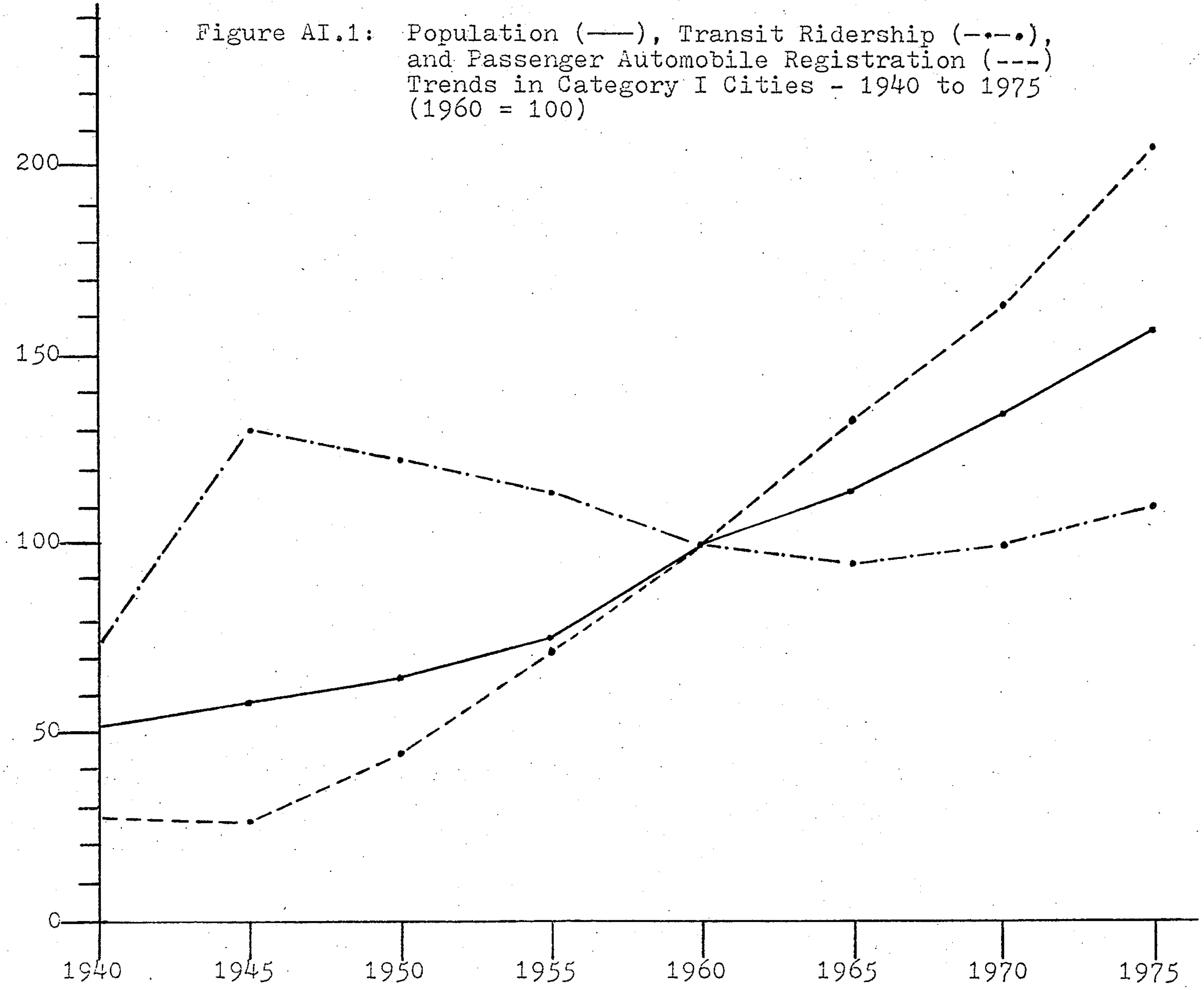


Figure AI.1: Population (——), Transit Ridership (-•-•), and Passenger Automobile Registration (---) Trends in Category I Cities - 1940 to 1975 (1960 = 100)

Figure AI.2: Population (——), Transit Ridership (-.-.-.), and Passenger Automobile Registration (---) Trends in Category II Cities - 1940 to 1975 (1960 = 100)

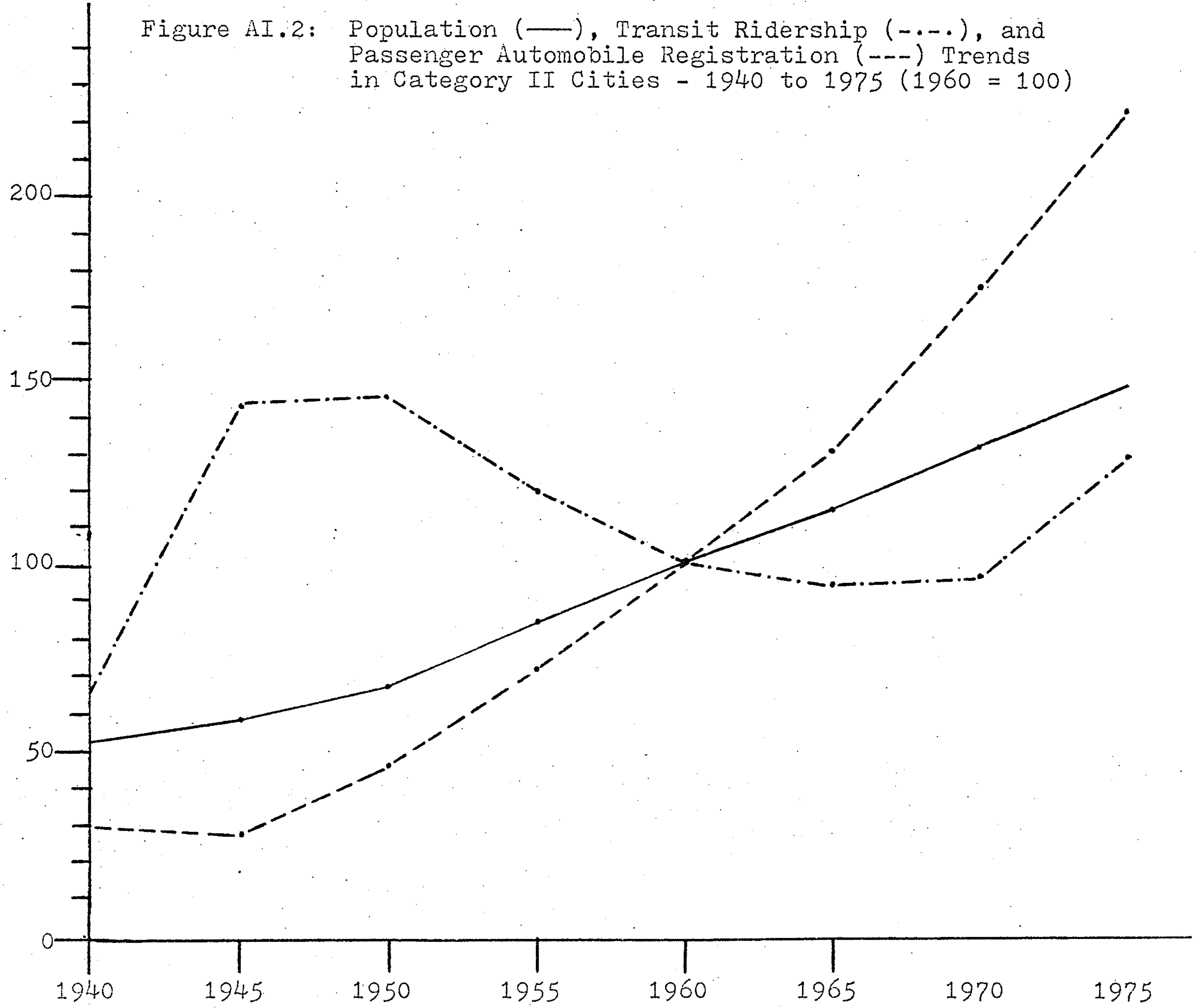
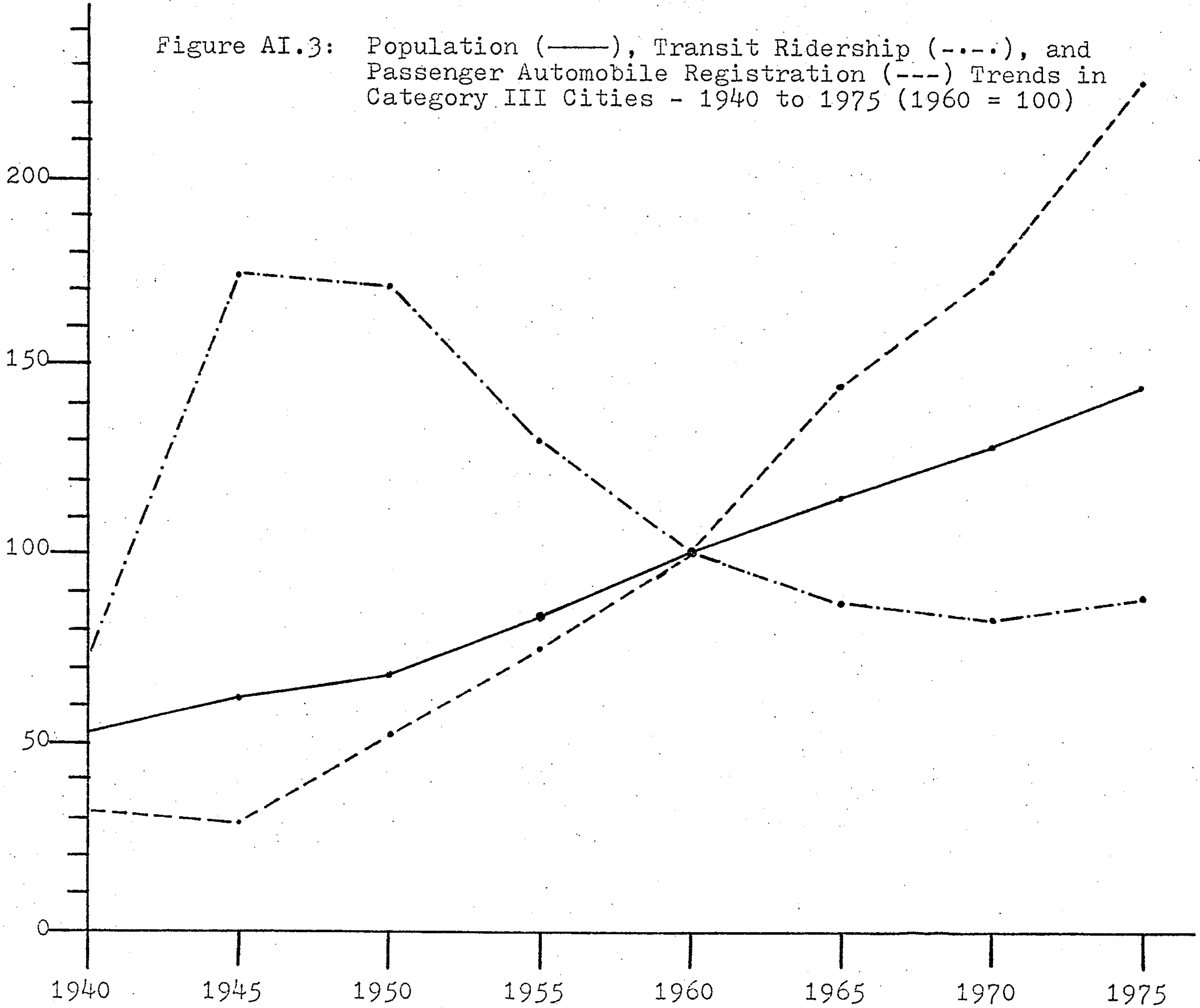


Figure AI.3: Population (——), Transit Ridership (-·-·), and Passenger Automobile Registration (---) Trends in Category III Cities - 1940 to 1975 (1960 = 100)



SOURCES

Table AI.1: (a) 1940 to 1960 - Census of Canada, 1961, Vol. 7, pt. 1., General Review - Population and Labour Force, Dominion Bureau of Statistics, Ottawa, Canada 1961.

(b) 1965 and 1970 - Census of Canada, 1971, Vol. 1, Sec. 7. 1-2, Population, Statistics Canada, Ottawa, Canada, 1971.

(c) 1975 - Unpublished Statistics Canada Estimate

Table AI.2: Unpublished urban transit ridership data for each individual city kindly provided by Mr. H. E. Brown - General Manager, Canadian Urban Transit Association.

Table AI.3: The Motor Vehicle - Part III, Registrations, 1950 to 1975 (1975 unpublished), Statistics Canada, Ottawa, Canada.

Figures AI.1,2,&3: Tables AI.1,2,&3.

APPENDIX II

THE COSTS OF URBAN TRAVEL

The costs derived below apply to the characteristics model of modal choice as developed in Chapter III. Here we shall deal with societal versus individual perceived costs and characteristics. All figures are in 1973 dollars.

First of all we assume that the value of time as perceived by individuals and society is common to both, equal to the average hourly wage rate and, based on the 1973 Canadian Industrial Composite average weekly earnings of $160.15[1] and a 40 hour work week, is equal to $4.00 per hour or 6.7 cents per minute.

Secondly, we require an assumption regarding the typical speed at which private automobiles and public transit buses travel. Reynolds claims that the usual automobile speed in heavy traffic would be in the neighbourhood of 15 miles per hour.[2] We are concerned with this "usual" speed and the traffic congestion associated with it for it typifies peak period conditions for which urban transport systems really must be planned. Furthermore the Ottawa-Hull

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[1]Statistics Canada, Employment, Earnings, and Hours, Cat. #72-002, Ottawa, 1974.

[2]D. J. Reynolds, The Urban Transport Problem, p. 73.

Area Transportation Study and others would suggest a car-transit speed ratio in the neighbourhood of 2:1 — that is, car travels twice as fast as bus.[3] This means that under conditions where cars are travelling at speeds of 15 miles per hour, buses are travelling at 7.5 miles per hour. These speeds would correspond to a four minute car trip and an eight minute bus trip (including waiting time) for journey lengths of one mile. Given these common elements to both decision-making groups, we now discuss the perception of costs and characteristics by the urban transportation planners (society).

Costs and Characteristics Viewed by Society

In planning urban transportation systems, society views two "types" of costs as being important in the decision-making process. These would include on the one hand costs of operation, maintenance and depreciation of the vehicles, transport system and right of way and , on the other hand the congestion costs imposed by each vehicle on all others.

The "average" costs of operation, maintenance

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[3]De Lieuw Cather and Co., op. cit.

and depreciation as viewed by the urban transport planners are taken from the T.D.N. "Transtats"[4] and consist of the following items:

	Cost Item	Private Automobile	Bus
1)	Vehicle operation, maintenance and parking	12.0	75.0
2)	Depreciation of vehicle and way	8.5	20.0
3)	Maintenance cost of way and system	0.5	20.0
4)	Total cost in cents per vehicle mile (1 + 2 + 3)	21.0	115.0

Now in order to determine the congestion costs imposed on other vehicles, we return to the road pricing concepts developed in Chapter IV of this thesis. This cost was determined to be the difference between marginal and average costs and was expressed as

$$c(a - s)/s^2 = \text{congestion costs in cents per vehicle mile}$$

where

c = value of time = $4.00 per hour

s = speed; car = 15 m.p.h. and bus = 7.5 m.p.h.

4Transport Development Agency, "Transtats", in Transport Development News (Montreal: Transport Development Agency), July, 1973.

and

a = speed at low traffic volumes

Reynolds states that the typical value of 'a' for automobiles is thirty miles per hour.[5] To determine this value for bus, we use the fact that car is twice as fast as bus, resulting in an 'a' value for bus of fifteen miles per hour. For private automobile the congestion cost per vehicle mile would be $400\ (30 - 15)/15^2 = 26.7$ cents. For bus however, we are informed that buses and trucks impose three times the congestion costs on other traffic as do cars.[6] These costs would therefore be expressed as $3\ c(a - s)/s^2$ or $(3)(400)(15 - 7.5)/(7.5)^2$ which equals 160 cents per vehicle mile.

The following table summarizes how the urban transportation planners view the relevant costs in the choice of mode:

Cost Components	Private Automobile	Bus
1) Total per vehicle mile cost of operation, maintenance, and depreciation of vehicles, system and right of way —	21.0	115.0
2) Congestion costs in cents per vehicle mile imposed on other vehicles—	26.7	160.0
3) Total costs per vehicle mile—	47.7	275.0

In addition to the above costs, we give numerical values to the characteristics, as defined in Chapter III, as they are viewed by the urban transport planners. Again, transportationness can be thought of as the ability to carry passengers. From a social point of view, this can be reflected in the average occupancy of bus and car. Therefore to the urban transport planners, car and bus have transportationness equal to 1.6 and 30 respectively. As concerns comfort-convenience quality (travelling conveniently in a pleasant or comfortable atmosphere), the difference between the price of the vehicle in use and that of the least expensive alternative capable of carrying the number of passengers usually carried on the vehicle in use, divided by average occupancy, gives the value of this characteristic. On the basis of data again taken from T.D.N. "Transtats" our characteristics can be given numerical values as follows:

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[5] D. J. Reynolds, The Urban Transport Problem, p. 73.

[6] Ibid.

[7] See note #4.

	Private Automobile	Bus
1) Cost of equipment in use ($)	5,000	45,000
2) Cost of least expensive alternative ($)	2,500	35,000
3) Gross comfort-convenience quality (1-2)	2,500	10,000
4) Average occupancy = Transportationness	1.6	30
5) Comfort-convenience quality (3 ÷ 4)	1,563	333

In summary then, for an expenditure of 275 cents, bus produces 30 units of transportationness and 333 units of comfort-convenience quality while private automobile produces 1.6 units of transportationness and 1,563 units of comfort-convenience quality for an expenditure of 47.7 cents.

Costs and Characteristics as Viewed by Individuals

A major problem besetting the car/transit balance problem is that individual decision-makers view the relevant costs involved in choosing a mode of urban travel quite differently than does society. For example, in making the choice between bus and car, individuals do not account for the operation, depreciation and maintenance of systems or the right of way; they do not even take into account the depreciation of their own vehicles. As regards congestion costs, it would appear foolish to think that an individual vehicle driver imposes delays and associated costs on other motorists. Rather the individual thinks in terms of the value of his own time corresponding to the journey length and the speed at which he can travel. The costs that enter into an individual's choice of mode are as follows:

	Private Automobile	Bus
1) Vehicle operation, maintenance and parking costs (cents per mile) —	12.0	0.0
2) Fare (flat rate in cents) —	0.0	25.0
3) Value of time in travel at 6.7 cents per minute with car trip = 4 minutes and bus trip = 8 minutes —	26.8	53.6
4) Total cost for a journey of one mile length as viewed by individuals —	38.8	78.6

In addition to viewing costs differently from the urban transport planners, individuals also view characteristics in a somewhat different way. Individuals view comfort-convenience quality in the same way as does society, realizing that the gross comfort-convenience quality of the vehicle in which he travels must be shared by the average occupancy of the vehicle. Therefore again, the value of this characteristic for car is 1,563 (i.e., (5,000 -2,500) - 1.6) and for bus is 333 (or, (45,000 - 35,000) - 30). The big difference is in the way the individual views transportationness. Rather than to view automobile and bus as producing 1.6 and 30 units of transportationness respectively as do the urban transport planners, individuals view either mode as producing only enough transportationness to carry the individuals themselves. Therefore each decision-making individual assigns a transportationness value of one to both private automobile and bus.

In summary then, from the individual's point of view, an expenditure of 78.6 cents on bus produces 333 units of comfort-convenience quality and 1 unit of transportationness while an expenditure of 38.8 cents on car produces again 1 unit of transportationness but 1,563 units of comfort-convenience quality.

APPENDIX III

CALCULATIONS

FOR THE

SHORTCUT MODAL SPLIT CURVE

Table A III. I: Calculations for Shortcut Modal Split Curves

Effective Cost (¢) Difference	$(P=1/1+e^{0.02\,x})$ (100) Time = 8.0¢/min.	$(P=1/1+e^{0.0239\,x})$ (100) Time = 6.7¢/min.	$(P=1/1+e^{0.0296\,x})$ (100) Time = 5.4¢/min.
180	2.66	1.33	0.48
160	3.92	2.14	0.87
140	5.73	3.40	1.56
120	8.32	5.38	2.79
100	11.92	8.39	4.93
80	16.80	12.88	8.56
60	23.15	19.25	14.48
40	31.00	27.77	23.43
20	40.13	38.27	35.62

Table A III, 1 (Continued)

0	50.00	50.00	50.00
-20	59.87	61.73	64.38
-40	69.00	72.23	76.57
-60	76.85	80.75	85.52
-80	83.20	87.12	91.44
-100	88.08	91.61	95.07
-120	91.68	94.62	97.21
-140	94.27	96.60	98.44
-160	96.01	97.86	99.13
-180	97.34	98.66	99.52

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