# A TRAFFIC DISTRIBUTION AND RELIEF MODEL BASED UPON STAGGERED WORKING HOURS

by

J. Stewart Taggart

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF ARTS

In the School of

COMMUNITY AND REGIONAL PLANNING

We accept this thesis as conforming to the required standard.

THE UNIVERSITY OF BRITISH COLUMBIA

April 1968.

In presenting this thesis in partial fulfilment of the requirements for an advanced degree at The University of British Columbia, I agree that the Library shall make it freely available for reference and study. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by the Head of my Department or by his representatives. It is understood that copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Department of Community & Regional Planning.
The University of British Columbia
Vancouver 8, Canada

Date May 2/68

ABSTRACT

North American cities are becoming increasingly difficult to live in and to work in largely because they are difficult to move around in. For many cities vehicle congestion has reached a saturation level for streets and highways thus creating the problem of traffic congestion. This problem is universally understood to be the urban transportation problem.

The transportation problem is largely a result of the growing concentration of population and economic activities within a small central area of land. Growth of population combined with rising incomes and increasing car ownership rates are continually increasing passenger and freight movement. With the increase of motor vehicles and vehicle usage the street system has proven inadequate to meet the increased demands for movement placed upon it.

This inadequacy is particularly evident in the central urban areas during two relatively short periods of the day. These periods of peak traffic demand are a function of the journey to work. They occur twice in the typical day, the first being in the morning, the second occurring in the late afternoon. At other times during the day and night the street system, under normal conditions, is capable of handling the traffic demand. Thus there appears a need to bridge the growing gap between the demand for and supply of street facilities at peak hours.

The basic approaches to the problem of bringing the demand for and supply of street facilities to a state of equilibrium are: to provide additional lanes of new or improved facilities to meet the traffic demands; to design developing areas on the basis of transportation demands and supply being in a state of equilibrium; or to re-assign traffic to existing street facilities in accordance with the capacity of these facilities.

The last method can be accomplished by staggering working hours.

The purpose of this thesis is to demonstrate the hypothesis: that by the staggering of working hours in the central business district, the peak congestion problem can be relieved. The study demonstrates the effect of staggering hours, in quantitative terms, on a particular transportation facility, the First Narrows Bridge, Vancouver, British Columbia.

The technique of staggering hours, in this study, is used to limit the volume of traffic by modifying the demand upon the system. This is accomplished by breaking the total demand into smaller demand segments, by giving each segment a different deadline. This method can in effect equate the demand with the supply over a given period of time. By this method the number of vehicles arriving at the entrance to an area of restricted capacity can be equated to the supply or capacity.

By applying this method to the case study it is possible to demonstrate the effects of staggering in eliminating peak period congestion delay time due to the limited capacity of a facility. Also determinable is the extent that traffic loads need be distributed over a period of time and how much time would be needed to effect economies in the level of service.

To minimize the disruption of the staggering of working hours, the C.B.D. was divided into four control areas or zones based on dominant function. The starting times of the functional zones or control areas are arranged in a work starting order so as to minimize functional disruption.

It is concluded from the illustration of the case study that some relief of congestion is possible through the staggering of working hours; and that this method is one contribution to improving the ability of the individual motorist to travel more economically and possibly at a more rapid rate.

TABLE OF CONTENTS

## LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENT

I should like to thank those persons who have given advice and assistance that has been helpful in the preparation of this thesis. Grateful appreciation is extended to Dr. H. Peter Oberlander for his constructive criticism and to my advisor, Dr. V. Setty Pendakur, for his guidance and encouragement and to my colleague, Mr. J. M. Lainsbury, for his assistance.

I am grateful as well to Central Mortgage and Housing Corporation for their financial assistance.

# CHAPTER I

## INTRODUCTION

One of the most severe problems associated with living and working in North American cities has been and may continue to be traffic congestion. Traffic congestion is unlike most other city problems primarily because it is usually not continuous. Normally traffic congestion occurs during two relatively short peak periods of the day, the first being in the morning and the second occurring in the late afternoon. These peaks, the result of the journey to work and return, are the greatest obstacle to acquiring a more smoothly functioning traffic network and are the principal cause of the urban transportation problem. The urban transportation problem is universally understood to be traffic congestion.

The magnitude of this problem is largely a result of the present city form which has produced excessive crowding of population and economic activity into a small central area of the city, the central business district. (C.B.D.) Also growth of population and the move to the suburbs, combined with increasing incomes and rising car ownership, are continually multiplying the volume of passenger and freight movement.

The effects of this problem are first suffered by the old central cities which lie at the heart of the metropolitan area. As crowded and expensive travel conditions add to the inconvenience of movement, people endeavor to escape the congestion problem by seeking pleasanter business and living conditions in outlying areas. The result is that property values in the central city fall, stores stand vacant and the high and medium-income groups become suburbanites in the communities that sprawl

on the periphery of every major city.[1]

Some of the main obstacles to acquiring a more efficiently functioning traffic network, besides the phenomenon of the peak or rush hour, are the obsolete structure of cities and the urban land scarcity.

Major North American cities with basically rectangular street systems, were not designed to accommodate the present day volume of vehicular traffic. Streets are often too narrow, especially when they serve the dual purpose of access and thoroughfare, not to mention the function of storage of vehicles.

An attempt to re-adjust the urban structure for achieving greater traffic mobility is a formidable task. Not only is it technically complex, but financially almost impossible. In the first place land is scarce, and what there is is extremely expensive. Secondly, added to the land cost is the expense of relocating families, stores and utilities.[2] Furthermore, whenever urban land is converted from private to public use a reduction in collectable property taxes results. Few cities are amenable to a loss of income.

Good transportation characterized by an efficient functioning traffic network is one of the most difficult things to achieve; but it is a basic necessity. The object of cities is multiplicity of choice. It is impossible to take advantage of multiplicity of choice without being able to get around easily. But multiplicity of choice and intensive city functions depend on immense concentrations of people, and an intricate

---

[1]Smerk G. M. Urban Transportation: The Federal Role Indiana University Press, Bloomington 1965 p. 3.

[2]Stonier C. E. "Metropolitan Traffic Crises," Traffic Quarterly Vol. II, January 1957 pp. 214-231.

mingling of uses and complex interweaving of paths. The question is how to accommodate city transportation without destroying the related intricate and concentrated land use.

> While traffic is not an end in itself, cheap transportation is a contributing factor to the economic division of labor. Ready accessibility of centrally located markets is of particular importance, because it determines the size of markets and the extent to which economies of large-scale production and distribution can be reaped. Congestion, by setting a limit and a premium upon the movement of persons and commodities, restricts the effectiveness with which the functions of centrally located markets can be performed. 3

The interaction among urban activities depends in large part on the transportation network for integrating the urban structure. Changes in the transportation operation will be reflected in the organization of economic activity throughout the urban space. These changes make themselves felt as changes in the cost conditions of production and distribution. Where the system is poor, this interaction takes place only under conditions of high and increasing costs. Ideally the solution is to develop planned urban communities in which satisfactory transportation is possible.

The transport system is a powerful variable in the comprehensive plan which, if manipulated in various ways, should yield a particular land development pattern. Land development can not be accomplished without adequate transport access and, on the other hand, it is the land activities that develop the very demand for transportation. Proper balance is necessary to healthy land development and to a smoothly functioning transportation system. The goals of transportation planning are intimately geared to the general economy of the community and to the general welfare

---

[3]Beckmann, Martin. McGuire and Winston, Studies in the Economics of Transportation Yale University Press, New Haven 1956 p. 95.

of its residents. It follows that transportation planning must be co-ordinated within a framework of comprehensive planning for the community.

Transportation should be thought of as a means to designing a more satisfactory environment. In the process, urban mobility would be well served. Urban transportation has many functions. Properly planned, it can make the urban environment more attractive, assist in guiding and stabilizing land use patterns, widen the range of employment opportunities for urban residents, improve regional accessibility for the movement of people and goods in both off-peak and peak travel hours and finally, strengthen the downtown center.

Transportation planning is one component of comprehensive city planning, but the steps and procedures of both are interdependent. Transportation planning steps cannot be isolated from over-all comprehensive city or regional planning. The role of comprehensive planning and the continuous planning process is to co-ordinate the many elements and goals of a community into a plan in order to permit a forward-moving community.

One of the implicit goals of planning for good or bad seems to be the preservation of the central city. The decision to save downtown is shown by the large amounts of money spent in construction in that area both private and public, in new office building and in urban renewal.[4] Some downtown interests are taking bold steps to modernize these central areas. There are often excellent opportunities of relating highway design to plans for re-design of the central area. Ideally, highway facilities and the central business district improvements should be

---

[4]"Transportation and the City" Architectural Forum Vol. 119 No. 4 Time Inc. Chicago October 1963 p. 63.

planned together to achieve co-ordination so as to alleviate excess traffic movement and congestion.

With the great increases that have occurred in recent years in the cost of everything to which planning relates, it is not always possible to work in this ideal framework of transportation planning and comprehensive planning. Often because of the high cost of improvements and the limited budget of most communities other solutions to transportation problems of movement and congestion are necessary. The author suggests that a system of regulation can be devised so that a better utilization of existing capacity is possible. This system of regulation would out of necessity be far short of restricting the private automobile in the C.B.D.

A regulatory system would 1) be within the financial means of the city, 2) would allow a better utilization of existing capacity, and 3) would allow a relatively concentrated central business district which one planning philosophy supports as desirable.

Regulatory devices may be divided into four categories: 1) controls of traffic movement and street use; 2) controls on access; 3) control of vehicle use; and 4) staggering of work hours.[5]

The motorist is already familiar with a broad range of rules and regulations concerning speed, direction of travel, parking and traffic signals and signs. Additional improvements in traffic flow are possible by means that go beyond the ordinary.

The designation of particular routes or lanes for various modes is a partial solution. Because the traffic flow nature of various modes of

---

[5]Smerk G. M. Urban Transportation: The Federal Role pp. 193-201.

transport are quite different, the joint use of streets by all modes denies the highest level of efficiency for each. For example, transit vehicles pause frequently to permit passengers to board and alight, hindering the through movement of the automobiles. Setting aside certain traffic lanes exclusively for specific types of vehicles might prove very useful. Exclusive bus lanes have been highly successful in many cities.[6] In addition, special lanes might be designated as one-way streets for transit vehicles to allow them to run against the tide of traffic.

Traffic flows along major arteries might be significantly augmented by closing off side streets with barricades during rush hours, creating rush hour expressways. Hazards from traffic entering from side streets would be greatly reduced and a substantial number of accidents might be averted.

One way streets are used widely to speed up traffic, reduce accidents, and increase street capacity. In general, the one-way device provides a relatively inexpensive means of traffic improvement. It appears feasible that much of the city street system could be redesigned to conform to a one-way pattern. A variation of the one-way street is the reversible lane. This system makes certain streets inbound-only in the morning and outbound-only in the evening. With this procedure, used in conjunction with the rush-hour expressway idea, substantial capacity increases are possible from present streets.

By controlling the amount and time of curb parking some increases in capacity can be accomplished. Curb side parking reduces the space available for vehicle movement. By eliminating parking at the peak hours

---

[6]Metropolitan Transportation "Separate Lane Speeds Buses Across Bay Bridge," Vol. 58, No. 3, March 1962, pp. 24-26.

an extra lane is made available in the direction of travel.

In addition to controls dealing with the flow of traffic in urban areas, the control of access and modal use are important factors in easing the problems of urban transport.

In recent years with the construction of freeways and expressways, limited access to highways has become generally accepted. This separates the access to land and through movement generation bidding direct access from major buildings to arterial streets, thereby preventing them from distributing traffic directly onto the busy thoroughfares. Limited access is a feasible way to help reduce the dangerous friction of side traffic entering major streets from a large number of accesses and impeding the speed and flow of traffic on arterial streets.

The control of modal use, accomplished by some form of rationing such as a toll, could be used as a devise to reduce the volume of traffic. Assuming that it is necessary to limit the private automobile, steep fees could be levied through gasoline or licence tax imposed on urban motorists, while at the same time public transport fares might be lowered or eliminated to make such modes more attractive. The high cost could force the occupancy rate up. This doubling up on car usage could reduce the cost to the user and also reduce the number of vehicles on the road.

Another method of control or regulation without additional capital expenditures is to stagger working hours. Much of the cause of congestion stems from the uniformity of working hours and the resultant peak traffic periods. The purpose or goal of staggered working hours is to distribute the period of peak travel over a greater time period and thereby reduce the magnitude of the peak.

This last method, the staggering of working hours is the topic of this thesis. It is this method the author would like to investigate as a method to bridge the growing gap between the demand for and supply of highway facilities.

The hypothesis to be tested in this thesis is: that by the staggering of working hours in the central business district the peak congestion problem can be relieved.

The objective of this thesis is to discover the effect of staggered hours on a street highway system in quantitative terms and to determine if it would have practical use for reducing congestion. This thesis will investigate a method of traffic assignment for effecting a staggered hours program in an urban area, by considering the capacity of the existing street system and the demands that are being made on it.

The basic approaches to the problem of bringing the demand for and supply of highway facilities to a state of equilibrium are:

1) to provide additional lanes of new or improved highways to meet the traffic demand;

2) to reassign or reallocate traffic to existing street facilities in accordance with the capacity of these facilities, or to bring demand to the level of supply;

3) to design newly developed areas on the basis of transportation demands and supply of facilities being in a state of equilibrium.

Approach three is ideal, but practicable only for areas that have not yet developed and for older areas which are scheduled for redevelopment, its effect on the total problem will be limited.

Highway planning activities throughout the country are based on approach one--the provision of highway capacity to meet the traffic demands.

It is an observation today that serious congestion can be found on the highways of any large metropolitan area, and the impression is growing that new freeways invariably become clogged with vehicles during peak hours within a few years of their completion. Experience of this sort has tended to breed scepticism among planners about the ability of urban highway expansion to stay abreast of the automobile flood, except by unduly large investment of public funds in roads. Available financial and land resources can not supply the capacity at a fast enough rate to meet the peak traffic demands, despite the current high ratio of expenditure.[7]

It therefore appears that an investigation should be made to check whether the second approach would be a more practical way of meeting the problem: that is, whether the redistribution of demand in accordance with existing highway capacity is the solution.

This approach will be tested to see if it will reduce congestion and will result in a greater, but more uniformly distributed, utilization of the existing highway facilities.

In the search for a method of appraising congestion and determining its degree or intensity, some expression of the two functions of the traffic capacity of the facilty-time and space--should enter into the basis of measurement as they are reflected in densities of traffic, volumes of traffic, travelling time, and other characteristics of traffic movement. The following definitions will be used:

---

[7]Carll R. R. and W. S. Homburger, Some Characteristics of Peak Period Traffic, Institute of Transportation and Traffic Engineering, University of Calfironia, Berkeley, 1962, p. 2.

1. Speed is the rate of movement of vehicles, expressed in miles per hour. It can apply to single vehicles, times and locations (spot speeds) but more often is averaged over a time or distance.

   Operating Speed is the highest overall speed at which a driver can travel on a given route under prevailing traffic conditions without exceeding the safe speed.

   Free-Flow Operating Speed applies only to passenger cars during extremely low traffic densities. The difference in values between operating speed and free-flow operating speed is a measure of the effect that commercial vehicles, traffic concentration and congestion have on the flow.

2. Volume is the number of vehicles passing a point during a time period of one hour or more and is expressed in terms of an hourly, daily or annual basis. Vehicles-per-hour (vph) is the term most often used. Shorter term counts of vehicles are to measure flow rates and are generally expanded to a 60 minute time base to give an "X-minute Rate of Flow" in vph, i.e., the number of vehicles which would have passed in one hour had that rate of flow been maintained, e.g., 30 vehicles passing in one minute is a one minute rate of flow of 1800 vph.

3. Density is a measure of the number of vehicles on a section of roadway and is expressed in vehicles per mile (vpmi) thus:

$$\text{Density (vpmi)} = \frac{\text{Volume (vph)}}{\text{Space-mean speed (mph)}}$$

   The significance of density to the automobile driver is that it is a measure of the spacing between vehicles which determines his freedom of movement and at high densities dictates the speed he must travel.

The Critical Density of a roadway section is that density at which the traffic flow through the section is at its maximum. If the density increases beyond this value serious congestion will result.

4. Capacity is the maximum rate of flow under stated conditions. Both speed and density are factors influencing rate of flow and various combinations of speed and density produce various flows. The maximum rate of flow on a particular route occurs at the point of critical density which in turn depends on the minimum headways that drivers find tolerable at particular speeds.

   Possible capacity - the maximum number of vehicles that can pass a given point on a lane of roadway during one hour under the prevailing roadway and traffic conditions.

   Practical capacity - the maximum number of vehicles that can pass a given point on a lane of roadway during one hour under the prevailing roadway and traffic conditions, without unreasonable delay or restriction to the driver's freedom to manoeuver.

   Design capacity - the practical capacity or lesser value determined for use in designing the highway to accommodate the design volume.

5. Congestion is a qualitative term generally understood by the motoring public to mean discomfort and inconvenience in driving. It generally occurs when a route is loaded to capacity. Criterion used to describe congestion as a traffic flow phenomenon must consider individual driver comfort and convenience and also the efficiency of operations of the road system.

6. Delay is the time consumed while traffic or a specified component of traffic is impeded in the movement by some element over which it has no control.

Fixed Delays are those experienced by a lone vehicle as a result of traffic signals and stop signs whereas Operational Delays are caused by interference between components of traffic, i.e., congestion from parked vehicles, turning vehicles, etc. Thus Operational Delay is a measurable relative quantity indicating the efficiency, congestion and load on a road system. Delay requires measurement with respect to a base or "normal" value which is the average time taken by vehicles traversing the route under the same operating conditions (signal timings, lane reversal systems, etc.) during periods of low traffic volume and unimpeded flow.
This factor being the measure of time "wasted" by drivers because of an insufficient facility to handle the traffic demand volumes and the additional time lost by congested flow conditions, is the most important quantity by which the motoring public gauge the value of any traffic improvements.

# CHAPTER II

## CONGESTION - ITS CAUSE AND EFFECT

One of the complaints commonly heard about modern urban life is traffic congestion. This condition exists when too many vehicles are trying to use too small a space at the same time. More precisely, traffic congestion may be defined as a condition of overcrowding or filling to excess of the street capacity so that the freedom of movement or circulation is impeded and is thereby held below a designed or desirable rate of flow although not necessarily brought to a complete stop.[1]

The image of urban congestion is often projected as block after block of city streets choked with cars, buses and trucks trying to move somewhere. This may be traffic congestion at its worst but it is not uncommon. Congestion may come in varying degrees. Traffic may keep moving steadily but frustratingly slower than at posted and or safe speeds. Whatever the degree of congestion it amounts to one thing: the actual traffic volume exceeds the practical street capacity, reducing the desirable level of service. The level of congestion, then, is indicated by the difference between supply and demand for street capacity, the demand very frequently exceeding the supply.

The automobile is often singled out as the major cause of congestion. The automobile is more a symptom than a cause, however, for congestion is not unique to an automobile society. Congestion is not a new problem

---

[1]Smerk, G. M. Urban Transportation: The Federal Role, p. 234.

by any means. It has existed almost universally since the time cities have been in existence. Wilfred Owen states that the long-standing nature or urban traffic congestion and its world-wide scope suggest, despite a variety of forms, that underlying factors may be universal and only partially related to modern methods of transport.[2]

Lewis Mumford states that the problem was acute in the early days of Rome:

> As soon as the increase in population created a demand for wheeled traffic in Rome, the congestion became intolerable. One of Julius Caesar's first acts on seizing power was to ban wheeled traffic from the center of Rome during the day. . .for vehicles impeded circulation everywhere. Hence Claudius extended Caesar's prohibition to municipalities of Italy; and Marcus Aurelius, still later applied it without regard to their municipal status to every town in the empire. In a century and a half, traffic congestion had gone from bad to worse. 3

Concerning a later period of time, still before the use of the automobile, Owen points out the severity of congestion and one of the causes:

> The congestion of people, horses and street cars before the appearance of motorized transport, the rush-hour madness of New York traffic, and the lines of automobiles inching their way through the traffic circles of Washington are all manifestations of a continuing imbalance between transportation demand and available transport capacity. 4

Traffic congestion then is not a twentieth century phenomenon. Although congestion is not new, its present proportions seem unprecedented. The present proportion or level of congestion is basically a result of the increased densities of population, employment and

---

[2]Owen, W. The Metropolitan Transportation Problem, p. 6.

[3]Mumford, Lewis, The City in History, Harcourt, Brace and World, New York, 1961, p. 219.

[4]Owen, W., Op. cit., p. 7.

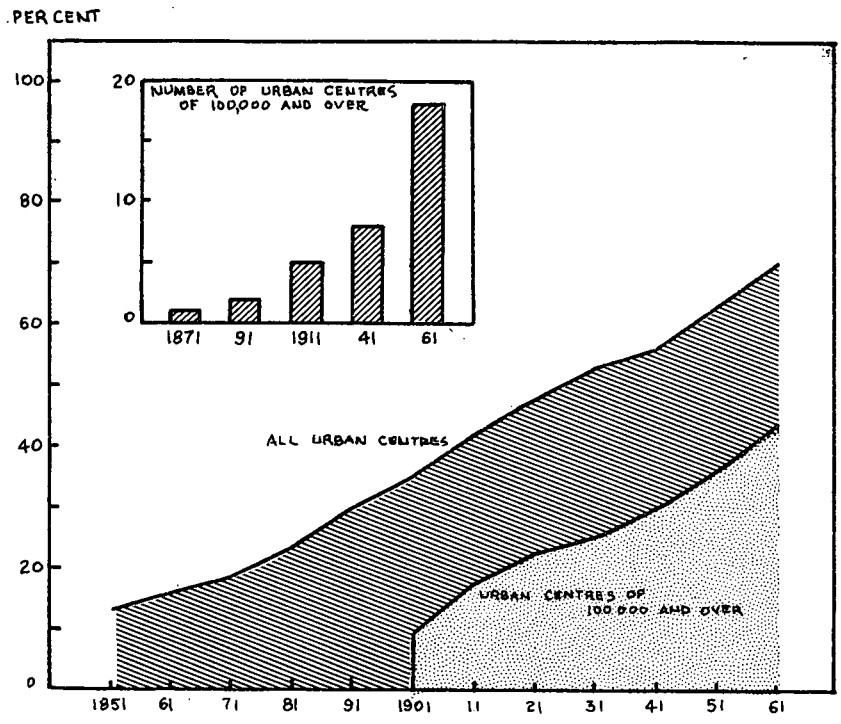
economic activity within a small land area. This concentration has created a heavy traffic load of passenger and freight movement that has become increasingly difficult to accommodate. Canadian urban areas are no exception to this phenomenon.

> By 1961 Canada's total population has increased sevenfold since 1851. Urban population however has risen about forty-fold and the level of urbanization has increased more than five times to 70 per cent. 5

These changes in the rural-urban population distribution are seen in Figure 1.

Figure 1

Degree of Urbanization - Canada




Note: Degree of urbanization for all centers is the percent share of total population in urban centers of 1000 persons and over: the degree of large city urbanization is the percentage share of total population in centers of 100,000 and over.

Source: Based on data from Dominion Bureau of Statistics Census Monograph on Urban Development in Canada by L. O. Stone.

---

[5]Economic Council of Canada, The Canadian Economy From 1960's to the 1970's. Fourth Annual Review, September 1957, p. 177.

There is evidence to suggest that Canada has had the fastest rate of urban growth among the industrially advanced countries for the post-war period as a whole.[6] The lower curve of Figure 1 indicates that the dominant feature of the overall trend has been the parallel growth of concentration in urban centers and complexes of large size--of 100,000 population and over. As seen from the lower curve of this figure the proportion of the total population in big cities has increased fivefold in 60 years.

Without the mobility and supply function provided by transportation the concentration of people, resources and activities in the urban areas would have been impossible. The time, cost and convenience of transport services have allowed a large amount of the population to seek and enjoy the economic, social and cultural opportunities that the central city provides.

The design and form of transportation facilities which allowed the population to gain advantage from the central city, has lead to the congestion problem. Owen states:

> At an earlier time, heavy densities of population developed because the urban radius was limited to distances that could be covered on foot, or at best by horse. As lines of inter-city communication were developed to serve the urban areas of the industrial age, they solved the problems of long-distance transportation that made it possible for great centers of production and employment to supply and support themselves. 7

---

[6]Economic Council of Canada, The Canadian Economy From 1960's to the 1970's. Fourth Annual Review, September 1957, p. 177.

[7]Owen, W. The Metropolitan Transportation Problem, p. 7.

The transportation system solved the problem of supply and support for the city but in so doing created the urban transportation problem. These transportation systems were principally designed to carry goods and people to the market for goods and services, the central city which was already characterized by too many people and an over concentration of economic activity.

But more recently this centripetal force which concentrated people in the central city is being met by a centrifugal "city to suburb" move resulting in a sprawled form which is emerging as the dominant new form of human settlement. This movement has been made possible by the common use of private motorized transportation which has greatly increased the area of travel for the urban resident.

The centrifugal force has accounted for a substantial dispersal of the place of work away from the central city in metropolitan areas.

> Between 1951 and 1961, for example, there was an absolute decline of 150,000 jobs in commercial, wholesale and retail trade, located within the central cities in all Canadian metropolitan regions, taken together. Again, it has been estimated that the total number of jobs in the central district of Toronto has not increased at all since 1956, despite the particularly rapid growth of that leading metropolitan area. [8]

This new form of city and suburb combines the central traditional ruling and organizing function of the city with the material production and living function of the suburb. This new city form is characterized by a separation of place of residence from place of work.

The separation of place of work from place of residence, together with the growth and expansion of the urban area has created a reciprocal movement of traffic from suburb to central city, known as the journey to

---

[8]Economic Council of Canada. The Canadian Economy From the 1960's to the 1970's, pp. 198-199.

work, that accounts for a larger volume of passenger traffic than any other cause.[9]

As a further adjunct to urban growth which is evident in Canada is the fact that as the size of the cities has increased so has the level of incomes per person and per family, (Table 1). The effect of higher income on traffic generation is significant. As one would expect, an increase in income results in an increase in trips made by the residents. It has been found that an increase in income led to an increase at a decreasing rate of trips generated.[10]

TABLE 1

AVERAGE NON-FARM INCOME BY PLACE OF RESIDENCE - CANADA 1961

| Place of Residence | | Average income per adult $ | Average income per family $ |
|---|---|---|---|
| Metropolitan areas | | 2,580 | 6,440 |
| Urban areas: | 30,000 to 99,999 | 2,310 | 5,850 |
| | 10,000 to 29,999 | 2,130 | 5,480 |
| | 1,000 to 9,999 | na | 5,070 |
| Rural | | na | 4,250 |

Source: Economic Council of Canada. The Canadian Economy From the 1960's to the 1970's, pp. 182-183.

With the higher incomes the growth of automobile ownership can be expected to increase:

> All indications suggest that the long-run upward pressure from rising numbers of automobiles and trucks is likely to continue. Between 1945 and 1965 the rate of growth in the motor vehicle population of Canada was 7.9 per cent annually, more than twice

[9]Owen, W. The Metropolitan Transportation Problem, p. 3.

[10]Mertz, W. L. "A Study of Factors Related to Urban Travel" U. S. Public Roads, U. S. Dept. of Commerce, Vol. 29, Washington, D. C. 1965, pp. 170-174.

> the growth rate of the human population. After modifying the trend for such factors as the low ownership ratios of 1945 and the explosion of demand after the wartime restrictions, it appears that population growth and a declining ratio of persons to vehicles could lead to a 60 per cent further rise by 1980. This would suggest almost 11 million vehicles in Canada in 1980, a ratio predicted for the United States in 1970. [11]

The afore-mentioned trends of rising incomes and increasing car ownership can be expected to generate a higher volume of traffic in urban areas. The increased number and greater usage of automobiles is one of the main causes of congestion.

The congestion in many central cities is also a result of a large number of people switching from public transportation to the private auto. Many people in North American cities once used mass transit systems to arrive at their downtown destinations. Since the Second World War transit riders have been switching to the private auto. This point is substantiated by the growth in automobile registrations for the United States and Canada, (Table 2), and by the decreasing trends in transit riding, (Table 3).

The trend to greater use of the private automobile is both a cause and a result of the movement to the suburbs previously discussed.

Areas of highly dispersed living cannot be served profitably or efficiently by public transportation. In low density land development a mass transit operation cannot operate successfully. All other things being equal, there are not enough people in a low density area to ensure that there will be sufficient passengers to pay the fares needed to make such a system economical.

---

[11] The Economic Council of Canada. The Canadian Economy From the 1960's to the 1970's, p. 199.

TABLE 2

PASSENGER AUTOMOBILE REGISTRATIONS FOR U. S. AND CANADA

| Year | Passenger Automobiles | |
|---|---|---|
| | U. S. | Canada |
| 1910 | 458,377 | 8,964 |
| 1920 | 8,131,522 | 407,064 |
| 1930 | 22,972,745 | 1,047,494 |
| 1940 | 27,372,397 | 1,234,637 |
| 1950 | 40,185,146 | 1,907,169 |
| 1960 | 61,300,000 | 4,104,415 |
| 1975 | 100,000,000 | |

Source: U. S. Statistical Abstract U. S. Bureau of the Dept. of Commerce and Labor, 1960. Canada Year Book - Bureau of Statistics, Ottawa, 1961.

TABLE 3

TRENDS IN TRANSIT RIDING BY TYPE OF TRANSIT

(Total Passengers)

| Year | Railway | | | Trolley Coach (mill) | Motor Bus (mill) | Grand Total (mill) |
|---|---|---|---|---|---|---|
| | Surface (millions) | Subway & Elevated | Total (mill) | | | |
| 1935 | 7,276 | 2,236 | 9,512 | 96 | 2,618 | 12,226 |
| 1940 | 5,943 | 2,382 | 8,325 | 534 | 4,239 | 13,098 |
| 1945 | 9,426 | 2,698 | 12,124 | 1,244 | 9,886 | 23,254 |
| 1950 | 3,904 | 2,264 | 6,168 | 1,658 | 9,420 | 17,246 |
| 1955 | 1,207 | 1,870 | 3,077 | 1,202 | 7,250 | 11,529 |
| 1959 | 521 | 1,828 | 2,349 | 749 | 6,459 | 9,557 |
| 1960 | 463 | 1,850 | 2,313 | 657 | 6,425 | 9,395 |
| 1961 | 434 | 1,855 | 2,289 | 601 | 5,993 | 8,883 |

Source: Transit Fact Book, 1962.

With severe financial losses as have been experienced in the past by transit operation it is necessary for them to curtail their operations and service to remain in a profitable position. This curtailment of operations and service in turn motivates more individuals to prefer the private mode.

All of these factors: the crowding of population and economic activity into a small area of land, the shift to the suburbs, the journey to work and the rush hour phenomenon, the increase in auto ownership and the decline in public transit usage all combine to produce the urban transportation problem.

In discussing congestion and attempting to find a solution for it, some assumptions and generalizations about the city are necessary. We could say the easiest way to solve the congestion problem is by default: to let the city strangle itself on that which once gave it life, a multiplicity of choice. Jane Jacobs suggests that

> good transportation and communcations are not only among the most difficult things to achieve; they are also basic necessities. . . .it is impossible to take advantage of multiplicity of choice without being able to get around easily. . . furthermore, the economic foundation of cities is trade. Even manufacturing occurs in cities mainly because of attached advantages involving trade, not because it is easier to manufacture things in cities. Trade in ideas, services, skills and personnel, and certainly in goods, demands efficient, fluid transportation and communication. 12

The problem is how to accommodate city transportation without destroying the related intricate and concentrated land use which is a cause of congestion.

If we do nothing constructive to solve the problem, the central city will decline. When this happens the activities and functions it

---

[12]Jacobs, Jane, The Death and Life of Great American Cities, Random House, N. Y. 1961, p. 340.

once attracted and facilitated will spread over a wide area and there will be little left to go to.

If left to default downtown congestion would be solved and the city would resemble a wheel without a hub where once its life used to rotate. The technological advances of transportation that in the first place allowed the development of the present day cities would have gone full circle. It is this possibility that the author believes is impractical and uneconomic.

What then is the city and what should it be? The foregoing physical description is a rather bleak picture of today's city but is often not far from the truth. But the city is more. The city generally has many natural assets that have allowed it to grow. A desirable climate, a productive hinterland, an energetic population, and good transport facilities are to mention a few.

It provides a central place for easy personal communications, for transacting business, for entertainment, education and the arts. However, too often today these obvious benefits are offset by inconveniences, not the least of which is traffic congestion. Congestion is already taking its toll. The evidence of this situation is the migration to the suburbs and in some cases the loss of population from the central city area. Associated with this loss of population in the major metropolitan areas is the loss of business in the C.B.D. For example, downtown shares of business are being lost in Dallas (38%), Chicago (26%), Los Angeles (38%), and New York (16%).[13] In other words, these downtown areas obtain a share of new business that is not in proportion to total shares already held. In effect their overall per cent share of the market is declining.

---

[13] U. S. News and World Report, "What's Happening to U.S. Cities," Vol. 48 (June 20, 1960), p. 84.

Also a point to note is that the C.B.D., especially the larger older ones, do not attract a substantially greater number of workers now than they did twenty or thirty years ago.[14]

With a transportation network free of congestion or with lessened congestion, the central city could conceivably, revitalize and reverse some of these present downward trends. If improvements are not found it is conceivable decline will continue and the core will die. But in the author's opinion the city, to be truly called a city, needs a central focal point with a clear identity. Without identity we would have faceless, uninteresting and institutional places in which to live, work and play.

Why has not the city been able to successfully accommodate the private car? There are several reasons which begin to demonstrate the impossibility of doing so. Firstly most city structures are obsolete in the motor age. The basic grid pattern upon which a major number of North American cities were built was not designed to accommodate a large flow of vehicular triffic. This pattern was devised primarily for its ease of real estate plotting and access to properties. They were laid out in a time when heavy traffic volumes were not a serious problem or indeed of major concern. The streets are often too narrow, especially when they serve the triple function of access, through movement and storage.

Land scarcity is another reason why cities do not accommodate the car. Scarce and consequently expensive urban land is densely developed.

---

[14] U. S. News and World Report, "What's Happening to U. S. Cities," Vol. 48 (June 20, 1960), p. 85.

In the United States 60 per cent of the population live on about one per cent of the land area and one-third live on one-tenth of one per cent of the land area. New York houses 24,537 persons per square mile and Manhattan 82,000.[15] Clearly then, city land is needed for the buildings in which people must live and work, not for massive urban highways. Add to this density of land the fact that land use is often poorly arranged. This poor arrangement results in a greater demand to travel and also congestion through cross movement between land uses.

The popular solution of adding to the existing street capacity, through the construction of new facilities, to maintain the downtown area would ultimately defeat the end it sets out to attain. Once the urban land is used for vehicle movement it is removed from the city tax roll. This has the effect of decreasing the city tax revenue, which in turn lessens the city's ability to pay for improvements. Besides the loss of revenue, as more room is required within the C.B.D. for freeways the city is forced to spread outwards, until it becomes an even more shapeless, formless mass.

Attempting to cure congestion by adding facilities for the use of the automobile is very expensive in both space and dollar terms. Los Angeles is a ready example of the philosophy of adding capacity as a solution to urban congestion. Already this city has used one-third of its central area for freeways and even more is needed. The downtown area as a result, has little of real interest and very often is used only as a means of getting from one freeway to another.

---

[15]Owen, W. The Metropolitan Transportation Problem, p. 12.

> One freeway interchange in Los Angeles is consuming approximately 80 acres of land area, and each average mile of freeway is requiring about 30 acres. One-third of the entire Los Angeles urban area is already required for transportation facilities. 16
>
> . . . .In the city of Elizabeth, the acquisition and clearing of right of way for the New Jersey Turnpike involved the removal or demolition of some 240 buildings and relocation of public utilities along the route cost over $8 million. 17
>
> . . . .In acquiring right of way for the Hollywood Freeway in Los Angeles, it was necessary to demolish 90 buildings and to move 1,728 others. The cost of right of way alone for the Los Angeles Harbour Freeway was $10 million for a single mile in the downtown area. Relocation of public utilities along the 22.8 mile route cost $2 million. 18

The dollar cost of construction of freeways in urban areas is tremendously high. For example:

> Boston's Central Artery Expressway: It cost the community $50 million to construct this mile of elevated highway in the heart of downtown Boston, and it required removing $16 million in property values from the tax rolls. . .this modern highway is costing $1.7 million annually in interest charges, $1.1 million annually in depreciation, over $1 million in lost taxes, . . .the total cost comes to more than $4 million annually. 19

U. S. Senator Harrison Williams of New Jersey testified in the Urban Mass Transportation - 1962 Senate hearings as follows:

> I would like to include. . .some figures, that are staggering, for the metropolitan area expressways. For what we call the Inner Loop in Washington, $300 million for 15 miles. For 22

---

[16]Taylor, S. S. "Freeways Alone Not Enough," Traffic Quarterly, July 1959, pp. 356-357.

[17]New Jersey Turnpike Authority, Annual Report, 1950, p. 57.

[18]Foley, W. L. "Rapid Progress on Harbour Freeway," California Highways and Public Works, May-June, 1954, pp. 3, 15.

[19]"Rail Transit: What's Ahead?" Railway Age, Oct. 17, 1960, p. 5.

> miles for a turnpike in the Boston $180 million. In Manhattan there is a one-mile of projected highway that will cost $100 million. 20

These figures clearly point out that the cost in both space and dollar terms of urban highway facilities is prohibitive to a general solution to the congestion problem. Also there is serious doubt if new freeway facilities actually solve the problem:

> It is a fact that today serious or incipient congestion can be found on the freeways of any large metropolitan area, and the impression is growing that new urban freeways invariably become clogged with vehicles during peak hour within a few years of their completion. Experience of this sort has tended to breed scepticism. . .about the ability of urban highway expansion to stay abreast of the automobile flood, except by unduly large investment of public funds in roads. 21

Rather than adding more capacity some people suggest that the number of cars allowed into the central city be restricted. This remedy is too extreme and not only impractical but politically impossible. In an age when activities and the home and work place are separated, the private auto is a necessity. Also one can not envisage any serious legislator presenting a plan of disallowing people to use their cars in the downtown area.

As outlined in this chapter the problem of traffic congestion is one which is very difficult to solve. The magnitude of the problem, and the forces which have brought it on all seem to be growing. A solution

---

[20]United States Government, The Urban Mass Transportation Act of 1962. United States Government Printing Office, 1962, p. 289.

[21]Carll, R. R. and W. S. Homburger. "Some Characteristics of Peak Period Traffic." Institute of Transportation and Traffic Engineering, University of California, Berkeley, 1962, p. 1.

to the problem, accepting our present popularly accepted mode of transportation, the private automobile, seems imponderable. The structural rigidities of our present city form can not accommodate large vehicular flow and the cost of overcoming these rigidities is beyond the capability of most urban areas.

The author feels that a partial solution or alleviation of the traffic congestion is possible through the better utilization of our existing capacity. As outlined above, our present capacity is quite capable of accommodating the urban traffic demands except at periods of peak demand. The peak demand or rush hour is a major cause of urban congestion. It is possible that the city streets could handle the present volume of traffic if it were not concentrated in such a small period of time. It is estimated that 40 per cent of passenger traffic in a city wants to move in only 12 per cent of the time available to it or in the three hours that make up the morning and evening rush periods.[22] The following chapter will examine the peak problem and the journey to work.

---

[22]Stonier, C. E. "Metropolitan Traffic Crises," Traffic Quarterly, Vol. 11, January 1957, pp. 214-231.

# CHAPTER III

## THE JOURNEY TO WORK AND THE PEAK PROBLEM

One of the main causes of traffic congestion is the "peak hour" or "rush hour" which is a manifestation of the journey to work. The journey to work is characterized by two elements which separate it from other trip purposes. In contrast to the general circulation journeys to shop, to school, to recreation, and for personal business, the journey to work is rigidly time oriented and secondly, the majority of trips may be centred in a particular location.

Common to virtually all wage-earners and proprietors in North American cities is the daily journey from home to work and back again. An easily observable characteristic of this travel is that most of it occurs at virtually the same time, the peak hours. Because of the general institutionalization of working hours, set in the framework of the seven or eight hour day and the five day week, the time at which the journey to work may be made is fairly rigid, at least for the bulk of the labor force. Typically the morning period of maximum volume occurs in most cases between 6:30 and 9:30 a.m. and in the evening another peak period of traffic flow in the opposite direction away from the work places occurs in the hours between 4:00 and 6:30 p.m.

In a metropolitan area of any substantial size, the principal destination of the journey to work is the central city. There is found the largest single proportion of jobs. There may be other, smaller periferal job centres within the metropolitan area, or in industrial districts within the central city; however, for the most part, there will

be one major focus of work journeys, the central city which is much larger than any of the others.[1]

The time and place orientation of the working journey is not easily altered. Even though workers may shift about through a variety of jobs within the range of their vocation, they may still find that as long as they remain in a given metropolitan area, the general location and hours of their work will not alter by more than a few blocks or minutes.[2]

The most notable characteristic of the quantity of traffic arriving in the C.B.D. is its time of arrival, and the difference between time distributions for work trips and trips for all purposes to the C.B.D. as a whole. From a study in Philadelphia, H. S. Lapin found:

> . . .that 40.4 per cent of trips for all purposes to the C.B.D. arrived in the two and a half hour period 7 to 9:30 a.m. while in the same period 68.4 per cent of work trips to the C.B.D. reached their destinations. Arrivals of trips for all purposes tended to be fairly evenly distributed throughout the remainder of the day while the proportion of C.B.D. destined work trips dropped off much more quickly after the morning peak. [3]

The fact of our twentieth century city is that work place and residence are separated. And because the C.B.D. is the largest single place of employment the journey to work is an unpleasant fact of life for a large number of city dwellers. D. L. Foley comments:

> In the contemporary large American city a mosaic of functional areas has evolved seemingly as an inevitable counterpart of the broad fact of economic specialization. Ecologists term this process segregation. So long as the city is characterized by specialization and segregation, . . .we can expect that

---

[1]Smerk, G. M. Urban Transportation: The Federal Role. Indiana University Press, Bloomington, 1965, pp. 182-183.

[2]Loc. cit.

[3]Lapin, H. S. Structuring of the Journey to Work. University of Pennsylvania Press, 1964, pp. 64-66.

> movements between divergent functional areas will be necessary if that city is to function as an integrated community. [4]

Thus the journey to work may be considered as a necessary link between functional areas. It is the movement of people from residential areas to those in which economic activity is dominant.

The movements from home to work have been described as movements of conflux and dispersion.

> This movement, when considered from the viewpoint of the dwelling place and the work place respectively, may be regarded as movements of dispersion from the former. . . inhabitants of a neighborhood leaving each morning on journeys and a movement of conflux at the latter. [5]

The common form of most North American cities is one of concentric circles or triangular shaped segments differentiated by function and land use. The C.B.D. is characterized by the centre of the circle or the vortex of the segment. The dominant residential areas are those on the fringes. The dominant trend of the tide of movement is therefore centripetal in the morning and centrifugal in the evening. This trend is illustrated by the amount of expansion and contraction between the night time and daytime populations of many large cities. (See Figure 2.)

From a statistical viewpoint, trips to work constitute the largest single grouping, by purpose of all trips leaving urban residences. In metropolitan areas, trips from home to work and return form generally about one-third of all trips made, and up to one-half of those made to the central business district may be for the purpose of work. As measured by

---

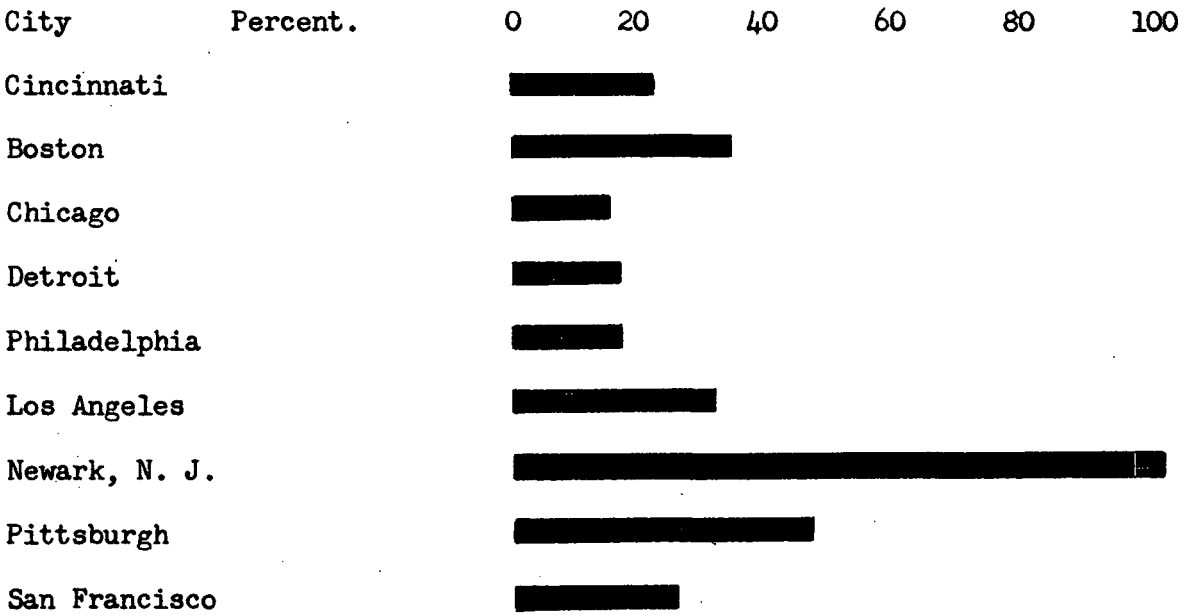
[4]Foley, D. L. "Urban Daytime Population. . .A field of Demographic-Ecological Research" Social Forces, 32, May 1954, pp. 323-30.

[5]Dickinson, R. E. City Region and Regionalism. London, Routledge and Kegan Paul, 1946, p. 124.

origin - destination studies in large cities, the work trips appear to represent from 50 to about 55 per cent of trips made to destinations in the designated C.B.D.'s. Reasons for the variations in this proportion lie in the differences from city to city in scale and influence of the C.B.D. relative to other local centres of commercial activity.[6]

Figure 2

Increase of Daytime Over Resident Population




Source: Owen, W. T. The Metropolitan Transportation Problem, p. 11.

What are the forces which create this heavy diurnal movement of people and vehicles to the central city? Besides the afore-mentioned causes others lie in the economic and social fields: in the structure and requirements of the modern society.[7]

The social and economic importance of the daily journey is in its role in supplying mobility to labor. The increasing length of the journey

---

[6]Lapin, H. S. Structuring of the Journey to Work, p. 34.

[7]Liepmann, K. K. The Journey to Work, London, Kegan Paul, Trench, Trubner and Co., 1944, p. 7.

to work widens the labor market, allowing the employee a wider choice of employment and a wider choice of employees to the employer. This increases the independence of the wage earner and the firm.

Further, daily travelling helps to preserve the family unit, by making it possible for various earning members to work in different localities while maintaining home life in one area.

The emergence of large-scale manufacturing as the most economic form of production in various branches of industry has led to the development of huge employment centers, employing many thousands of workers. Daily travelling by the workers has thus become necessary to secure the concentration of labor in plants of size demanded by technical and economic considerations. From the point of view of the worker the principal significance of the journey to work is that it extends the market in which he is able to offer his labor and therefore enlarges his economic independence.

The prime benefit which the employer derives from the journey to work is the possibility of drawing on his labor force from an area wider than the immediate environs of his place of employment.

The movement of vehicles, as a result of the diurnal cycle, over the transportation facilities is highly concentrated in time, the result being peaks in demand* immediately prior to and following the work periods.

---

*Peaks in demand can be simply defined as high points in the level of demand separated by decreases, troughs and increases in demand. Peaks need not be regular in occurrence, of any particular duration. Implicit in this definition is the importance of the time factor when referring to peaks. Although peaking must be measured in terms of the density of use of a facility at a particular point in time, actual definition of a particular point in time or the peak point will depend upon the span of time under consideration.

Because the assembly and dispersal of employees is governed by deadline conditions, massive demands are made upon the transportation system. At the same time capacity is limited for automobiles to the number of lanes that are available.[8]

Theoretically then the capacity of a street should be designed as nearly as possible to the greatest demands placed upon the street.

The greater demands of peak hours necessitate additional facilities which are of only limited use:

> On highways leading into the center of our metropolitan areas, two traffic lanes may be more than sufficient to carry the traffic during 20 hours of the day, but with the advent of the peak demand hours, six lanes may not be enough. 9

Urban highways, therefore, since their capacity must be designed to meet peak demands, are burdened with the problem of providing capacity for heavy but quite short-lived traffic loads.

The capacity and therefore the cost of a metropolitan transportation system is largely increased by this uneven demand for its use on a time basis. It is generally estimated that in large urban centers forty per cent of the total passenger traffic wishes to move within three hours or twelve and a half per cent of the available time per day. To accommodate this demand often means that a six-lane rather than a four-lane highway, or eight lanes instead of six lanes, are required. For urban land, the marginal cost of each added lane rises in geometric proportion to the initial lanes built.[10]

---

[8]Wingo, Lowden. Transportation and Urban Land, Resources for the Future, Washington, 1961, p. 36.

[9]Smerk, Urban Transportation: The Federal Role, p. 210.

[10]Stonier, G. E. "Metropolitan Transportation Crises," p. 217.

Wingo suggests this short-lived for transient traffic load is a function of the journey to work. It is a condition in the movement system which results when the instantaneous demand on the system exceeds its instantaneous capacity, that is, when the number of units required to arrive at a given point such as an employment center is greater than the ability of the system to admit them simultaneously. Its primary characteristic is queuing or congestion and its essential consequence is a time loss to each unit which depends on 1) the velocity with which the queue moves, and 2) the position of the unit in the queue.

Congestion losses arise from the reduction of the "free-flow," or desired velocity imposed on a unit because of the behavior of other units in the system. In a "saturated system" where passing opportunities are rare or non-existent the movement of all units may be dictated by the slower speeds of the early entrants. This "system dominant velocity" may very well be less than the capacity velocity of the system; and accordingly the system will experience a lowering of the level of service.

Given the capacity characteristics of a transportation system, the peaks in demand will necessarily result in the system's operating under conditions of saturation - where no additional vehicles could be added without their delaying those following - for at least some period of time.[11]

This condition of saturation or congestion has the effect of lowering the peak percentage values measurable from present traffic flows. If roads were available in such plentiful supply that the rigors of the peak hour played no part in drivers' decisions, a curve depicting the rate of traffic flow over the peak period would probably resemble a mountain peak

---

[11]Wingo, Transportation and Urban Land, pp. 36-46.

having a pointed summit, whose altitude would be the size of the peak demand. However, the typical traffic profile for the crowded urban arterial in the peak hours has more the appearance of a mesa than a mountain - a mesa with a nearly flat plateau at its maximum height, whose altitude is limited by the capacity of the road to move vehicles. As the peak is flattened, it spreads; and the more potential demand there is during the maximum time period, the wider the spread is likely to be. The spreading of the peak reduces the percentage of total traffic occurring in the maximum unit of time.[12]

But trying to satisfy peak hour demand may be very expensive and perhaps uneconomic. Many persons now travelling off peak to avoid the worst traffic congestion would in the event of new facilities shift to peak hour driving. Thus the additional public investment in transportation facilities sharpens the peak and lowers the "load factor"* (the ratio of average to peak use) and increases the per trip cost of the urban transportation plant. With a shift from traffic movement in off-peak hours that cost little or nothing before, the cost of the additional capacity per additional trip - the cost of peak hour marginal movement - becomes extremely high.[13]

---

*If the "load factor" is defined as the ratio of the average to the peak volume of use of the transportation system, the Chicago data exhibit a load factor of about .484 over all but only .294 for work trips. That is, if work trips were the only kind made, the streets would be used to only about 29 per cent of capacity, or 71 per cent idle, instead of the current 49 per cent utilization rate. Chicago Area Transportation Study, Vol. 1, Survey Findings, Chicago 1959, p. 35, Figure 15, reported in Lowden Wingo, Jr., Transportation and Urban Land, Washington: Resources for the Future, Inc., 1961, p. 31.

[12]Carroll, R. R. and W. S. Homburger. Some Characteristics of Peak Period Traffic. Institute of Transportation and Traffic Engineering, University of California, Berkeley, 1962, p. 2.

[13]Thompson, W. R. A Preface to Urban Economics, Resources for the Future, Johns Hopkins Press, Baltimore, 1965, p. 334.

Not only may the solution to the peak problem be very expensive, it may be practicably impossible given the phenomenon of traffic equilibrium.[14]

Where the majority of commuters travel by auto, the opening of a new expressway reduces peak-hour congestion on many previously existing streets, as a large number of commuters shift onto the new expressway because of the time advantage. This time advantage draws more users, thus bringing more congestion on the new route, whereas the time required on alternate routes falls as traffic on them decreases. When the travel times become identical, equilibrium is restored. Route-shifting onto the new facility will continue until the average speed on the new route is reduced to below the average speed on alternative routes. The new route may be designed to handle traffic at higher speeds than previously existing roadways; yet, at equilibrium, traffic on it is moving more slowly than traffic on the older routes. Therefore one can say that congestion on the new route has risen to surpass its optimal capacity. This result is a natural outcome of the forces of traffic equilibrium.

Such facilities would have to be wide enough to carry most of these commuters simultaneously. Some auto driving commuters attempt to avoid peak-hour congestion by leaving earlier or later than the period of greatest crowding. However, even if a new route were wide enough to carry all the peak period traffic formerly moving on conventional streets, a telescoping of this "spreading out" over time would probably occur after the expressway opened. Drivers who previously left earlier or later than the peak moment to avoid maximum crowding would soon discover that they could depart closer to the peak moment, since the new facility would reduce

---

[14]See: Downs, Anthony. "The Law of Peak Hour Expressway Congestion" Traffic Quarterly, Vol. 16, No. 3, (July 1962), pp. 393-409.

congestion at that moment. Therefore more and more commuters would tend to leave right at or around the moment of maximum convenience (assuming most government offices and business continued to open and let out at about the same time).

This would tend to push the level of crowding at that moment back to where it was before the expressway was opened, although it would also make the total peak period of shorter duration. Thus convergences in commuters' time schedules as well as their route schedules tend to force the level of congestion on a new facility during peak hours upwards to the maximum capacity of the facility.

Theoretically, only a road or system of roads wide enough to carry every commuter simultaneously at an optimal speed would be sufficient to eliminate all peak-hour congestion. It is obvious that no such roads are practical unless we convert our metropolitan areas into giant cement slabs. Therefore congestion at the peak hour will rise until the commuters' average speed is forced below the optimal speed for which the facility was designed.

A new expressway serving the downtown district of a city in which the majority of commuters travel by car will have the following effects:

1) It will reduce traffic on existing streets, thereby decreasing the average journey time on those streets for the commuters who still use them.

2) It will carry much heavier traffic loads during rush hours, heavier than its optimal capacity; hence serious congestion will be created. Nevertheless, commuters using the expressway will have faster commuting trips than they had before it was opened.

3) It will shorten the duration of the peak period traffic congestion.

The question is, will the total time savings experienced in a city after a new expressway is opened - plus other benefits, such as greater safety - be sufficient to balance the cost of constructing the road. As discussed in Chapter II the cost of new physical structures may be very high.

What then are the costs of the journey to work? The journey to work is composed of two kinds of costs: the direct money-costs for the service of transportation (operating cost), and the time costs absorbed in movement between two points in space. (See Figure 3.) This illustrates how the average costs of operations, accident and time, increases with volume of vehicles.

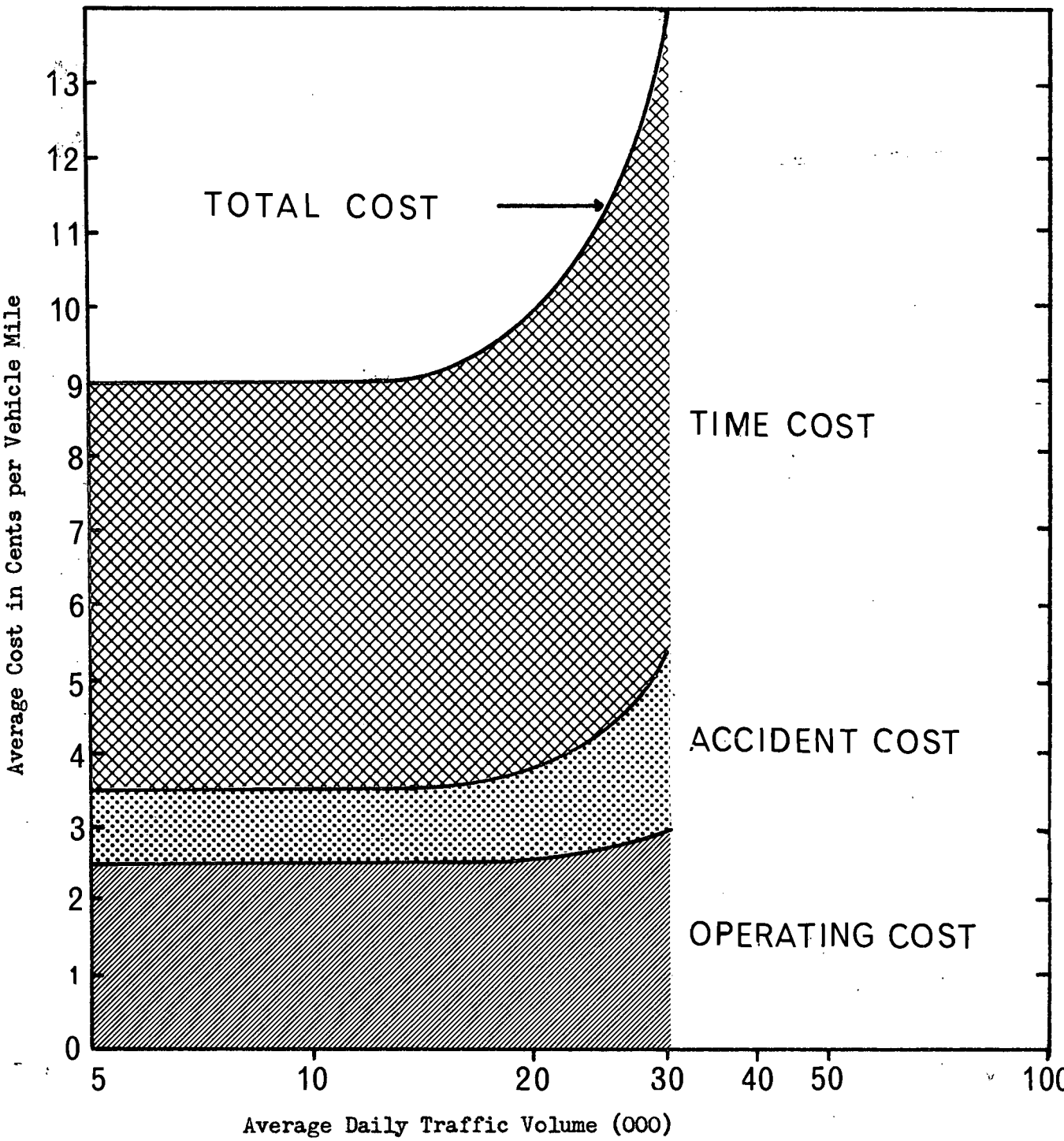
For the worker the time consumed by the journey to work is a true cost. Time is a valuable commodity which must be "spent" if the trip is to be made. It is an expenditure of time which would not be incurred if the worker were employed at home. In a study done in Philadelphia (1956) a wide range of median time length of trip from home to work was found. The range was from 17 to 47 minutes, and the median figure for all trips of interest was about 27 minutes.[15] This travel time has the effect of lengthening the working day and consequently reduces the wage rate by the cost of the time spent in travel.

The value of time is difficult to estimate. If it could be calculated time-costs could be valued in money terms and added with direct costs to total a single work trip price. Because the mechanism for valuing time is imperfect, the traveller's time does not have the interchangeability necessary to measure the opportunity costs of other uses

---

[15]Lapin, Structuring of the Journey to Work, p. 4.

Figure 3




Travel Cost-Volume Functions For Arterial Streets

Source: Carroll, J. D. "Fitting Transportation Systems Plans to Urban Land-Use Projections" The Dynamics of Urban Transportation, Automobile Association Inc., 1962, pp. 10-25.

of his time. Time is not a homogeneous commodity as is currency - an hour of time does not have the same value for the individual throughout the 24 hour day, because of the difference in alternative possibilities for using it.[16]

In the introduction to Lapin's book, Structuring the Journey to Work, he states:

> Estimates made for both the London central area and Lower Manhattan indicate that time spent in the journey to work lengthens the workday by a gross amount of almost 20 per cent. Thus, for the approximately three million employed persons who travel into Lower Manhattan each workday, over ½ million man days are consumed in travel en route. 17

Although the above quote may illustrate an extreme case and one not solely representative of motor vehicles, the same trend is evident in a Minneapolis-St. Paul study.

TABLE 4

COMPARISON OF AVERAGE DISTANCES FROM C.B.D. TRAVELLED IN PEAK AND OFF-PEAK PERIODS - MINNEAPOLIS AND ST. PAUL

| Cumulative time (in minutes) | Cumulative distance | | | |
|---|---|---|---|---|
| | Minneapolis | | St. Paul | |
| | peak | off-peak | peak | off-peak |
| | (in miles) | | | |
| 5 | 0.8 | 1.0 | 0.6 | 1.1 |
| 10 | 2.2 | 2.6 | 2.2 | 3.2 |
| 15 | 3.9 | 4.6 | 4.4 | 6.4 |

Source: Minnesota Department of Highways, St. Paul - Minneapolis Traffic Survey, 1950, pp. 43-45.

---

[16]Wingo, Transportation and Urban Land, p. 53.

[17]Lapin, Structuring of the Journey to Work, Introduction.

This study indicates considerable differences between average speeds attained and distances covered on urban facilities as measured during off-peak and peak periods of traffic flow.

The St. Paul data indicate that about 45 per cent more distance was covered in the first 15 minutes of travel from the downtown area in the off-peak as compared with the peak period of traffic flow. The equivalent figure for Minneapolis was 18 per cent. Despite the considerable difference between the two figures, the retarding effect of traffic of the great volumes of workers who travel at the same time is evident.[18]

In addition to the time - cost, direct outlays by the worker for transportation must be brought into the calculations, and the impact of this will vary with the mode of transportation. However valued, they are likewise costs chargeable against the gross returns from the worker's employment and can be treated in a fashion similar to that of the time - costs. They can be expressed as a constant with respect to time and distance, as in the case of a single-fare transit system; or as a function of distance, as in auto mileage costs.

The money cost of operating automobiles in urban traffic conditions is high and congestion increases it. The cost of using a car in a congested area is frequently overlooked, since many of the costs associated with operating a car are ignored by most motorists. Average fully allocated costs of driving a private car are approximately 10 cents per mile. This is far higher than the per-mile cost of using some other form of public transportation. In Table 5 the average costs for travelling by several modes of urban transportation are compared. The fully allocated costs of operating a car appear to be substantially higher than alternative means.

---

[18]Lapin, Structuring of the Journey to Work, p. 61.

TABLE 5

AVERAGE COST FOR ONE PERSON TO TRAVEL ONE MILE
(in cents)

| | | |
|---|---|---|
| Commuter rail coach | | 2.6 |
| Subway or elevated | | 3.2 |
| Bus | | 3.2 |
| Auto | Out of Pocket Cost | Full cost* |
| one rider | 3.5-4 | 10-11 |
| two riders | 1.8-2 | 5-5.5 |
| three riders | 1.2-1.3 | 3.3-3.7 |

* Full cost includes depreciation, insurance, etc., but not downtown parking.

Source: "Tide Turns for Transit" Business Week, October 20, 1962, p. 8, Table 3 reported in G. M. Smerk, Urban Transportation, p. 64.

As illustrated in this chapter much of the problem of congestion and its most serious cause, the peak hour, stems from the uniformity of working hours. If peak-travel periods could be scattered, the pressure imposed on the transport system would be considerably lessened. This could be done by a staggering of working hours which could mitigate the peak in a city significantly by spreading arrival and departure times over as broad a period as possible.

As previously stated the problem of peak hour congestion is one of supply and demand; the supply of available space falls short of the instantaneous demand placed on the system. This difficulty can be overcome by the expansion of the physical transportation plant at great cost. Once overcome there is some doubt as to how long the system will operate congestion free because of the process of traffic equilibrium. The doubt arises out of the desire of drivers to minimize the time spent in travel. A new facility will reduce the time factor causing a shift to the new route and will also draw more people from other roads. It will further

allow more drivers to depart closer to the peak moment since the new facility would reduce congestion at that moment. This would encourage more commuters to travel at or around the moment of maximum convenience. Therefore any new facility would be congested at peak hours, soon after it was constructed.

By a system of staggering starting times in the congested central area it would be possible to distribute the moment of maximum convenience, therefore reducing the "altitude" of the peak and also giving a more even "load factor."

This reduction of the peak by a staggering of hours, to accomplish a spreading of arrival and departure times, would extend the period of maximum convenience for a proportion of the vehicle operators. This in turn would reduce the instantaneous demands being placed on the transportation facility which produce congestion. If the existing capacity of the street system were large enough to absorb these fewer number of automobiles into the system, which are a result of the staggering of the time of the maximum convenience, no new facilities would be needed to accomplish a reduction in both time and operating costs.

Chapters IV and V will investigate the feasibility from a technical point of view, of maximizing the use of our existing capacity, so as to equate the supply of facilities with the demand for them. Staggered hours will be the method investigated to bring about this equilibrium of supply and demand.

# CHAPTER IV

## FEASIBILITY OF STAGGERING

As discussed previously the congestion problem is a result of the imbalance between supply of capacity and the demand for traffic movement during the peak hours. At other times during the day and at night the street system is capable of accommodating the traffic demand. One solution is the redistribution of demand in accordance with the existing street capacity through the staggering of working hours.

The purpose or goal of staggering hours is to spread out the periods of maximum demand, thereby reducing the magnitude of the peak demand.[1] If peak hour travel volumes could be spread, the pressure imposed on the transportation system could be lessened. This approach is based on the fact that maximum travel demand is not constant and is cyclical.

The idea of relieving the heavy congestion during the peak hours by the adoption of staggering working hours is not new. It was proposed as early as 1920 in England.[2] An Advisory Committee on London traffic expressed the view that appreciable benefit would be derived from even a slight modification of the times of beginning and ending the daily work of employees in certain classes of business.

---

[1]Betz, M. J., J. N. Supersad, J. C. P. Kole, A Method of Analysis of Peak Hour Traffic Demand For Effecting a Staggered Hours Program in Urban Areas. Engineering Research Center, Arizona State University, Tempe, October, 1964, p. 5.

[2]"Crush Hour Travel in Central London," Ministry of Transport and Civil Aviation, Her Majesty's Stationery Office, 1958, p. 1.

Later during World War II, when there existed the need to conserve national resources, the compulsory staggering of working hours was introduced, with one of its principal objectives the maximization of the use of available transportation equipment. Available reports on this wartime experience indicate that the staggering of working hours was successful in meeting this objective.[3]

Staggering was first used in North America over 30 years ago. During World War II approximately 60 U. S. cities used this method to help alleviate the critical problem of mass transportation. In all cases some degree of success was achieved and in many cities peak travel demand was reduced as much as 30 per cent. After the war all major staggered hours plans were terminated.[4] One of the most successful staggered hours plans was that implemented in Washington, D. C. in 1941.[5]

The staggered hours resulted in significant reductions in peak hour volumes. The programme resulted from an order by President Roosevelt which shifted the time of work for some 75000 employees. Hours for reporting, which were mostly at 9 o'clock were staggered at 15 minute intervals from 7:30 to 9:15 a.m., with the closing times varied accordingly. The results were that peaks in the hours of beginning and ending work were reduced to half of what existed before the staggering. (See Figure 4.)

---

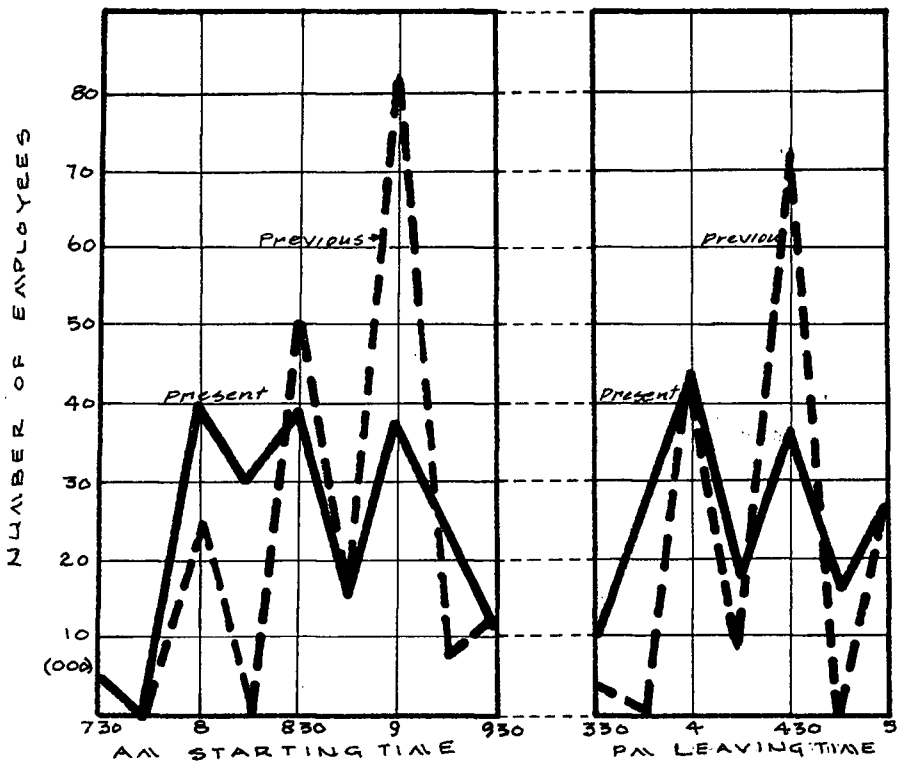
3Betz, Supersad, et al., A Method of Analysis of Peak Hour Traffic, etc.,

4Santerre, G. L., An Investigation of the Feasibility of Improving Freeway Operation by Staggering Working Hours, Texas Transportation Institute, Texas A & M University, 1967, p. 3.

5Transit Journal, Vol. 85, No. 5, 1941, pp. 156-59.

Figure 4

Peaks in the hours of beginning and ending work. Before and after a staggered working hours plan - Washington, D. C., 1941.




Source: Transit Journal, Vol. 85, p. 157.

This data demonstrates how the volume sharpness of the peaks is greatly reduced, the maximum number starting or leaving work at any one time having dropped from more than 80,000 to some 40,000, or about half. Although this plan was primarily designed for the improvement of transit operations its findings demonstrate the effects of staggering hours.

One important aspect of a staggered hours plan is the effect that may arise for an organization if a change in its working times is expected. In the study done by Mr. Santerre several different organizations were questioned as to the effect of such a plan and the problem

areas that the administrators felt existed. The following is a list of Mr. Santerre's findings:[6]

1. a) Organization - Senior High School.

   b) Person consulted - Assistant Superintendent of Schools Secondary Education Department, and a high school principal.

   c) Problem Areas:

      i) In many instances parents must take students to school prior to their going to work, therefore some synchronization is necessary.

      ii) School bus routes must be co-ordinated to provide required transportation.

      iii) All schools should have approximately the same schedules in order that intra-school meetings can be held in the afternoon following classes.

      iv) If schools have widely varied schedules, teachers with children could be adversely affected.

   d) Receptiveness to Staggered Hours - Uncommitted.

2. a) Organization - Telephone Company.

   b) Person consulted - Assistant Manager District Toll Office.

   c) Problem Areas:

      i) Personnel must be on duty during peak telephone traffic periods.

      ii) Working hours must be overlapped to provide smooth, continuous operation.

---

[6]Santerre, An Investigation of the Feasibility. . .Working Hours, pp. 7-9.

d) Receptiveness to Staggered Hours - Receptive.

3. a) Organization - Executive Offices of Major Oil Firm.

b) Person consulted - Assistant Personnel Relations Officer.

c) Problem Areas:

i) A relatively few employees must be on the job by 7:30 a.m. in order to make field contact each morning.

ii) Any change would involve passage by Board of Directors in order to assure a smooth transition.

iii) No insurmountable obstacles can be foreseen.

d) Receptiveness to Staggered Hours - Highly Receptive.

4. a) Organization - General Post Office.

b) Person consulted - Personnel Management Officer.

c) Problem Areas:

i) No major obstacles to minor changes.

ii) It would not be beneficial to change working hours because shift changes occur during traffic off-peak times.

d) Receptiveness to Staggered Hours - Receptive.

5. a) Organization - Wholesale Distributor.

b) Person consulted - Personnel Manager.

c) Problem Areas:

i) This is a highly competitive organization that cannot allow itself to be put at an unfair disadvantage when dealing with customers.

ii) The working hours of this organization are dictated by the requirements of its customers.

d) Receptiveness to Staggered Hours - Not Receptive.

Although the above list does not include all types of organizations, it does give an overall picture of some of the problems that may arise if a staggered hours program is instituted.

From a more comprehensive study done for Central London, the chief reasons given by firms in explanation of their inability to co-operate in a scheme of staggered hours are summarized below.[7]

TABLE 6

REASONS AGAINST A SCHEME FOR STAGGERED HOURS

| | Percentage of Firms |
|---|---|
| Loss of Business Efficiency | 72 |
| Staff Difficulties | 23 |
| Long Distance Passengers | 6 |
| Integration of Departments | 4 |
| Official Times not Regularly Worked | 7 |
| Late Delivery of Mail | 5 |

From the above table, it is seen that loss of business efficiency is the reason most frequently given.

There is widespread belief in the minds of management that any departure from their established starting or finishing times would lead to a loss of efficiency. The explanation most generally offered is that efficiency would be impaired and trade lost due to a restriction of

[7]"Crush Hour Traffic in Central London," Ministry of Transport and Civil Aviation, Her Majesty's stationery Office, 1958, pp. 15-27.

contacts with customers, branches, factories and business associates. Some offices worry that the change in starting or finishing time will decrease the time periods for coast to coast communication.

Expected staff difficulties are the background to much of the reluctance to experiment with staggered hours. Some firms, who have difficulty recruiting staff, feel they cannot take the risk of adopting new starting and finishing times which may impede recruitment or lead to further resignations. The domestic obligations of married women have been frequently quoted as a reason for not adopting times before 9:00 a.m. or finishing times after 5:30 p.m.

In the Central London Study, a number of firms conducted a census of staff opinion. The results have occasionally shown the staff to be almost wholly opposed to any change, suggesting that some people would rather endure uncomfortable travel conditions than alter their domestic arrangements in order to work staggered hours.[8]

Because a firm's employees may be spread over not only a large area but a long distance some firms argue that a staggering of hours would necessitate some of their staff rising at an unreasonably early hour.

Another method of staggering hours, a form of internal time stagger, is not popular because work of various departments is so closely integrated that standard starting and finishing times are essential. It is also maintained that under present conditions, disciplinary control of the proper fulfilment of the prescribed working day can only be maintained under standard hours.

---

[8]"Crush Hour Traffic in Central London," Ministry of Transport and Civil Aviation, p. 19.

Although there were some problems resulting from the Central London Case, the results were significant. The changes introduced were mainly moves forward of 15 minutes from the 5:00 p.m. and 5:30 p.m. finishing times to 4:45 p.m. and 5:15 p.m., accompanied by earlier starting times.

The overall effect of the changes was to reduce the maximum finishing time - 5:30 p.m. - by 8768, and to remove from the peak hour - 5:30 p.m. to 6:00 p.m. - 6439 persons.[9]

The effects this had on travel movement is illustrated by the following extracts from letters received by the Committee.[10]

An Insurance Office:

> . . .the change was made at the request of the staff, which was prompted by a virtually unanimous experience that travelling was very much easier at the time.

A firm of Wholesale Milliners:

> . . .the scheme. . .is working smoothly and there is no doubt that real benefit is being obtained especially from the easier travelling conditions.

A firm of Office Equipment Supplies:

> . . .the staff whose names we have now staggered are all very much appreciative of the easier travelling, which the new working hours have offered. In one particular case, a journey which took over an hour has been reduced to something under 45 minutes.

A firm of Clothing Manufacturers:

> . . .our new hours of 8:45 a.m. to 4:45 p.m. appear to be proving quite satisfactory and we think we can safely say are popular with the staff. We have not so far had any adverse reports at all. Finishing a quarter of an hour earlier is very helpful because our staff are thereby enabled to beat the rush at 5:00 p.m.

---

[9] "Crush Hour Traffic in Central London," Ministry of Transport and Civil Aviation, pp. 14-17.

[10] Loc. cit.

A Banking House:

> . . .practically everyone agrees that by leaving at a quarter to five instead of five, the journey to work is infinitely more comfortable.

The above references, although very superficial, do suggest some of the problem areas and relief measures which can be derived from a staggering of hours. While the problems seem diverse, the benefits to the user seem evident, travel is easier in peak periods.

The London Committee's experience suggested that the difficulties of implementing such a system are often more real in contemplation than in practice. In nearly every trade or business in which some firms have rejected a change of hours other firms can be found in the same business who have successfully applied the scheme.[11] One major problem of instituting a staggered hours program is that human habits are hard to change. It should be expected that some criticism to any change will result. Probably the most effective method of handling this problem would be to precede any change with a massive public relations and public education programme.

There are several possible methods by which such a plan could be implemented. One might be through a general order such as was given by President Roosevelt to stagger hours in Washington, D. C. This method may succeed in specific cases where the major employer in a given city is a single organization. A second method is by tying a staggered hours plan to a zoning bylaw which would compel businesses which locate in a specific area to have certain starting and finishing times.

Although the method of implementation of such a plan is of major importance this thesis has not prescribed such a method. This thesis

---

[11] "Crush Hour Traffic in Central London," p. 28.

has only outlined some of the problems which need to be considered in devising a plan for implementation.

One method of staggering hours and its application to a case study will be the subject of the following chapter. The method investigated is based on calculating a staggered hours system which will result in an optimization of demand and capacity loads; ideally this would be a volume - capacity ratio equal to or less than unity for a given travel link. The objective of this study is to evaluate the effects of staggered hours on the highway system in quantitative terms. It would determine the extent that traffic loads can be distributed over a longer period and how much spread of hours would be needed to effect improvements in the level of service.

# CHAPTER V

## METHOD AND CASE STUDY

The purpose of this chapter is to develop a method of equating the demand for traffic movement to the existing supply in order to eliminate congestion delays. Accepting the constraints of demand and supply and the goal of eliminating congestion delay time it is proposed that work starting times be staggered in order to extend the demand over a period of time so that it will not exceed the maximum given supply. The demand for movement or the traffic demand is concerned with the aggregate number of trips that people in a given urban area desire to make. This demand has several characteristics; it may have a certain distribution in time (load demand) and require a certain number of vehicles to pass a given point at a specific time (flow demand). When this point is the common destination for a number of trip movements, it is called the deadline demand.[1]

The term supply of movement has meaning as a general description of the physical plant available for movement--fundamentally this is what is meant by practical capacity.[2]

If the demand for movement is related to time, the load characteristics of an urban transportation system are revealed. The dominance of

---

[1]Wingo, L., Transportation and Urban Land, Resources For the Future, Washington, D. C., 1961, p. 28.

[2]Ibid., p. 29.

the work trip sets the level of the demand throughout the system.[3] The load factor shows a concentration of demand in time. It is the ratio of the average to the peak or maximum volume; a low load factor (approaching zero) reflects a high degree of concentration of demand such as exists at the peak period, while a high load factor (approaching one) describes hourly volumes among which there is little variation.

Given the capacity or supply characteristics of a system, the peaks in demand will necessarily result in the system operating under conditions of low load factor or high volume demand. A volume increase beyond a certain value creates a condition of critical flow. Characteristics of this type of flow are the appearance of congestion and the drastic reduction in traffic volume and speed. The precise location of the point where critical flow begins is not known.[4]

Once critical flow has been established, non-critical flow can only return when the traffic volume input is reduced. Critical flow congestion losses arise from the reduction of the free flow or desired velocity imposed on a unit because of the behavior of other units in the system.[5] If only one point on a long, heavily travelled facility converts to critical flow, the lower capacity at this point will create an overload that will spread throughout the system. Wingo refers to this condition as a saturated system:

---

[3]Wingo, L., Transportation and Urban Land, p. 30.

[4]Ryan, D. P. and S. M. Browning, "Some Fundamental Relationships of Traffic Flow on a Freeway," Highway Research Board Bulletin 324, January 1962, p. 73.

[5]Wingo, L., op. cit., p. 47.

> In a saturated system where passing opportunities are rare or non-existent the movement of all units will approach a uniform flow where velocity may be dictated by the slower speeds of the early entrants. This 'system dominant velocity' may very well be less than the 'capacity velocity' of the system and accordingly, the system will experience a high level of loss of time. [6]

In order to avoid a high level of loss of time traffic flow should be maintained in the range of non-critical flow because it represents the desirable traffic flow volume from a point of capacity and economy.[7]

The concepts, critical and non-critical, can be illustrated in graphic form (Figure 5).

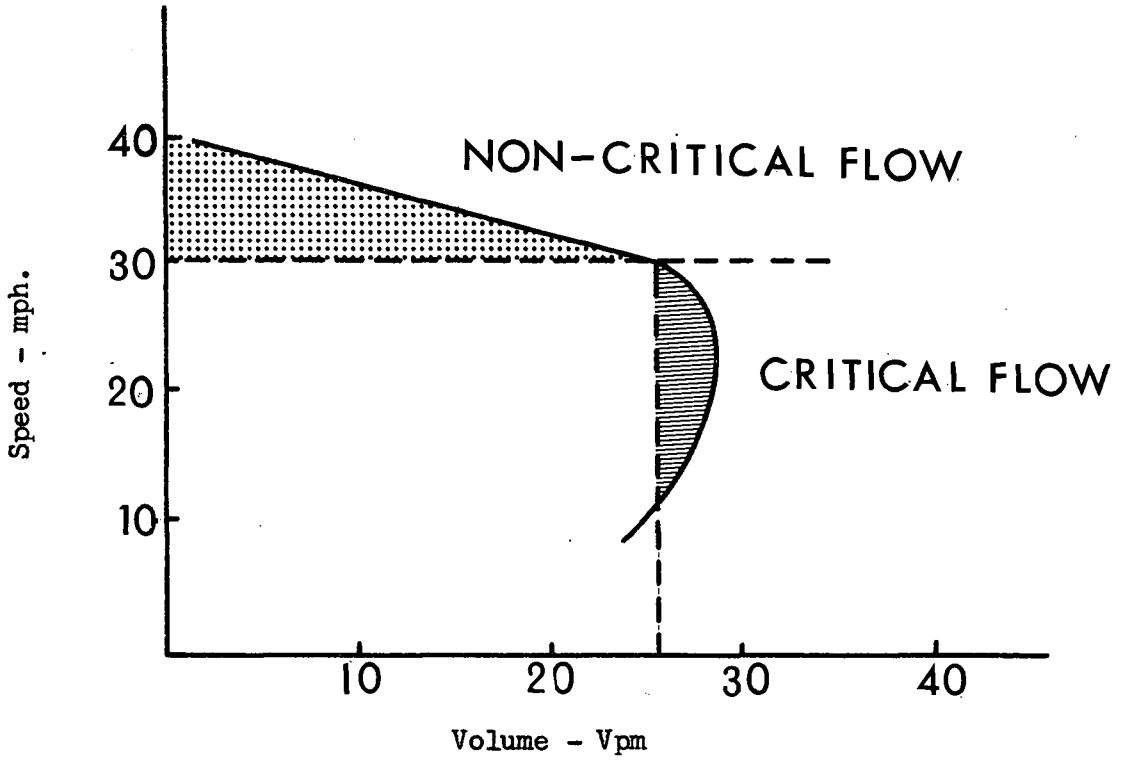



Figure 5. A Comparison of Speed - Volume Relations

---

[6]Wingo, Transportation and Urban Land, p. 50.

[7]Ryan and Browning, Highway Research Board Bulletin 324, p. 74.

Linearity of relations of the fundamental characteristics of speed - volume have been suggested in various studies. Good linearity seems to exist in the range of non-critical flow. Linearity is lost at the boundary where flow becomes non-critical. Therefore it is suggested that the end of the linearity of flow marks the boundary between non-critical and critical flow.[8]

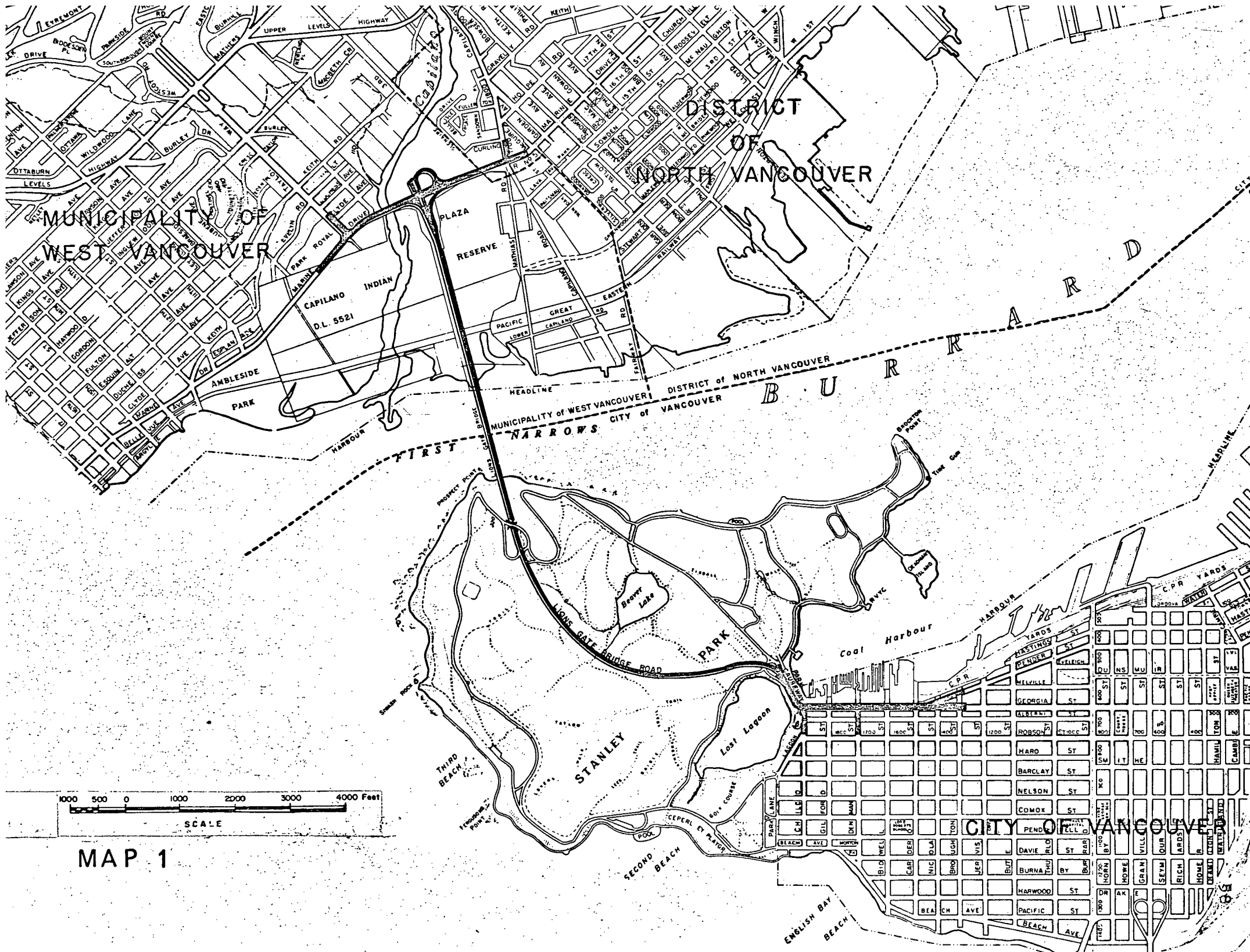
The critical point therefore represents the supply or capacity level which can be maintained over a given period of time. Once the supply has been determined the demand must be equated to it over a period of time.

The method used to limit the volume of traffic to the non-critical zone is the staggering of working hours. This is a technique for modifying the demand upon the system by breaking the total demand down into smaller segments, by giving each segment a different deadline demand. This in effect will equate the demand with the supply over a period of time. By this method the number of vehicles arriving at the entrance to an area of restricted capacity can be made equal to the capacity. By equating demand and supply at a restricted facility waiting time delays can be eliminated.

The remainder of this chapter is devoted to an application of the above method to a case study of the morning peak period traffic demand crossing the First Narrows Bridge (Lions Gate Bridge) Vancouver, B. C. See Map 1.

---

[8]For a discussion of speed - volume relationship see:
(1) Greenshields, B. D. and Weida, F. M. "Statistics with Application to Highway Traffic Analysis", End Foundation For Traffic Control (1952)
(2) Olcott, E. S., "The Influence of Vehicular Speed and Spacing on Tunnel Capacity", Operations Research For Management, Johns Hopkins Press, 2: 57-81, 1956.
(3) Ryan and Browning, op. cit.
(4) Underwood, R. T., "Speed, Volume and Density Relationships", Quality and Theory of Traffic Flow, A Symposium Bureau of Highway Traffic, Yale University (1961).


MUNICIPALITY OF WEST VANCOUVER
DISTRICT OF NORTH VANCOUVER
CITY OF VANCOUVER
BURRARD
FIRST NARROWS
HEADLINE
MUNICIPALITY of WEST VANCOUVER
DISTRICT of NORTH VANCOUVER
CITY of VANCOUVER
CAPILANO INDIAN RESERVE
CAPILANO D.L. 5521
PLAZA
AMBLESIDE PARK
HARBOUR
LIONS GATE BRIDGE ROAD
STANLEY PARK
Beaver Lake
Lost Lagoon
Coal Harbour
THIRD BEACH
SECOND BEACH
ENGLISH BAY BEACH
CEPERL CT PLACE
GOLF COURSE
PROSPECT POINT
BROCKTON POINT
TIME GUN
CLARKSON ISLAND
C.P.R. YARDS
HASTINGS
PENDER
MELVILLE
GEORGIA
ALBERNI
ROBSON
HARO
BARCLAY
NELSON
COMOX
PENDER
DAVIE
BURNAB
HARWOOD
PACIFIC
BEACH AVE
1000 500 0 1000 2000 3000 4000 Feet
SCALE

MAP 1

In order to illustrate the effects of staggered hours on a traffic facility, the following assumptions are necessary:

First, there are numerous references in literature to the predominance of work trips during the peak periods of the average work day. In particular, Voorhees has stated that O-D studies indicate that work trips are the most common type in the metropolitan areas and total about 40 per cent of all trips during an average day. This percentage is higher--often 60 or 70 per cent--during peak hours.[9] In a survey conducted by N. D. Lea and Associates in Vancouver it was found that 86 per cent of all auto trips in the peak period to downtown Vancouver are to work.[10]

Secondly, the critical section for limiting the capacity of the system under study is the First Narrows Bridge capacity and that relieving the bridge of excess demand will have a beneficial effect on the accumulation of traffic at its approach.

Thirdly, since in most industrial and commercial enterprises various phases of operations are in some way interdependent, plus the fact that many employers use car pools for getting to and from work, any staggering of working hours should necessarily attempt to minimize any disruption of these relationships.

Fourthly, that there is a tendency for businesses with similar interests and functions to concentrate in particular areas of the C.B.D. The effect of each employment zone as such on the street system and its contribution of work trips will be considered as a unit. The basic data needed for this analysis are:

---

[9]Voorhees, A. and Morris, R., "Estimating and Forecasting Travel for Baltimore by Use of a Mathematical Model," Bulletin 224, HRB Washington, D. C., (1959), p. 107.

[10]Lea, N. D. and Associates, Measures to Improve Bus Transit and Traffic Flow Across the First Narrows Bridge, Dept. of Highways, May, 1967, p. 57.

(1) peak period trips across the bridge, their numbers, and their destination in the C.B.D.

(2) bridge capacity and actual demand.

(3) employment zones, their location and number of vehicles destined to each zone in the morning peak period.

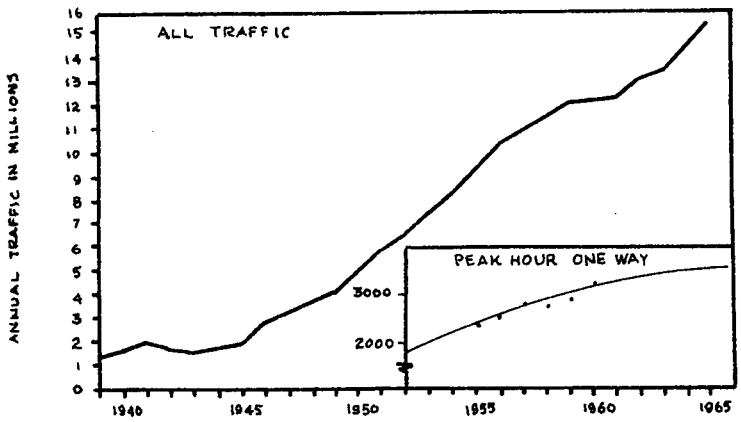
The existing condition in the peak period is that traffic is delayed and brought to a halt for a considerable distance at the approaches to the bridge. This condition exists because traffic is approaching at a volume greater than the capacity of the bridge. Measurements illustrate that the daily volume of traffic using the First Narrows Bridge is increasing every year and that although the highest volumes occur in the summer months the volumes are constantly high throughout the entire year; that weekday volumes are considerably higher than weekend volumes; and that volumes are greatest on Thursdays and Fridays. (See figures 6-8.)

The peak traffic flows on week days are of major importance because although they occupy only approximately one-quarter of the total time period each day, almost one half of the traffic crosses the inlet in this period. (See Figure 9.)

These high volume peak periods make the route unable to handle more traffic due to having reached its saturation volume. These saturation volumes produce severe congestion and delays. The peak period is spread as delays occur between the time when vehicles wish to cross and the time they actually do. Because the growing peak period desire volumes have exceeded the capacity of the route, the length of the congested period is increasing. In 1958 the morning peak period was approximately two hours, currently it is two and a half hours and by 1973 it will exceed

Figure 6

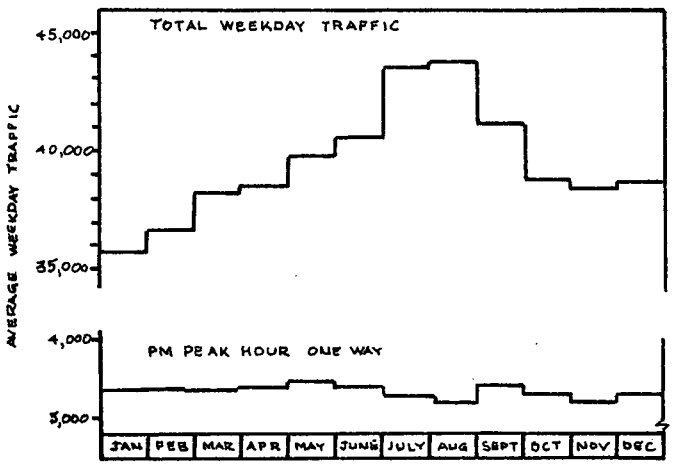
Annual Traffic Growth, First Narrows Bridge




Source: City of Vancouver Memorandum, August 1965

Figure 7

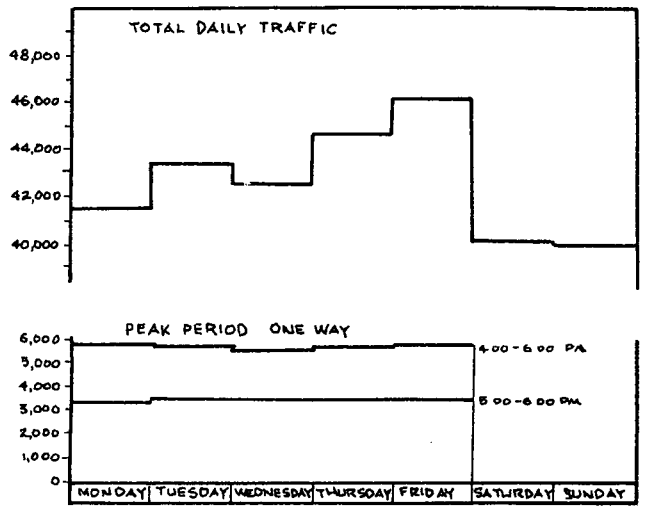
Seasonal Variation In Traffic Flow
First Narrows Bridge




Source: B. C. Dept. of Highways - Bridge Patrol 1964

Figure 8

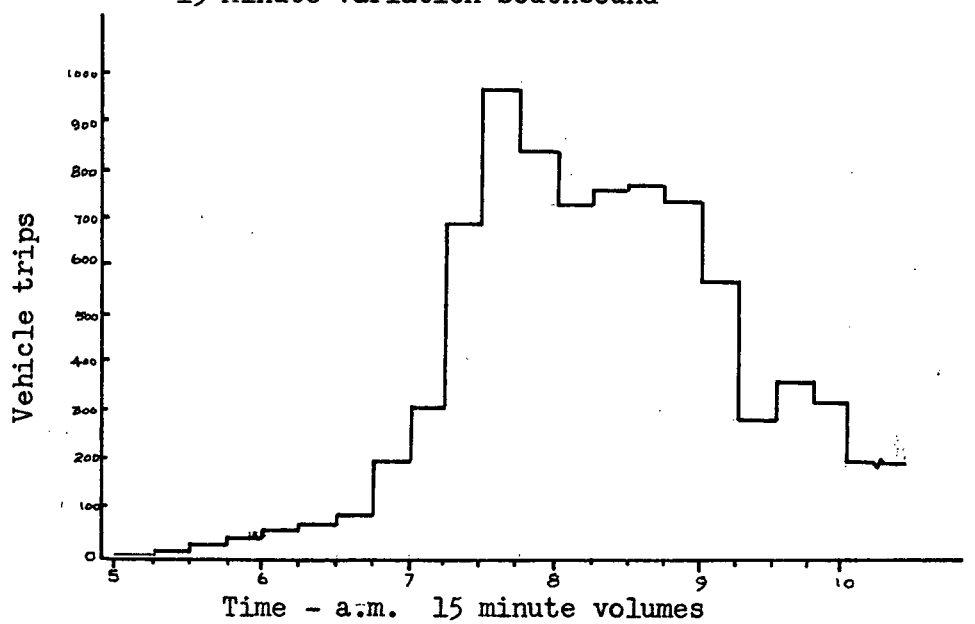
Daily Volume Variation, First Narrows Bridge




Source: City of Vancouver Memorandum - August 1965

Figure 9

15 Minute Variation Southbound

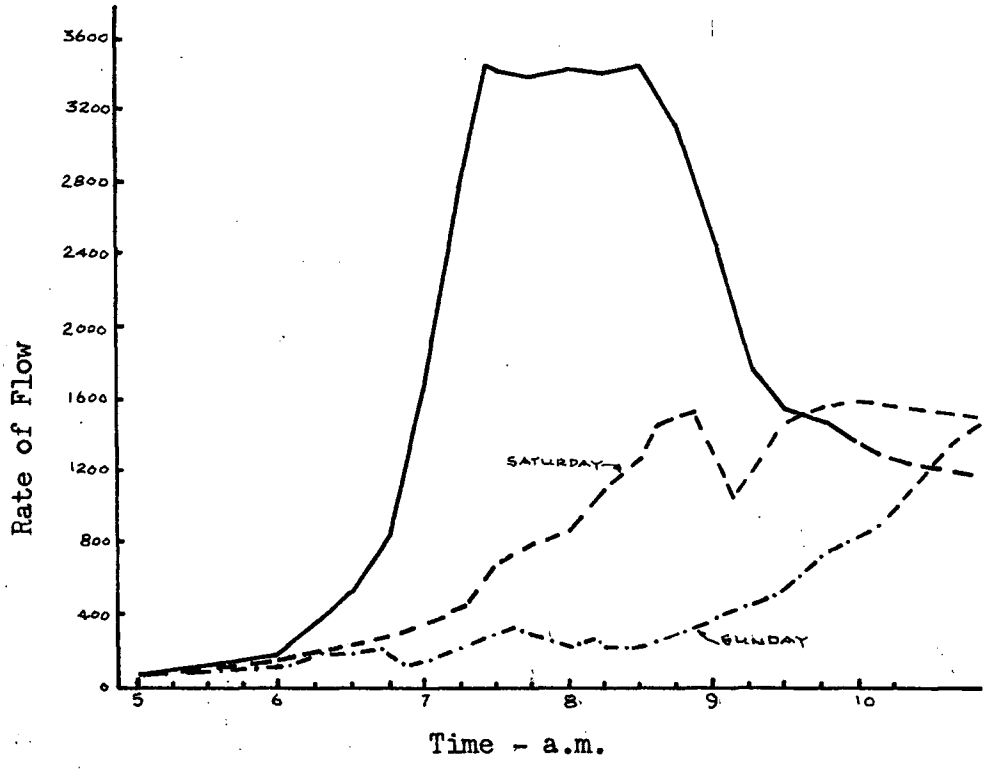



Source: City of Vancouver Measurements, August 18, 1966

three hours.[11]

Within the peak period, short term fluctuations in flow were investigated to examine the effect the capacity restraint of the existing route. Fifteen minute rate of flow measurements, show that the First Narrows' maximum peak hour capacity is actually the one hour maximum volume of the route. (See Figure 10.)

Figure 10




Morning Peak South Bound

Source: N. D. Lea, February 4, 1967 to February 10, 1967, Traffic Count.

The peak hour capacity as defined represents the maximum rate of flow which can be maintained for 60 minutes. At the time of measurement (January-February 1967) this was approximately 3400 vph at 25 mph

---

[11] N. D. Lea and Associates, op. cit., p. 5.

south-bound in the morning peak period.[12] Because 3400 vph is the capacity volume which can be maintained over a considerable period of time it is designated as the critical level of supply. This capacity is not a fixed quantity but varies slightly with weather and lighting conditions, traffic characteristics and operational control. Some consistency in maintaining high capacity has been achieved by improving operations, including lane signals and police control.[13]

It is important that all possible measures are utilized to maintain the highest feasible rate of flow across the bridge during the peak periods. This highest rate is in the region of 1800 vph per lane and is usually maintained for about a quarter of an hour at the commencement of the morning peak period. See Figure 9 (7:30 a.m. to 8:00 a.m.). Thereafter congestion occurs and the rate falls. Sometimes the reduction in the rate of flow is due to an accident or a disabled vehicle in the traffic stream, but often it is caused by an intrinsic breakdown in the flow conditions.[14]

Traffic congestion is the most frequent cause of low speeds and reduced rates of flow at the First Narrows, rather than poor alignment, narrow lanes, or intersection controls.[15] A single vehicle on the bridge could maintain a speed related to the speed limit and the physical restraints of the roadway itself. As additional vehicles enter the critical section, volume increases and density increases without much variation in speeds until a density is attained where individual drivers

---

[12]N. D. Lea and Associates, op. cit., p. 10.

[13]Ibid., p. 12.

[14]Ibid., p. 26.

[15]Ibid., p. 17.

become concerned with other vehicles and thereafter congestion results.[16]

With regard to the bridge, Lea's report suggests the important point about this process is that an external event (a breakdown, accident or pedestrian) is not needed to trigger the critical stage. All that is necessary is for a group of closely following vehicles to pass through a section in which each slightly decelerates for any reason such as the natural fall in speed of vehicles on the 5 per cent grade on the bridge. With closely following traffic the effect of slight deceleration is cumulative. After enough vehicles the speed and spacing is such that a positive deceleration by braking is required in order to prevent collision. This is the commencement of a shock wave of stoppages often described as a concertina traffic flow. The traffic flow through the roadway from this time onward is limited by the rate at which vehicles can accelerate from a standing start. In practise this flow is lower than is attained when traffic speeds are maintained. This loss of flow can be reduced by controlling traffic into the critical road section when necessary in order to prevent shock waves.[17]

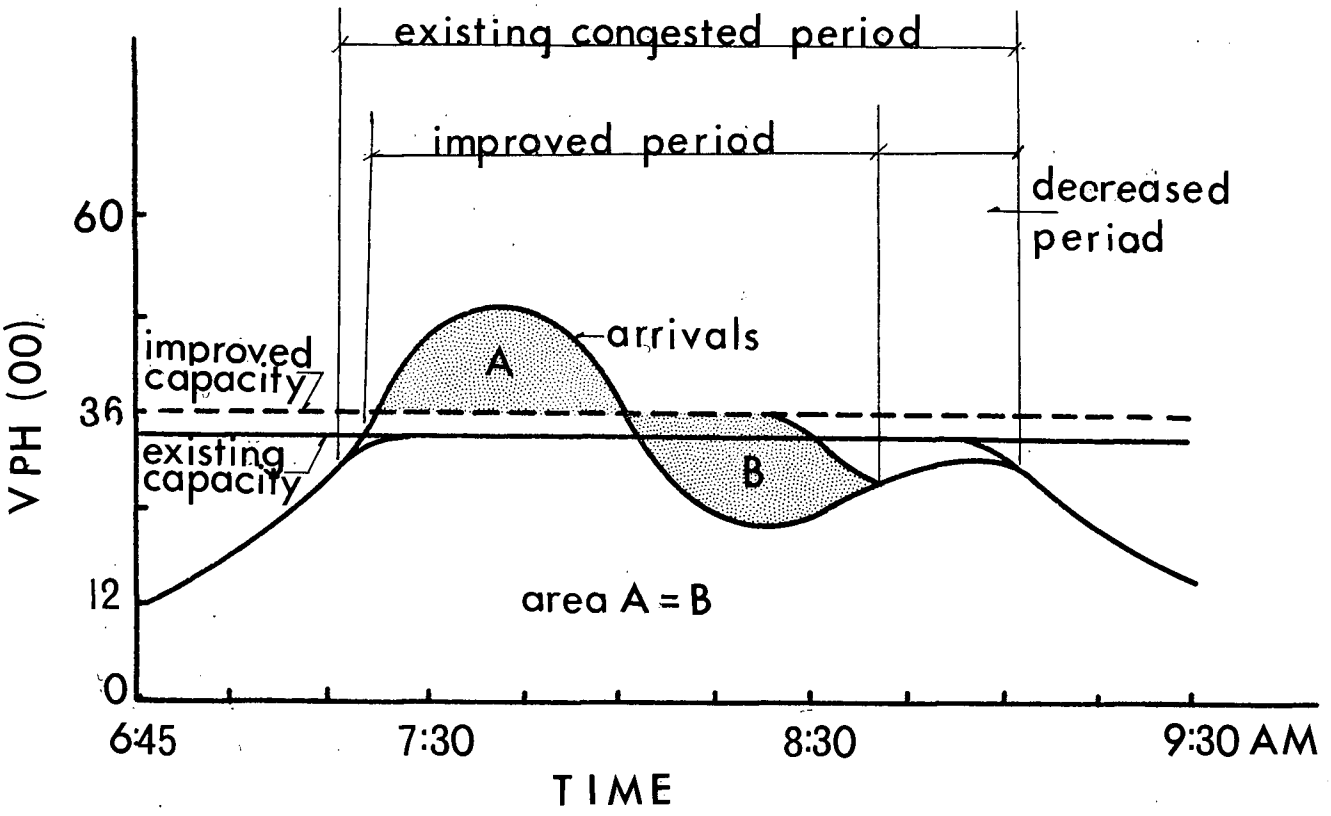
A secondary effect of staggering work hours may be in its effects of controlling traffic into the critical road section and thereby avoiding the "concertina effect." If it were possible to control the amount of traffic into the critical road section so that the highest 15 minute volumes could be maintained for a longer period of time, there would result an improvement in capacity and a reduction of the congested period. (Figure 11 is a hypothetical example.)

---

[16] N. D. Lea and Associates, p. 17.

[17] Op. cit.

Figure 11




Reduction of Congestion Due to Increased Capacity

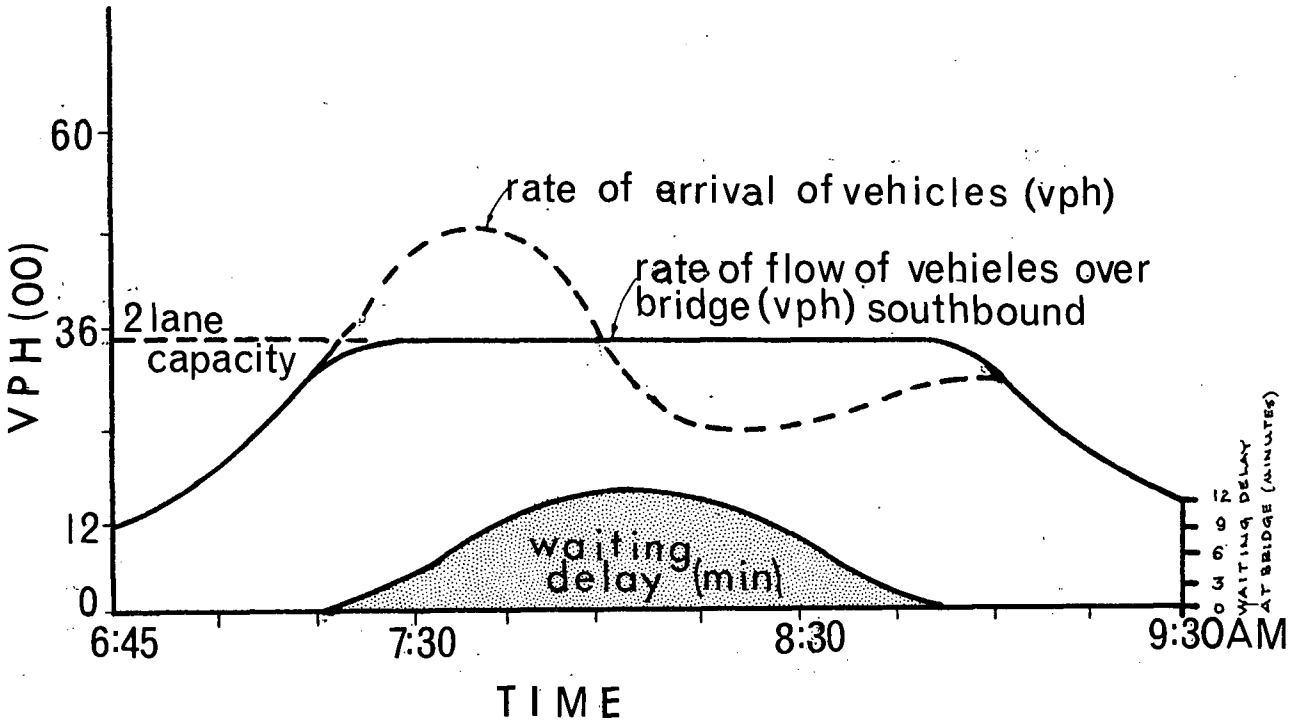
Figure 11 shows superimposed on the present arrival and capacity graph the effect of a small increase in capacity. This capacity increase has produced a significant reduction in the length of the congested period.

The existing relationship between the rate of traffic arrival and the rate of flow at the bridge is shown in Figure 12. Plotted on the graph is the rate of arrival of vehicles at the entrance to the bridge on an average day in the morning peak period and is based on field measurement.[18]

---

[18]N. D. Lea and Associates, p. 40.

Figure 12




Peak Direction Flow on First Narrows Bridge

The maximum capacity sustainable flow of the bridge is shown by the flattening out of the rate of flow line at about 7:20 a.m. and from this period until 8:00 a.m. more vehicles are arriving than can be accommodated on the bridge lanes. Thereafter the rate of arrival or demand drops below the bridge capacity and the back up of waiting vehicles begins to reduce. The waiting delay curve is directly related to the difference in the rate of arrival or demand and capacity and is shown in Figure 12 also. At the present capacity of the bridge (3400 vph) it is calculated that the average vehicle delay is equal to six minutes, the approximate

maximum delay is equal to 12 minutes and the total delay is equal to 36,000 vehicle minutes.

Once the critical level is determined, the supply is known, and through actual volume counts the peak period demand is known. Given the fact of a limited capacity of 3400 vehicles per hour, the morning peak period demand will be re-assigned in deadline demand segments to the facility in accordance with its capacity; thereby eliminating the existing delay time.

A study of the C.B.D. of Vancouver indicates a number of zones which can be generalized as having a dominant function and for which is known the peak period demand for movement into these zones via the First Narrows Bridge. It is proposed that work starting times in the C.B.D. can be staggered using the above-mentioned zones as control areas. (See Figure 13.)

In the C.B.D. zones designated as control areas are concentrated the administrative offices of a great variety of financial and commercial establishments, and the headquarters of many offices and trade organizations together with extensive facilities for shopping and amusement. All these activities contribute to the peak period flow of vehicular traffic.

The flow destined for these areas was computed from a survey conducted by N. D. Lea and Associates, in which they attained the destinations of the peak period flow across the bridge. The nine traffic zones which they differentiated in the C.B.D. were grouped, for the purpose of this thesis, into four control zones. The total flow into these four areas is 4503 vehicles during the peak period on an average day: 1560 destined to the office zone, 981 to the financial zone, 1611 to the retail recreation zone and 351 destined to the wholesale - warehouse zone. (See Figures 13 and 14.)

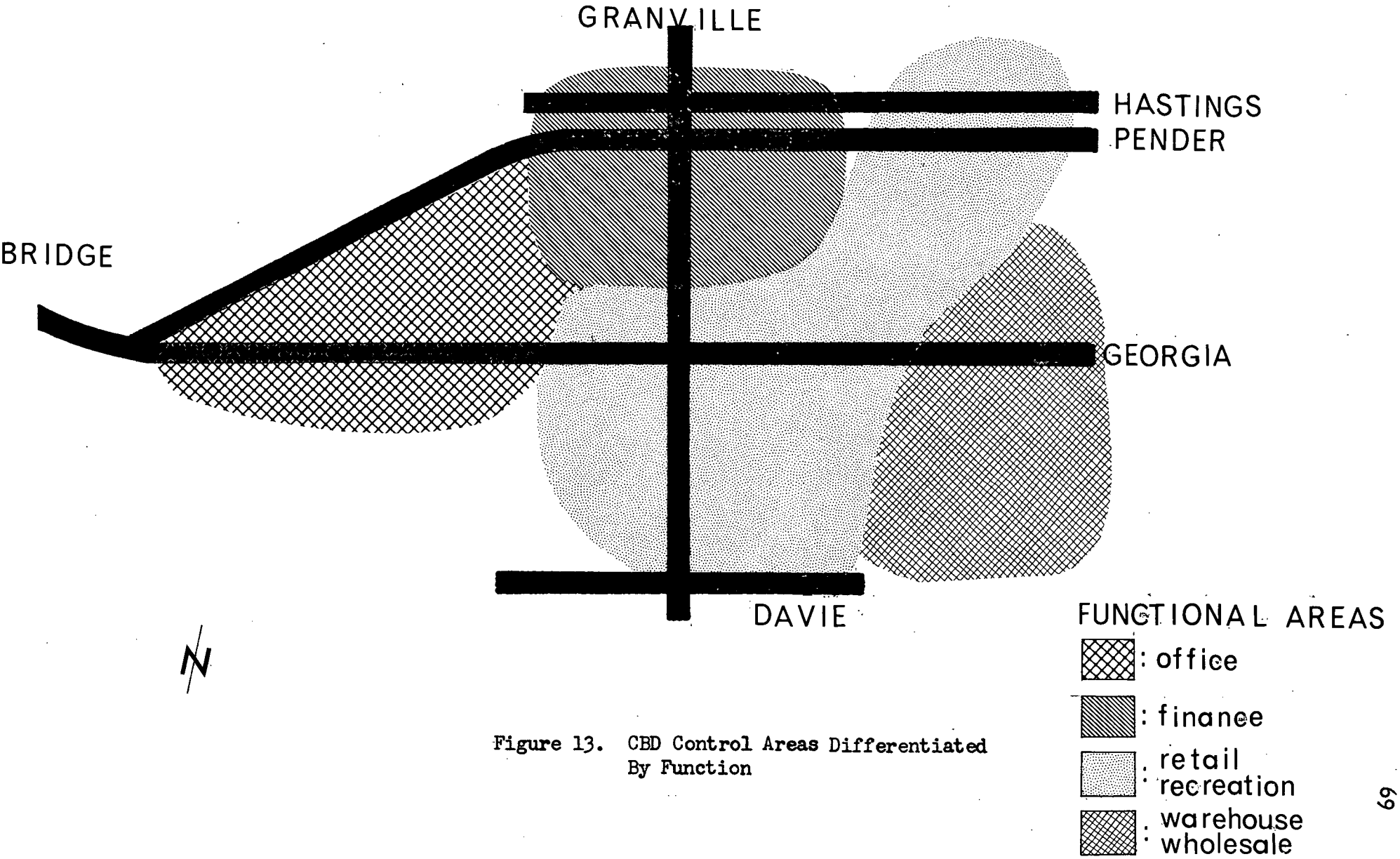



Figure 13. CBD Control Areas Differentiated By Function

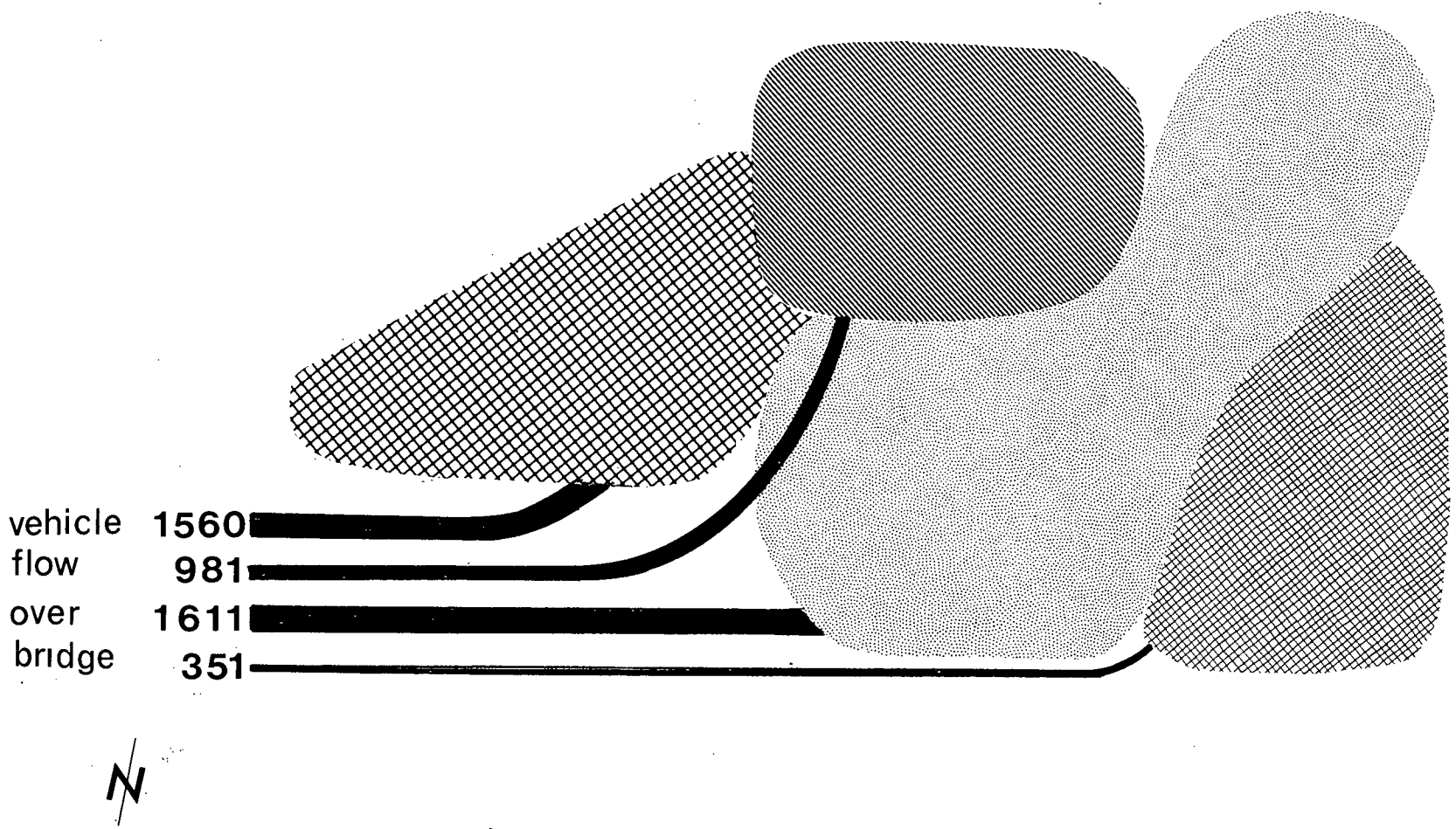



Figure 14. Morning Peak Period Vehicle Flows Across the First Narrows Bridge Destined to CBD Control Areas

In determining these zones it was assumed that there is a tendency for businesses with similar interests and functions to concentrate in particular areas of the C.B.D. It was also assumed that within these areas there exists some homogeniety of work starting times. Therefore it was concluded that by staggering the zones as illustrated by Figure 13, the minimum amount of disruption in the functioning of the C.B.D. would occur.

To minimize the disruption of the staggering of starting times, the order in which the zones are staggered is important. For example, if the financial zone was started first this would give them an increased amount of time in which they could deal with the Eastern financial interests, then if the office zone was started next, the interrelationship between the financial zone and the office zone would not be lagged for a large amount of time. If the wholesale - warehouse zone was started next it could be ready to supply the retail - recreational zone by the time it started. By starting the retail - recreational zone last it would allow all of the traffic destined for the C.B.D. to be off the road and at their destination before the shopping trips began. It would also allow the retail stores to remain open later at night, to the advantage of the other worker-shoppers in the C.B.D.

Accepting the above rationalization of zone starting time orders, the capacity of the Bridge and the flows into the four zones, Table 7 can be calculated.

Column one, Table seven, is the control area starting order based on the starting order rationalization. Column two shows the total volume demand broken into smaller demand segments destined to each control area (Figure 14). By breaking down the total travel demand into smaller segments as illustrated in column two, and assigning each volume to the

TABLE 7

Work Starting Times

| 1<br>Control Area Starting Order | 2<br>Traffic Flows Destined to Each Control Area (Fig. 11) | 3<br>Time to Accommodate Demand Segment to Each Zone (minutes) | 4<br>Time of Arrival at Bridge Approach For 1st Car of Deadline Demand Segment | 5<br>Time of Arrival* At Work Destination For Last Car of Deadline Demand Segment (work starting times) ** |
|---|---|---|---|---|
| 1. Financial | 981 | 17 | 7:33 | 8:00 |
| 2. Office | 1560 | 27 | 7:50 | 8:27 |
| 3. Wholesale-Warehouse | 351 | 4 | 8:17 | 8:31 |
| 4. Retail-Recreation | 1611 | 29 | 8:21 | 9:00 |
| Total Demand | 4,500 | | | |

* It was assumed the travel time from the approach of the bridge to any zone is the same and for this study the travel time was assumed to be ten minutes.

** This time span analysis does not account for the volume of flow destined outside the C.B.D. Because the major destination is the U.B.C. this could be classified as another control zone and be given a starting time at either end of this range. This would account for 97 per cent of the traffic volume.

existing facility in accordance with the capacity of the facility* the amount of time needed to satisfy each segment demand can be determined. Column three is the time in minutes that are needed to accommodate the flows to each control area, given the limiting capacity of the bridge (3400 vph). Column four is the calculated time of arrival at which the first vehicle of each demand segment must enter the bridge approach, to ensure a steady continuous flow and column five is the calculated starting times, or staggered hours programme. By staggering the work starting times by the amounts shown in column five the demand to each control zone destination is equated to the supply or capacity. By this method the total amount of vehicle delay time, at the approach to the bridge will be eliminated, resulting in a user benefit savings of 36,000 vehicle minute delay time which presently exists.

Therefore by staggering working hours as a regulatory device for equating demand with supply, the total peak period congestion delay time due to the limiting capacity of a facility can be eliminated - thus substantiating the hypothesis.

From this case study there seems to be definite evidence that a staggered hours program is feasible and the results could be highly beneficial.

---

* It is realized that this capacity figure should not represent the total capacity of any particular part of the system for in most cases there is a substantial proportion of peak hour traffic which can not be directly affected by the staggering of working hours. This proportion would include traffic which is on the network for other purposes than work trips, i.e., shopping, school, social trips, etc. In addition, there is work-oriented traffic with origins at smaller employment places which also could not feasibly be included in the plan. In this study this problem did not arise because 97 per cent of the peak hour demand crossing the First Narrows Bridge is destined to a work destination and can therefore be directly affected by the staggering of work starting times.

# SUMMARY AND CONCLUSION

Traffic congestion is and may continue to be one of the most critical problems associated with living and working in our cities. The major urban transportation movements, to work and to shop, are largely an experience to be done with as quickly as possible; speed becomes a prime objective and traffic congestion, which slows movement, the major problem.

Traffic congestion itself is unlike most other city problems primarily because it is usually not continuous. Today as in the past there has been serious overcrowding of the street facilities during the peak period. The prospect of relief from this condition is not in sight. Peak period traffic demand, which is mainly a function of the journey to work, is the major cause of traffic congestion. At other times during the day or night the street system is generally capable of handling the demand.

Chapters IV and V of this thesis illustrated a method of relieving peak traffic congestion by staggering working hours and have demonstrated that this method is one means of improving the ability of the individual motorist to travel more economically and at a higher rate of speed.

This method evaluated the effects of staggered working hours on a specific transportation route, the First Narrows Crossing, in quantitative terms. It determined the extent that traffic loads need be distributed over a period of time and the amount of time needed to effect economies in the level of service.

The case study considered only the morning peak traffic volumes destined to a limited number of work zones in the C.B.D. The work zones were functionally differentiated so as to minimize the amount of disruption due to the staggering of working hours. The traffic volumes destined

to each zone were compared to the practical capacity of the facility and the time needed to accommodate each zonal volume was computed. The zones were then staggered accordingly. It is the author's conclusion that the staggering of working hours is one solution in reducing peak period transportation congestion.

The solution to the transportation problem is basically an economic problem. Given the technicians, and a sufficient supply of land, labor and capital, the congestion problem can be alleviated. The critical factor in carrying out the transport policies necessary to meet the stated objectives is thus the process of choosing among alternative possibilities to find the method of achieving the desired end at the least economic and social cost.

In recent years several methods have been employed or suggested to reduce traffic congestion. Using the explanation of traffic congestion that the traffic system is inadequate, the most effective solution is to increase the physical capacity through the construction of new high speed, high volume facilities.

Although movement facilitating improvements are under way or planned, it is unlikely that the available financial resources will permit the building of new facilities or the carrying out of improvements on a scale that would appreciably relieve overcrowding during the peak period.

Looking at the problem from the viewpoint that the demand for service is excessive has yielded other methods of reducing traffic congestion. One of the most promising of these methods is proper land use planning and control. While land use planning has several objectives, one of the most important is the reduction of travel demand in congested areas by grouping land uses in such a manner so as to eliminate cross movement. Although this method yields benefit in new and rapidly developing

areas, the benefits in older and more densely developed areas are necessarily slow and do not affect a large number of people. Because of the limited effect of this approach it should in the short run, assume less importance.

Another method similar to land use planning and control (in that it views the problem as one of excess demand) is the staggering of working hours. The purpose or goal of staggered working hours is to reduce the magnitude of the peak, thereby easing the congestion problem while using the limitations of the current, nearly fixed stock of transportation facilities.

There are therefore two alternatives available, in different degrees, to provide the needed transportation. For any given system one may stagger working hours to such an extent as to allow each worker to use his desired routing at a higher level of service. Secondly, an optimal solution could be obtained in increasing the capacity on any given route such that the supply or capacity would be sufficient to satisfy the highest peak demand.

The results of this thesis have illustrated that the first alternative is effective from a scheduling standpoint in reducing congestion. However, little is known about the costs which would be generated by such a system. The second alternative is what is essentially happening on our urban transportation networks. Although cities are presently working the second alternative, it must be realized that the needs of a transportation system can be satisfied through either.

By making any proposal for traffic improvements to the C.B.D., the broad assumption is made that our cities are worth saving, which is another way of saying that the net benefits of trying to improve present urban centers exceed the net benefits of scrapping them and building new centers. Secondly, the renovation and improvement of urban transport systems are a

vital part of preserving our cities. Thirdly, that the policies adopted should aim at an optimum combination of alternatives that will produce a desired result at the lowest cost to society.

In adopting any alternative there are numerous and varied implications, of either proposal. Some of these implications can be well expressed in both physical and economic terms while others are non-quantifiable.

Undoubtedly an important aspect of any staggered hours plan is the comparison of the costs and benefits the plan produces over the alternative proposal of the addition of new capacity.

While both alternatives may have common goals and equal transportation benefits the costs are not equal or of the same nature. The major costs of staggering hours would be caused by disruption of businesses' external contacts. As the number of business hours in common are reduced the costs of doing business are increased. If a significant increase in the cost of doing business results from delay in the transmission of messages and the transactions of exchange, then commuting congestion has been relieved only by intensifying communication congestion.[2] The question then is would a net gain ensue and if so how would the gain be distributed.

A change in an organization's working hous may cause difficulties in recruitment and losses amongst its staff, or tend to diminish a firm's internal efficiency. All of these inconveniences are costs to the firm. These private costs must be weighted against the potential public gains to a travelling public relieved of the costs and inconvenience of congested peak hour movement.

---

[2]Thompson, R. W. A Preface to Urban Economics, p. 334.

The addition of new capacity would be more expensive in terms of engineering works and more expensive in compensation for land acquisition and disruption. The costs of the new facility would be a public cost while the costs of the staggered hours system would be borne by the private sector. The transportation benefits of both alternatives would accrue to the public sector.

The construction of a new facility would destroy the compactness and interrelated land use of the city, whereas a staggered system would leave them physically undisturbed. Through a staggered hours plan the need to supply additional highway or street capacity in the downtown area would be decreased, resulting in both cost and space savings in the downtown area. The city cost savings accruing to the city might well be applied to other non-transportation urban needs.

With respect to street oriented transit operations the improvements in the system through either alternative can be of benefit to transit operations in two ways. The transit operators will benefit from the overall reduction of congestion in much the same way as the auto users. Either alternative will increase the operating speed of the transit vehicles and decrease time losses due to general congestion. But staggered hours will decrease the peak demands for transit at the major generators. This will decrease the general congestion at the major bus stops and allow more orderly efficient operation at these points. Secondly the staggering of hours might enable increased use of transit vehicles. This would be accomplished if one vehicle used during the beginning of the stagger period might return to the major generator in order to obtain a second load of passengers within the staggered time limit. Both these effects which would enable transit operators to improve their level of service could also reverse the trend away from transit. The greater use of transit could

have significant benefits in reducing the number of vehicles in the C.B.D. With a transportation network free of congestion or with reduced congestion, the central city could revitalize and reverse the present downward trends.

With the adoption of a major staggered hours program several other non-traffic aspects of a city's functioning may be favorably affected. Such services as water, sewage, telephone, and other communications services, and electric power could have their peak requirements substantially reduced.

All in all, the rationalization of urban transportation involves a very complicated series of trade-offs between the joint costs of speed, comfort, cost and physical functioning.

The immediate need of transportation improvements is to effect a more efficient flow of traffic, given the existing network of transportation facilities and the existing land use pattern. While more basic long-run solutions are being worked out, the daily problems of moving people and goods must be performed within the limitations of the current, nearly fixed stock of transportation facilities and the current demand for movement originating in the temporarily fixed land use patterns. The staggering of working hours appears to be a suitable short run solution.

# BIBLIOGRAPHY

# BIBLIOGRAPHY

a) Books:

American Institute of Planners. Report of the Planning Policy Committee on Urban Transportation. Washington, D. C. (February, 1964.)

Betz, M. J., Supersad, J. N. A Method of Analysis of Peak Hour Traffic Demand for Effecting a Staggered Hours Program in Urban areas. Arizona, Arizona State University, Engineering Research Centre, 1964.

Canada. Dominion Bureau of Statistics. Canada Year Book. Ottawa, Queen's Printer, 1961.

_____. Economic Council of Canada. Fourth Annual Review: The Canadian Economy from the 1960's to the 1970's. Ottawa, Queen's Printer, (Sept. 1967).

Carll, R. R., Homburger, W. S. Some Characteristics of Period Traffic. Berkeley, University of California. Institute of Transportation and Traffic Engineering, 1962.

Dickinson, R. E., City Region and Regionalism, London, Routledge and Kegan, Paul, 1947.

Fitch, Lyle C. Urban Transportation and Public Policy. San Francisco, Chandler Pub. Co., 1964.

Gallion, Arthur B., Eisner, Simon. The Urban Pattern. 2nd ed. Princeton, N. J., Van Nostrand, 1963.

Great Britain. Ministry of Transport and Civil Aviation. Crush Hour Travel in Central London. London, H. M. S. O., 1958.

Highway Research Board. Highway Capacity Manual (Special Report 87) Washington, D. C., 1965.

Jacobs, Jane. The Death and Life of Great American Cities. New York, Random House, 1961.

Kennedy, N. Major Problems of Metro Transportation. Berkeley, University of California. Institute of Traffic and Transportation Engineering, 1959.

Lapin, H. S. Structuring the Journey to Work. Philadelphia, University of Pennsylvania Press, 1964.

Liepmann, Kate K. The Journey to Work; its Significance for Industrial and Community Life. London, K. Paul and Co., 1944.

Lichfield, N. Economics of Planned Development Walker and Co. Ltd., Twickenham, England, 1966.

Mumford, Lewis. The City in History. 1st ed. New York, Harcourt, Brace and World, 1961.

Owen, Wilfred. The Metropolitan Transportation Problem. New York, Doubleday and Co., 1961.

Santerre, G. L. An Investigation of the Feasibility of Improving Freeway Operation by Staggering Working Hours. Texas, A & M University, Texas Transportation Institute, 1967.

Smerk, G. M. Urban Transportation: The Federal Role. Bloomington, Ind., Indiana University Press, 1965.

Thompson, W. R. A Preface to Urban Economics; published for Resources for the Future. Baltimore, Johns Hopkins Press, 1965.

U. S. Bureau of the Census. Statistical Abstract of the United States. Washington, D. C., Government Printing Office, 1960.

Wingo, J. Lowdon. Transportation and Urban Land. Washington, Resources for the Future, 1961.

Yale University. Bureau of Highway Traffic. The Quality and Theory of Traffic Flow; a symposium by Bruce D. Greenshields and Others, 1961.

b) Articles:

Architectural Forum. "Transportation and the City" (October, 1963), pp. 61-94.

Bartholemew, Harland. "Metro Transportation Problems," American Society of Civil Engineering (Journal of the Urban Planning and Development Division) Vol. 91 (July, 1965), pp. 7-18.

Berman, J., Carter, A. "Increasing the Traffic Carrying Capacity of Urban Arterial Streets," Highway Research Board Bulletin, No. 271 (1960), pp. 1-13.

Betz, M. J., Supersad, J. N. "Traffic and Staggered Working Hours," Traffic Quarterly XIX (April, 1965), pp. 188-203.

Cowderoy, J. E. "Public Co-operation in Transport" Institute of Transport Journal, Vol. 21, No. 14 (January, 1943), pp. 561-66.

Downs, A. "The Law of Peak-hour Expressway Congestion" Traffic Quarterly XVI (July, 1962), pp. 393-409.

Drew, D. R., Pinnell, C. "A Study of Peaking Characteristics of Signalized Urban Intersections as Related to Capacity and Design" Highway Research Board Bulletin, No. 352 (1962), pp. 1-54.

Edie, L. C. "Analysis of Single-Lane Traffic Flow" Traffic Engineering XXXIII (January, 1963), pp. 21-27.

Foley, D. L. "The Daily Movement of Population into Central Business Districts," American Sociological Review XVII (1952), pp. 538-543.

_____. "Urban Daytime Population. . .A Field of Demographic-Ecological Research" Social Forces, 32 (May 1954), pp. 323-330.

_____. "Rapid Progress on Harbour Freeways" California Highways and Public Works (May-June 1954).

Gorman, D. A., Stedman, T. H. "Characteristics of Traffic Entering and Leaving the Central Business Districts," U. S. Public Roads, Vol. 30, No. 9 (August, 1959), pp. 213-220.

Hall, E. M., George, S. "Travel Time - An Effective Measure of Congestion and Level of Service" Highway Research Board (Proceedings) XXXVIII (1959), pp. 213-220.

Hodgkins, E. A. "Effects of Traffic Improvements on Operation of an Urban Arterial Street" Highway Research Board Bulletin, No. 308 (1961), pp. 1-18.

Johnston, W. W. "Travel Time and Planning," Traffic Quarterly X (January, 1956), pp. 67-78.

Mertz, W. L. "A Study of Factors Related to Urban Travel" U. S. Public Roads, Vol. 29, No. 7, (April, 1957), pp. 170-174.

Metropolitan Transportation. "Separate Lanes Speeds Buses Across Bay Bridge," Vol. 58, No. 3, (March, 1962), pp. 24-26.

Moskowitz, K., Neuman, L. "Notes on Freeway Capacity," Highway Research Board Record, No. 27 (1963), pp. 44-68.

Murphy, R. E. "The Central Business District and Its Implications For Highway Planning, Highway Research Board Bulletin, No. 221 (1959).

Rothrock, C. A. "Urban Congestion Index Principles" Highway Research Board Bulletin, No. 86 (January, 1954), pp. 26-34.

Rothrock, C. A., Keefer, L. E. "Measurement of Urban Traffic Congestion" Highway Research Board Bulletin, No. 156 (1957), pp. 1-13.

Ryan, D. P., Brenning, S. M. "Some Fundamental Relationships in Traffic Flow on a Freeway," Highway Research Board Bulletin, No. 324 (1962), pp. 73-85.

Stonier, G. E. "Metropolitan Traffic Crisis" Traffic Quarterly XI (January, 1957), pp. 214-231.

Taylor, S. S. "Freeways Alone are not enough" Traffic Quarterly XIII (July, 1959), pp. 346-365.

U. S. News and World Report "Trouble in Cities" Vol. 48, No. 25 (June 20, 1960), pp. 84-92.

Urban Land Institute. "Crowded Streets," (A Symposium on Public Mass Transportation) Technical Bulletin No. 26 (June, 1955), p. 77.

Vaughan-Birch, K. "Planning For Future Transportation in Central Business Districts of Metropolis Areas," Proceedings of the Institute of Traffic Engineering (1958), pp. 38-52.

Voorhees, A. M. "Forecasting Peak-hours of Travel," Highway Research Board Bulletin, No. 203 (1958), pp. 37-46.

Voorhees, A. M., Morris, R. "Estimating and Forecasting Travel for Baltimore by Use of a Mathematical Model. Highway Research Board Bulletin, No. 224 (1959), pp. 105-114.

Wingo, L. "Measurement of Congestion in Transportation Systems" Highway Research Board Bulletin, No. 221 (1959), pp. 1-28.

Wohl, M. "Costs of Urban Transportation Systems of Varying Capacity of Service" Highway Research Board Record, No. 64 (1965), pp. 1-70.

Wynn, F. H. "Transportation Service to Downtown Areas" Traffic Engineering XXXIII (May, 1963), pp. 14-24.

c) Unpublished Material:

Lea, N. D. and Associates. Measures to Improve Bus Transit and Traffic Flow Across the First Narrows Bridge; done for the Department of Highways, B. C., May 1967.