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THE UNIVERSITY OF ALBERTA

COMMUTING PATTERNS OF WORK TRIPS OF A DORMITORY COMMUNITY

by

© DAVID SIONG-SENG CHIU

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

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FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled COMMUTING PATTERNS OF WORK TRIPS OF A DORMITORY COMMUNITY submitted by DAVID SIONG-SENG CHIU in partial fulfilment of the requirements for the degree of Master of Science.

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J. Bakker (Supervisor)

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S. Teply

....
R. G. McIntosh

Date ...... June 2, 1975

ABSTRACT

This study is an investigation of the commuting patterns and characteristics of work trips originating from a dormitory community, specifically the Town of St. Albert. St. Albert lies ten miles north-west of Edmonton's C.B.D. St. Albert has a population of about 20,000 and provides employment for barely 20% of the total labour force. Recent Origin-Destination surveys in fact indicate that 75% work in the City of Edmonton. This dormitory pattern of the town was found to have remained stable over the years between 1967 and 1974, even though population had doubled in the interim. The data base used in this study was the civic census. Additional questions about work trips were asked in the civic census of 1967, 1972 and 1974.

The 1974 O-D survey data on work trips were also checked to determine any correlation with actual traffic conditions during the morning home-to-work (St. Albert to Edmonton) traffic movement. Comparison was made with the vehicular counts tallied by a traffic counter which was set up just north of the 137 Avenue on Highway 2. It was found that for the cumulative totals between 6.00 and 9.00 A.M., the two sets of data showed fairly close agreement quantitatively (within 10%).

Attempts were made to estimate future growth of St. Albert work trips corresponding to future population levels by means of a simplified prediction model developed in this thesis. What is referred to in this thesis as the "CONGESTION THEORY" was then

applied at these predicted future levels of work trip productions to assess the desired improvement in public transportation. Unless roadway capacity was greatly improved, transit mode split of commuting work trips would need to be substantially increased in order to cope with the ever-growing number of commuters. The "CONGESTION THEORY" rests upon the concepts that starting times of work are relatively inflexible, but as traffic congestion becomes pronounced commuters are compelled to advance their leave-home times in order to arrive at work on time. Congestion is thereby accompanied by a longer auto travel time. To alleviate the problem, better transportation facilities must be implemented. Application of the "CONGESTION THEORY" revealed the future important role played by the public transit (in terms of its share of the work-trip mode split) when the existing roadway capacity was subjected to the limitation of the service volume at service level D, and if the dormitory patterns of St. Albert were to continue.

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1. Alberta Highways and Transport Department, Edmonton

2. Town Hall, the Town of St. Albert

3. Transportation Planning Department, the City of Edmonton.

Gratefully acknowledged is the co-operation given by Mr. L. C. Chen (of the Alberta Highways and Transport) in making available the St. Albert 1974 O-D survey data.

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CHAPTER I

INTRODUCTION

The knowledge of the peak-hour travel patterns is fundamental to the sound planning of a transportation system. So that appropriate transportation facilities can be designed, it is essential that transportation planners and designers will be able to forecast the magnitude of the peak-hour load. By and large, work trips constitute the bulk of the peak-hour travel. Many practitioners in the field of Transportation engineering accept the home-to-work trips as a basis of the morning peak-hour volume estimation (Ref. 1).

Unlike the home-to-work trips, the home-from-work trips are not as rigidly bound by schedule. Some home-from-work trip makers often voluntarily staggered their home-bound journey by either leaving late to avoid the traffic congestion or starting early to "beat" it. Moreover, many such homeward bound trips have various points of call on the way, thus staggering the peak further. However, other trip purposes such as shopping, recreation etc. occur more in the P.M. peak than in the A.M. peak. Some traffic counts carried out on the St. Albert-Edmonton corridor indicated that the weekday A.M. and P.M. directional peak hour volumes agreed to within 5% to 15% (usually to within 10%). This is shown in Appendix E.

The work trip information obtained from an Origin-Destination (O-D) survey can aid as a good tool in peak-hour volume estimation. In his thesis project (1970), Ng performed a study of the work trips bound for the Edmonton's Central Business District (C.B.D.) between 7.00 to 9.30 A.M. A comparison of the results obtained from the 1967 O-D data and that obtained from the cordon count indicated that the volume of work trips from the O-D data accounted for 86% of the A.M. peak volume obtained from the actual cordon count; but he further cited that there were strong quantitative indications to suggest the O-D survey as having been made on only 85% of the population (Ref. 1).

Certain distinctive characteristics of the work trip movement together accentuate the acuteness of the peak-hour problems. Among these are its regularity in performance, its occurrence concentrated within a short time period, and then also within a limited space at each employment centre. Many employment centres are closely grouped together. Furthermore, the occurrence of work trips increases quantitatively as a function of the growth of the community. The study of the work trip characteristics and movement is, therefore, of paramount importance.

The focus of such component of study in this thesis is on the Town of St. Albert. A satellite town of the City of Edmonton, St. Albert is located some ten miles north-west of Edmonton's C.B.D. (see Figure I - 1). Several factors inherent to St. Albert combine to pose growing problems to the transportation of the town. Among these noticeable factors are: (1) its lack of local employment,

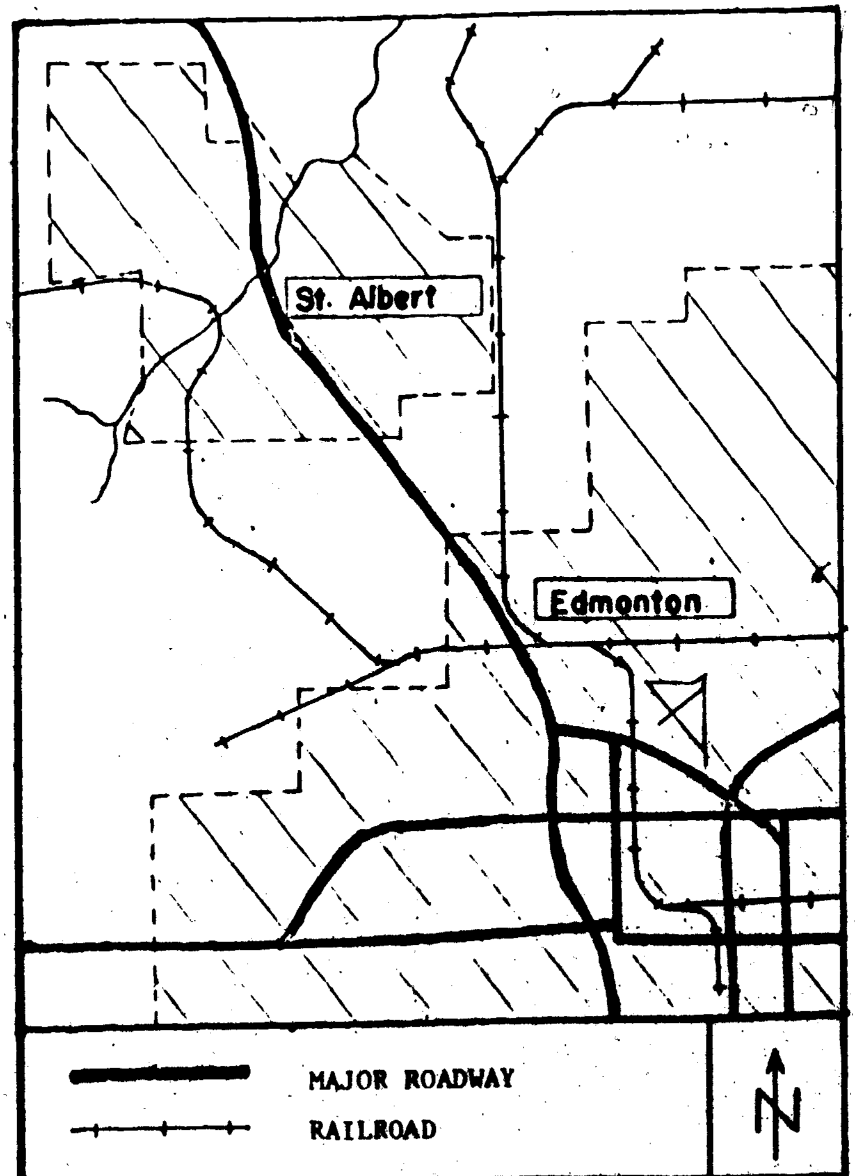

FIGURE I - 1: ST. ALBERT AND NORTHWEST EDMONTON

(2) its rapid growth, (3) its lack of shopping opportunities and (4) its proximity to the City of Edmonton. The rapid growth of population of St. Albert is portrayed in Figure I - 2, which shows an almost doubling of population in the last half decade between 1969 and 1974.

Typical of most transportation problems, the journey to work (work trips) is a major concern. Because most jobs start and end at the same time, this high volume of traffic is necessarily and inevitably concentrated over a short time period. To add to the other deterrent factors just cited, a recent survey indicates that approximately three quarters (75%) of the workers living in St. Albert are employed in Edmonton as opposed to only 20% within St. Albert itself; thus makes it what is generally referred to as a dormitory community for Edmonton. Moreover, in terms of highway facilities, presently only one major highway (Highway 2) connects St. Albert and Edmonton (see Figure I - 1), and it is only via this access that the major inter-city traffic flow is accommodated. Thus, St. Albert work trip makers concentrate not only in time, but in space as well.

1. STATEMENT OF THE PROBLEM

This thesis deals with the investigation of the characteristics of the commuting work trips of St. Albert and a study of the trends of the dormitory patterns of the community. It is desired to find out whether or not the commuting patterns of the dormitory

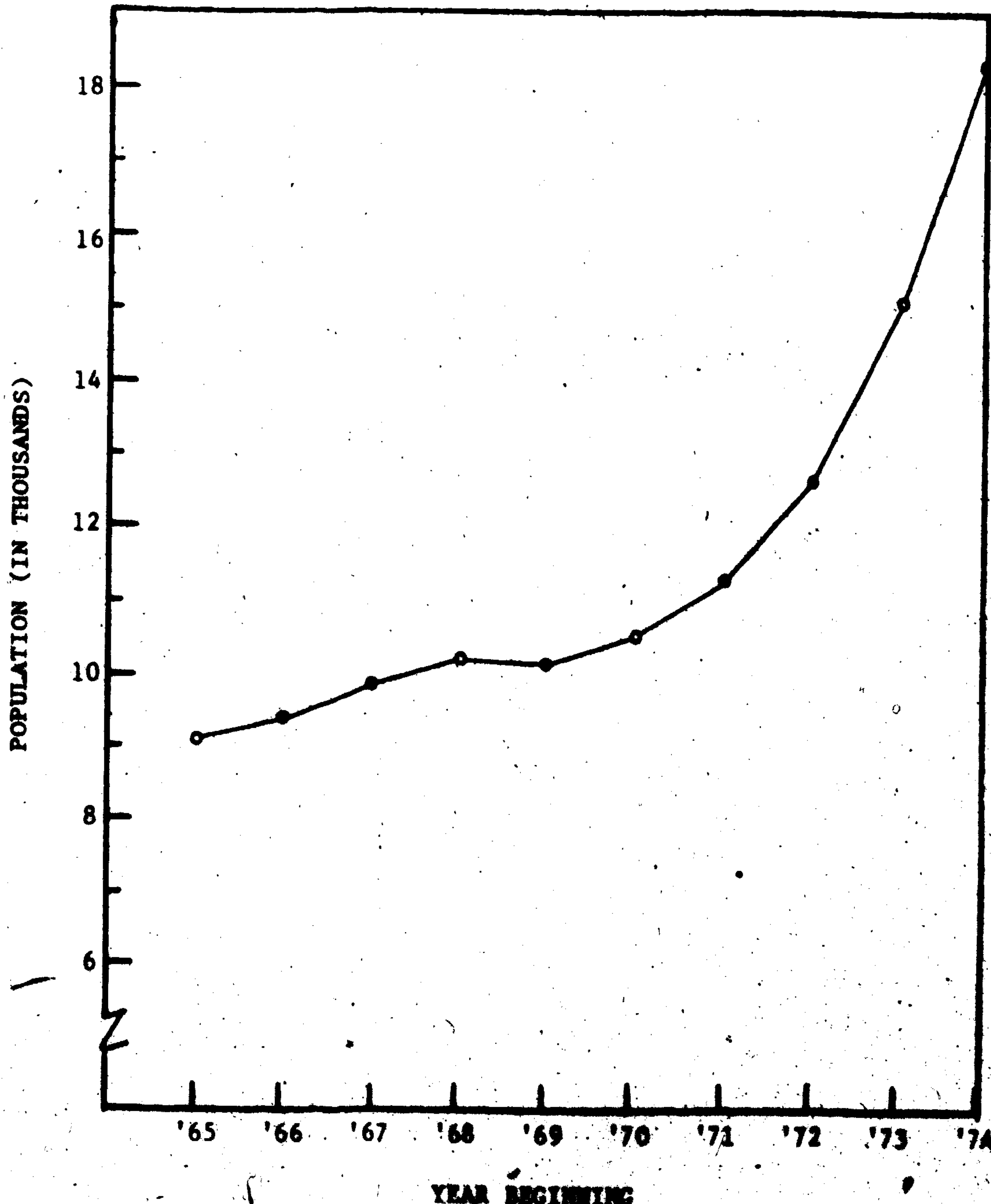

FIGURE I - 2: POPULATION GROWTH OF ST. ALBERT town of St. Albert are stable with respect to population growth, particularly whether or not the percentage distribution of St. Albert work trip destinations is stable as its population grows. Work trip information collected in the 1974 O-D survey (see Appendix D) is compared with data gathered in previous years.

Investigations will also be extended to the study of the reliability (or otherwise) of the O-D work trip information as means of relating to the A.M. traffic movement from St. Albert to Edmonton. Attempts are made to develop a work-trip prediction model by the simple regression analysis method; and for a representation of the single variable of the prediction equation, a choice will be made between the variable household and the commonly used population. The choice is based on the indications of superiority (in predicting) of one variable over the other. This will be documented.

What is referred to in this thesis as the "CONGESTION THEORY" has been hypothesised with two intentions in mind: (1) to demonstrate the applicability of the theory to the real situations of St. Albert in showing future travel demand and, hence, the needs in the future for improved inter-city transportation facilities if the dormitory town of St. Albert were to keep growing, and (2) to assess the desired improvement in public transportation in terms of an increase in mode split by transit should roadway capacity not keep pace with an increase in traffic demand. St. Albert work trip productions will be estimated corresponding to some future population levels. The problem is to assess the transit mode splits of the St. Albert-to-

Edmonton work trips at these population levels. This will be estimated on the assumption that the existing Highway 2 will neither deteriorate nor be improved upon as regards to its traffic carrying capability.

2. SOURCES OF THE DATA

The study carried out in this thesis is based heavily on the data collected in the Origin-Destination surveys. The home-to-work Origin-Destination surveys by mode were taken as part of the St. Albert census in January of 1967, 1972 and 1974. The door-to-door surveys were conducted by the Town of St. Albert. A questionnaire form used in the 1974 O-D survey of St. Albert is shown in Appendix D. The preliminary results of the 1974 O-D survey have been made available to the author by the Alberta Highways and Transport Department, Edmonton.

3. LIMITATIONS

While this thesis investigates work trip characteristics and commuting work trips of a dormitory community, it has limited its study to the community of St. Albert only. Any conclusions drawn, therefore, may not necessarily be applicable to other dormitory situations. The January 1974 O-D survey made use of the division of St. Albert into 24 areas called polling divisions. For the sake of simplicity and convenience, these "polling divisions" will hereinafter be referred to in this thesis as simply "zones". The preliminary results of the 1974 O-D survey on which this study heavily relies, unfortunately, are not comprehensive in that they represent only eighteen of the twenty-four zones within St. Albert. It was learned that the data from six zones was inadvertently destroyed by the Town prior to analysis.

Although the later portion of this thesis attempts to examine the implications on transportation demand of the future commuters' work trips to Edmonton, no intention whatsoever is implied to draw conclusions concerning any specific approach - be it roadway expansion or improved transit system - most feasible and best suited to satisfy the demand. Furthermore, this part of the study has been confined only to the A.M. home-to-work trips using Highway 2 and destined for Edmonton.

The low 4% mode split by transit of St. Albert work trips as was obtained from the January 1974 O-D survey may have been partly due to the unattractiveness of the transit service at the time. In January of 1974 (when the survey was conducted) the St. Albert-Edmonton transit service was operated by Western Bus Lines, a private operator. The service was inadequate and unsatisfactory. The operator faced the situation in which the operating costs exceeded revenues. The Town Council of St. Albert refused to subsidize a private operator. In February 1974 Western Bus Lines notified the Town that it would cease bus service to and from St. Albert on April 1, 1974. Subsequently, therefore, the St. Albert-Edmonton transit service was taken over by the Edmonton Transit

Service; and since April 1974 bus patronage has steadily increased.

A final note worth mentioning is that in this thesis whenever the term "work trips" is encountered, unless otherwise stated, it is taken to mean the inclusion of trips made by students attending school, N.A.I.T. or the University in Edmonton while residing in St. Albert. This is due to the original analysis of the O-D survey data, in which no attempts were made to separate these student trips from actual work trips.

CHAPTER II

REVIEW OF PREVIOUS WORK

Though major transportation studies on St. Albert have been minimal, voiced appeal for improved inter-city transportation facilities is by no means unheard of. On July 31, 1972, a report prepared by Councillor Bakker (Ref. 2) was presented to the Town Council to give background information on the St. Albert-Edmonton bus services. The deficiencies and inefficiency of both the intra-city service within St. Albert and the inter-city service were duly cited. Proposals for improved system and better standard were presented and a cost estimate amounting to a deficit of over $200,000 per year was worked out. More than a year later, in November 1973, with growing concerns about the transportation needs between St. Albert and Edmonton, the Town submitted to the Provincial Government a brief regarding St. Albert-Edmonton transit service (Ref. 3). As Bakker in his report on "St. Albert Transit 1974" puts it (Ref. 4): "This brief was instrumental to make the Provincial Government more aware of public transport needs and that the problem of transit was not confined to big cities alone."

MISSISSAUGA, ONTARIO

A recent study was conducted on the commuting problems of the City of Mississauga (Ref. 5). This survey had indicated that 75% of the City's labour force consisting mostly of white-collar workers found employment in Metropolitan Toronto. On the other hand, the industrial or blue-collar occupations in Mississauga attracted a significant number of persons outside the City, mainly from Metropolitan Toronto. The primary focus of the study was on commuting between Mississauga and Metropolitan Toronto. Four scenarios for the development of Mississauga to the year 2000 were dealt with. These scenarios are briefly described in the following:

1. A balance in white-collar employment and labour force.

2. A trend towards the dormitory situation, with white-collar labour force exceeding white-collar jobs available.

3. Pure dormitory situation, with white-collar labour force substantially greater than white-collar jobs available.

4. A trend towards a dormitory community.

Scenario 4 differs from Scenario 2 only in the level of employment. Scenario 2 has total labour force equalling total employment, whereas in Scenario 4 total labour force exceeds total employment available.

A transportation model was developed to determine the transportation implications of the four scenarios. The major conclusions of the analysis stated the following:

1. "Changing the composition of employment within reasonable limits has less of an impact on travel demands than do changes in level of employment."

2. "Providing high levels of employment and a balance between labour force and employment is expected to result in about a 20% reduction in peak directional travel demands, when compared with a more dormitory type development."

3. "The reduction in travel demand through balanced development can be translated into capital cost saving in the order of $150 million for regional transportation facilities between Mississauga and Metropolitan Toronto."

RESTON, VIRGINIA

In the past few years the unique demand-response systems known as commuter bus club operations have aroused nationwide interest in the United States. Such operations involve chartering of buses from the bus operator by the commuters for transportation to the areas of their employment. Commuters and users of the service, rather than the bus operator, determine the schedule, pick-up route and drop-off points. This is one element distinguishing such operations from normal bus transit service. An example of one such successful operation is the Reston Commuter Bus, Inc. (Ref. 6).

When the Reston commuter bus club was initiated in 1968, the population of Reston (in the State of Virginia) was only about 3,000. The residents of Reston are affluent people. Reston is located some 25 miles from the District of Columbia's Central Business District, but Reston residents who had to commute to work in Washington, D.C. at the time were faced with the inadequacy and inefficiency of bus service. Commuting workers had no alternative to the automobile. In March 1968, a group of volunteers, the Reston Community Association, initially chartered one bus from the bus operator. Pick-up route within Reston and drop-off places within D.C. were determined by these commuting "professionals". In light of the success of the operations, additional buses were subsequently put on as soon as revenues exceeded break-even point by a minimum amount. Eventually in late 1971 the volunteer group incorporated as the non-profit Reston Commuter Bus, Inc. (RCB) which runs and decides issues relating to the service.

A survey on commuting patterns conducted in September of 1970 indicated that of the total Reston commuters, 13.4% used the bus, 71.5% were auto drivers, while 12.3% used car pools. However, considering only commuting trips to employment areas that were served by the Reston buses, the analysis disclosed that approximately 35% of the commuters were bus riders (one out of three commuters)! Users of the bus service could by no means be termed captives. Survey in January 1973 showed that only 18% of the bus commuters reported that an automobile was not available for their work trips, while average licensed drivers numbered 2.06 per household and average household income amounted to $24,800 per year.

PHILADELPHIA - LINDENWOLD, N.J.

Numerous reports have been written about the remarkable achievement of the Philadelphia-Lindenwold Hi-Speed Transit Line (Ref. 7, 8, 9, 10, 11, 12). Its success demonstrates that standard transit modes can successfully compete with alternatives available to commuters who travel downtown from the suburbs if they are adequately financed, modern and well-operated.

The highly automated Lindenwold line (opened in February 1969) runs 14.5 miles in total from suburban Southern New Jersey bedroom communities to Philadelphia's city centre. There are 12 stations in all - 6 in N.J. suburban areas, 2 in the City of Camden, and 4 in Philadelphia. Although some feeder buses have recently been introduced, access to the stations is predominantly by automobile from the relatively low-density areas the line serves. Actual running time to travel the length of the line (14.5 miles) from Lindenwold, N.J., to the city centre of Philadelphia is 22.5 minutes. For comparison with the other competing modes, travel times for automobiles and buses are 45 minutes and 60 minutes respectively. Indeed, the attractiveness of the transit to the commuters is shown by the rapid rise in patronage. From an initial level of about 15,000 rides per day in February 1969, patronage doubled in about a year to 32,000 rides per day in April 1970. With increases in parking facilities at suburban stations, patronage had reached 34,000 by November 1970. The figure had jumped to 37,000 rides per day by the end of 1971. The average weekday patronage in 1972 was near 40,000.

Total annual patronage in 1973 was reported to be 10,127,076, while in 1974 it was 11,110,112.

Prior to the Philadelphia-Lindenwold Line, public transportation service in the area consisted of two railroad lines, the Camden Bridge Hi-Speed Line and some 49 bus routes operated by six private companies. Declining patronage was suffered by all three modes. The implementation of the most modern and fully developed Lindenwold Line was primarily to connect suburbs with the metropolitan hub. Its continuing success in providing service to commuters and in relieving peak traffic volumes (particularly on the Ben-Franklin Bridge) (Ref. 10) is, indeed, "one of deep significance for the future of commuters everywhere".

SHAKER HEIGHTS, OHIO

Shaker Heights is a rich suburb in the United States. In 1930 the Shaker Heights Rapid Transit suffered a drop in patronage by 33%. Thompson attributed this loss of patronage primarily to the system coverage (Ref. 13). Prior to 1930, Shaker Heights trains made numerous stops upon entering downtown Cleveland. After 1930 high-speed trains were used with station spacing of one mile. The loss of this patronage due to the elimination of most station stops on the approach into downtown Cleveland was never regained. Thompson contents that "high regional transit modal split is not dependent upon high speed, but is dependent primarily upon attention to system coverage, route orientation and transfer connections.

CHAPTER III

THEORY

To investigate the effects of traffic growth on highway operating conditions the theoretical concept of capacity and level of service is being adopted (Ref. 14). It presents the idea that every roadway has a carrying capacity related to some level of service. 'Capacity' is defined as "the maximum number of vehicles which has a reasonable expectation of passing over a given section of a lane or roadway in one direction (or in both directions for a two- or three-lane highway) during a given time period under prevailing roadway and traffic conditions". The term 'level of service' denotes "any one of an infinite number of differing combinations of operating conditions that may occur on a given lane or roadway when it is accommodating various traffic volumes". A 'service volume' is the "maximum number of vehicles that can pass over a given section of a lane or roadway in one direction on multilane highways (or in both directions on a two- or three-lane highway) during a specified time period while operating conditions are maintained corresponding to the selected or specified level of service".

That a given highway, or section thereof, can be assigned varying service volumes stems from the fact that in practice a roadway may operate at a wide range of levels of service depending upon the time of day, day of the week, or period of the year. What is being aimed at is to ascertain that for a particular locality of a roadway the level of service does not drop below that deemed operationally practical and economically feasible.

The hypothetical approach being presented will be known in this thesis as the "CONGESTION THEORY". Diagrammatic illustrations of the concepts of the theory are displayed in Figure III - 1. These figures represent graphs of volume - vs - time. In Figure III - 1A the horizontal line labelled L marks the limiting service volume related to some level of service for a particular roadway. Curves F_i ($i = 1, 2, 3$) exemplify three flow patterns of varying volumes with F_1 and F_2 occurring within limit L. In a theoretical sense, when considering only such regular trips as work trips, increasing total traffic volume does not alter the general pattern of the flow so long as the limiting service volume of the roadway is not exceeded. Curve F_3 indicates a condition when traffic volume in excess of the limit is observed between 7.30 and 9.00 A.M. and marked by the letters c and d. Flow pattern such as indicated by F_3 cannot be maintained. Now, since times of starting work are relatively fixed, some trips will be compelled to start earlier. Consequently, a redistribution of the "excess" trips results in the kind of flow pattern labelled C, in which instance a longer peak period is experienced. In theory, by confining the service volume within limit L, the numerical sum of a and b must equal to the sum of c and d. It can also be stated that the areas enclosed within curves C and F_3 and indicated by A_1 and A_2 are equal to each other.

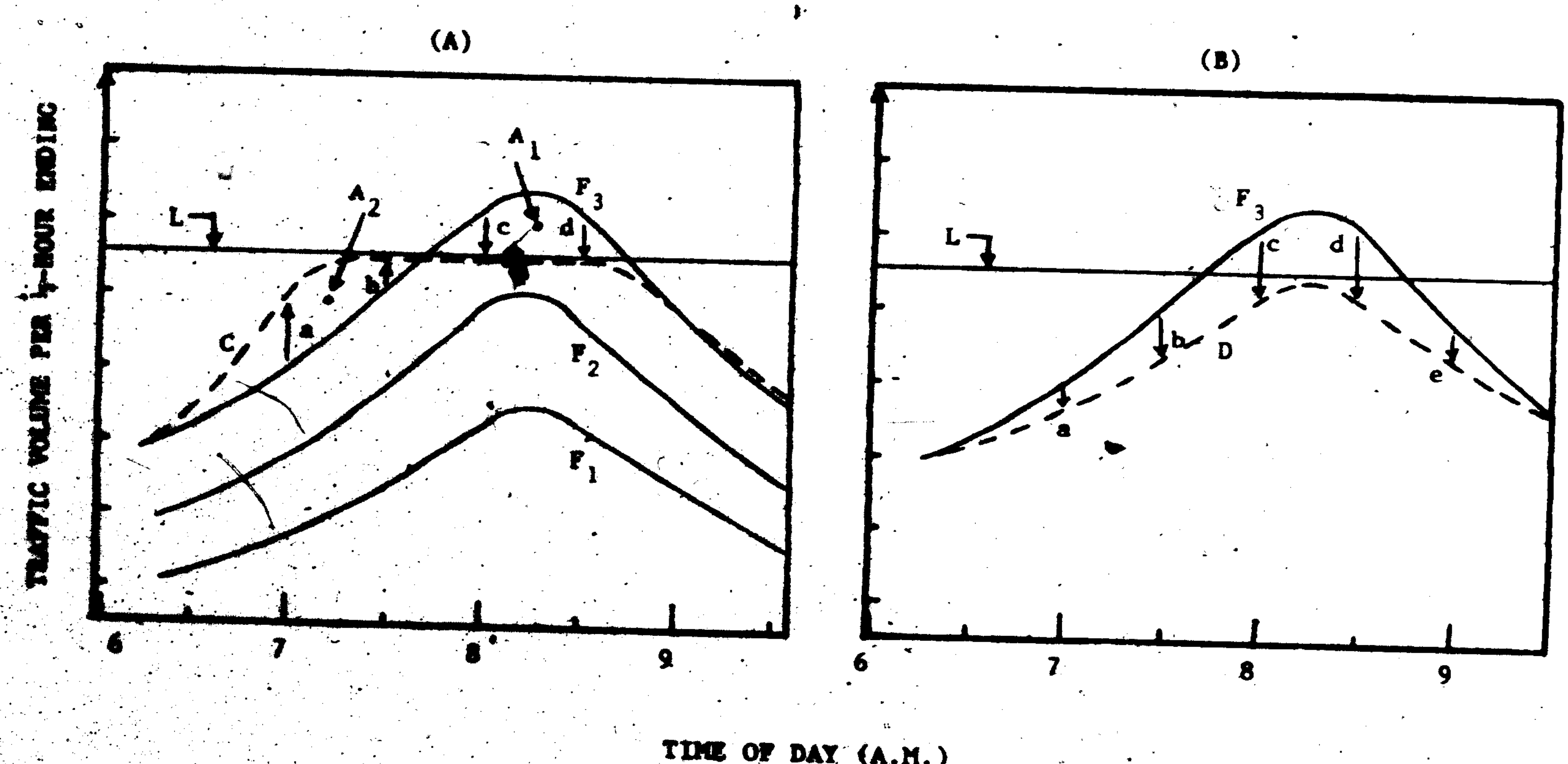

FIGURE III - 1: SCHEMATIC REPRESENTATION OF TRAFFIC FLOW PATTERNS

Not every trip maker is willing to sacrifice the extra travel time associated with the flow pattern C, however. To alleviate the problem, alternative solutions need to be introduced. Depending upon the individual's viewpoint (transportation engineer's or trip maker's), the "ideal" solutions could take the form of increasing roadway capacity, car pooling, or the introduction of a transit system attractive to the automobile users. In this study, attention is focussed only on the transit approach. Figure III - 1B is intended for reference to this approach.

The apparent problem that now arises is the determination of what form of flow pattern or what "quality" of traffic flow we are aiming to attain. Illustratively, in Figure III - 1B suppose that Curve D denotes the type of quality of traffic flow desired (note that at no time interval is the service volume L exceeded); in order to meet this demand, public transit must move the number of people quantified by the numerical sum (a + b + c + d + e) multiplied by average car occupancy.

In essence, the fundamental concepts of the so-called "CONGESTION THEORY" postulate the ideas of the association of longer travel time with increased traffic on a roadway. The compulsory and regular home-to-work trips constitute the traffic component of any concern. An increase in traffic beyond some limit of the roadway service volume hampers stability of flow, causing longer travel times and as a result of fixed starting work time, some work-trip makers will inevitably choose to advance their leave-home times. This may only results in an obvious longer time spent on the journey but also causes a longer staggered peak. To alleviate the problem by the transit alternative, the quality of service offered by the transit system must be highly competitive with the private automobile both in terms of relative travel time and in passenger comfort. Travel time by transit can be vastly improved by providing special transit right-of-ways (such as exclusive lanes), efficient routing to minimize walking distance, better scheduling and short headways to lessen waiting time as well as transfer time etc.

In relation to passenger comfort in volumetric terms, a transit system can be assigned varying levels of quality of service according to the volume of passengers carried at one particular time. This is analogous to the assignment of different levels of service to a roadway according to the volume of traffic it carries (see Chapter VI.1 on the discussion). The limiting v/s ratio (analogous to the v/c ratio) can similarly be applied to the transit. In this case v is the actual volume of passengers being serviced, and s being the full seated load of the transit. In the case of a bus having 52 seats (52-passenger bus), the hierarchy of the levels of service as related to volume of passengers being carried can be formulated in the following manner:

LEVEL OF SERVICE	v/s RATIO	SERVICE VOLUME (52-pass. bus)
A	≤ 0.5	≤ [illegible] pass.
B	≤ 0.75	≤ [illegible] pass.

LEVEL OF SERVICE	v/s RATIO	SERVICE VOLUME (52-pass. bus)
C	$\leq$ 1.0	$\leq$ 52 pass.
D	$\leq$ 1.1	$\leq$ 57 pass.
E	$\leq$ 1.5	$\leq$ 78 pass.
F	> 1.5	> 78 pass.

A capacity bus with all seats occupied and no standees is assigned the level of service C. As is evident, higher values of the v/s ratio (implying more crowding in the bus) correspond to lower levels of service.

In the estimating process of future work trip generation, the commonly used statistical methodology has been utilized. Specifically, a simple linear relationship between production of work trips (Y) and the number of households (X) has been developed. The expression of the form

$$Y = a + bX$$

defines a linear regression equation, where a and b are some derived constants. The derived equation enables us to estimate, with some level of confidence, the number of work trips produced corresponding to a known number of households in an area. Further discussion of the analysis of linear regression is found in Appendix A.

CHAPTER IV

DATA ANALYSES AND RESULTS

The discussions on the data pertaining specially to the work trips of St. Albert will be analysed under the sub-headings listed below:

1. Household size, households and car ownership.

2. Distributions of work trips.

3. Correlating O-D survey of work trips with screen line count.

1. HOUSEHOLD SIZE, HOUSEHOLDS AND CAR OWNERSHIP

The two household-related factors that are quite easily obtained from an O-D survey are the household size and household car ownership. These variables in some way dictate the vigorousness of human activity. With the presence of the automobile and adequate highway facilities, the demand for trips can easily be met. Although the effect of increased family size on trip production is more readily detectable in the non-work category than in the work trips, an increase in the number of wage earners in the family directly affects an upward rise in the work trip production.

Presently, average car ownership for St. Albert is a [illegible] figure of 1.65 passenger cars per household, equivalent to [illegible] imately one car to every group of 2.37 persons (or 0.42 cars per person). Average household size is at the rate of 4.0 persons per household. By comparison, St. Albert has a relatively higher car ownership. The 1971 Federal census indicated that for the City of Edmonton car ownership rate was at one passenger car to 2.67 persons; for the Province of Alberta it was one to 2.92 persons; and for the entire Canada it was one car to 3.10 persons. On the other hand, car ownership for the Town of St. Albert at the time was shown to be at the rate of one passenger car to every group of 2.56 persons. This clearly indicates a comparatively higher ownership of passenger cars for St. Albert.

In Table IV - 1 a breakdown of the household size as related to car ownership is given. Overall, it indicates that about half (48.9%) of the households in St. Albert each has two cars in their possession while 40.8% of them fall in the one-car category. Figure IV - 1 shows clearly the noticeable association of higher vehicle ownership with larger household size. As household size increases, there is an obvious rise in the percentage of household owning three or more cars. On the other hand, percentage of the one-car group decreases quite sharply with increased household size. The fact that more than 50% of the households in each of the household sizes of 4, 5 and 6 fall within the 2-car category accounts for the high of 48.9% of 2-car households in the overall total. It is interesting to note also that the percentages of 2-car ownership do not vary much for household sizes of 3 or more.

TABLE IV - 1: CAR OWNERSHIP RELATED TO HOUSEHOLD SIZE
IN ST. ALBERT

HOUSEHOLD SIZE	NO. OF CARS PER HOUSEHOLD: 0	1	2	3 +	TOTAL
	← PER CENT →				
1	26.9	68.3	1.9	2.9	100
2	2.9	53.1	42.4	1.6	100
3	1.3	43.3	47.9	7.5	100
4	0.9	36.8	54.4	7.9	100
5	0.6	35.5	54.4	9.5	100
6	0.6	29.2	54.1	16.1	100
7	2.9	27.9	46.2	23.0	100
8	-	36.0	46.0	18.0	100
9	3.0	24.2	51.5	21.3	100
TOTAL	2.1	40.8	48.9	8.2	100

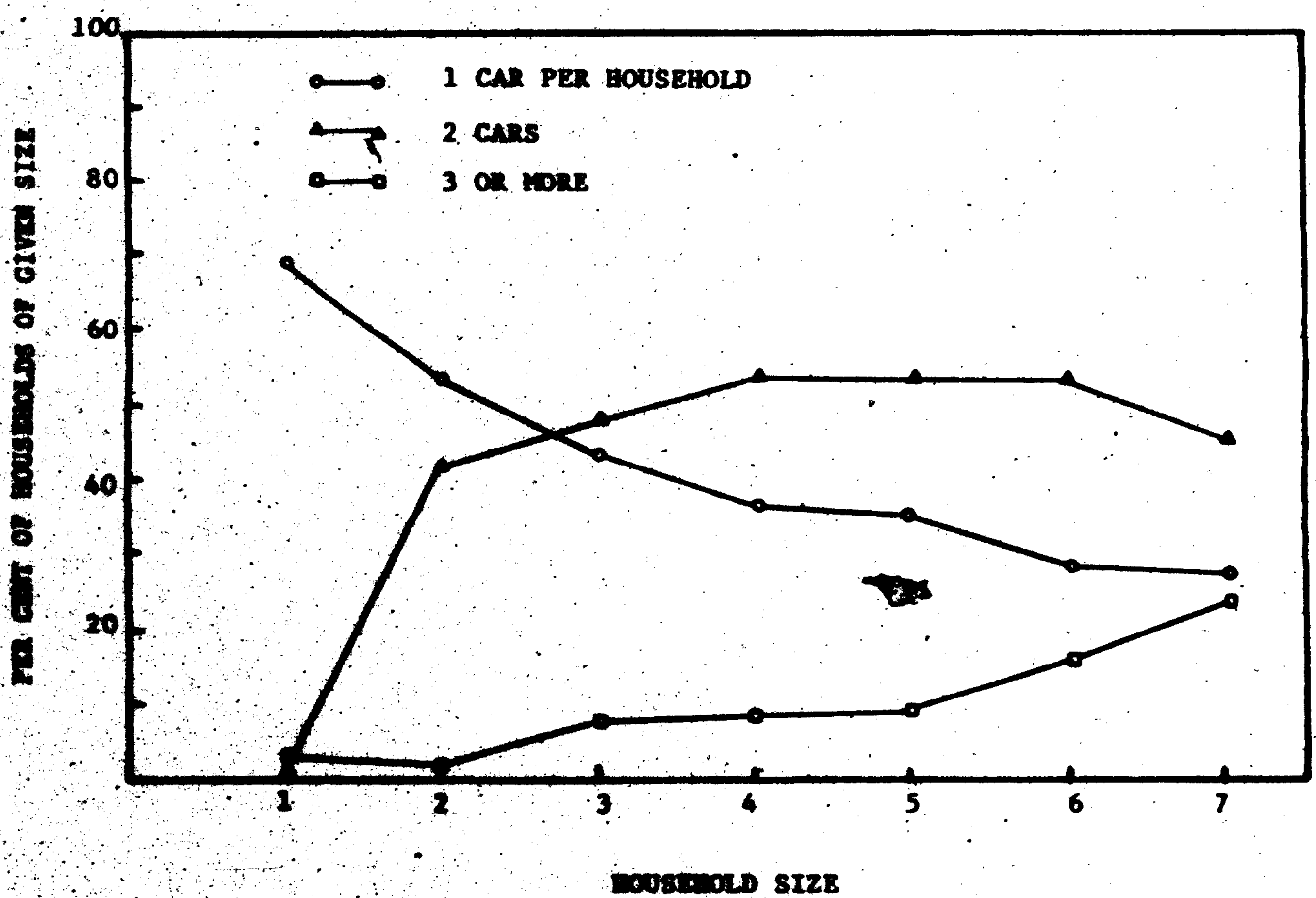

FIGURE IV - 1: PER CENT OF HOUSEHOLDS BY CAR OWNERSHIP

To study the effect on work trip production by variations of one or both of the independent variables, the technique of cross-classification analysis (or category analysis) can be utilized. It consists essentially of a multi-dimensional matrix with each dimension representing an independent variable. A two-dimensional type of application is exemplified in Table IV - 2 with household size and car ownership as the independent variables of the work trip production. Each categorized cell of the matrix is allotted appropriately the observed number of work trips produced and the corresponding number of households in the same category. The average number of work trips produced per household belonging to each category can then be obtained. Furthermore, the effect of varying one independent variable while holding the other constant can be studied. It is apparent from the table that the increase in the average number of work trips produced from each household is a direct function (almost a linear one in the case of the weighted total of all household sizes) of the increase in car ownership. Conversely, we might state that households with a higher proportion of wage earners on the average own more cars. Variations in household size at any level of car ownership do not produce as remarkable an effect. This is very likely due to the fact that in families of 3 or 4 persons the proportion of family members below working age is usually higher. This can be witnessed in Table IV - 2 where we observe that for car ownership of 2 or less (and in the overall total) there is a trend of decreasing average work trip production per household even by increasing household size from 2 to 4 persons successively. There quite

TABLE IV - 2: WORK-TRIP PRODUCTION CROSS-CLASSIFICATION

PERSONS PER HOUSEHOLD		NO. OF CARS PER HOUSEHOLD: 0	1	2	3 +	TOTAL
1	*A	5	62			67
	B	28	71	-	-	99
	C	0.18	0.87			0,68
2	A	10	561	530	18	1119
	B	21	389	310	12	732
	C	0.48	1.44	1.71	1.50	1.53
3	A	5	350	506	107	966
	B	8	273	302	48	631
	C	0.63	1.28	1.68	2.19	1.53
4	A	4	450	796	181	1431
	B	9	357	527	76	969
	C	0.44	1.27	1.51	2.38	1.48
5	A		322	570	147	1039
	B	-	237	363	63	663
	C		1.36	1.57	2.33	1.57
6	A		121	285	134	540
	B	-	96	178	53	327
	C		1.26	1.60	2.53	1.65
7	A		33	77	65	175
	B	-	29	48	24	101
	C		1.14	1.60	2.71	1.73
8	A		37	68	47	152
	B	-	26	40	16	82
	C		1.42	1.70	2.94	1.85
TOTAL	A	24	1936	2832	697	5489
	B	66	1478	1768	292	3604
	C	0.36	1.31	1.60	2.39	[illegible]

*A: Work-trip productions of households in category
B: Number of households in category
C: Work-trip productions per household in category

obviously lies the shortcoming in relating work trip production to number of people (population) alone. Figure IV - 2 is a graphical representation of Table IV - 2. The observation that higher vehicle ownership is associated with higher number of work trips is clearly pictured in this figure. This is further supported by the findings that while 2.1% of the total households do not own any car (see Table IV - 1) only 0.6% of the working members do not have a car available in their households.

Work trips are, therefore, not so much related to the mere size of households (hence, population) as they are to the other elements of households such as the adult (working age) composition in them. Especially in this time of still continuously decreasing family size, the proportion of the non-employed (e.g. children) likewise is diminishing. In the subsequent chapter, in developing a simple model for predicting future work trip production statistical correlation tests in fact show that the use of population as the independent variable is indeed inferior to that of household.

2. DISTRIBUTIONS OF WORK TRIPS

DISTRIBUTION BY MODES

Of the total 5,504 St. Albert work trips surveyed (preliminary results incomplete), the private automobile appears to be by far the single most popular mode of transportation for work trips. More than three quarters reported as auto drivers. The O-D survey also shows a surprisingly low car occupancy rate of 1.14 persons per

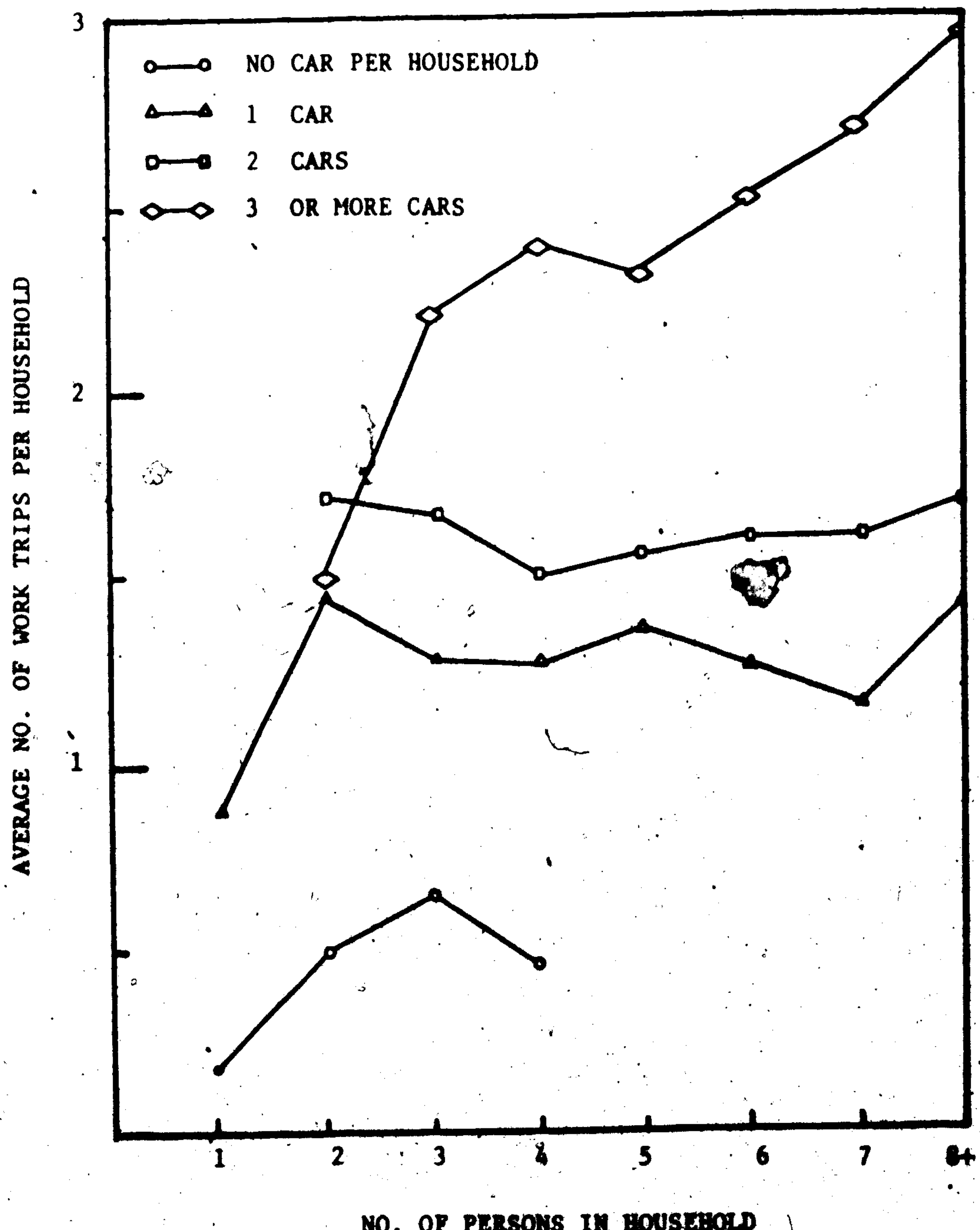

FIGURE IV - 2: AVERAGE WORK TRIPS PRODUCED PER HOUSEHOLD RELATED TO HOUSEHOLD SIZE AND CAR OWNERSHIP car for the journey to work. The percentage distribution by modes of travel to work is as follows:

Auto driver:	77.2%
Auto passenger:	11.1%
Bus passenger:	4.0%
Walk:	3.7%
"Other" and not specified:	4.0%
Average car occupancy:	1.14 persons/car

The close connection of household work trip production and household car ownership has already been documented previously. Household car ownership, to some extent, also influences mode choice of St. Albert work trips. Table IV - 3 analyses this effect. The table shows that almost half the work trips with no car available in the households rely on the bus as their usual mode of transportation to work. One quarter of the work trips in the same category did not specify their travel mode. This is probably because the majority of these people do not have a fixed or definite mode of transportation to get to work and, hence, refused to specify. The percentage of work trips by bus drops abruptly as we compare no-car households with one-car households, and this gets progressively lower with higher car ownership. One is therefore much inclined to believe that the then transit (bus) patronage consisted mainly of captive riders rather than choice riders.

TABLE IV - 3: MODE OF TRANSPORTATION TO WORK
RELATED TO CAR OWNERSHIP

TRIP MODE	NO. OF CARS PER HOUSEHOLD 0	1	2	3 +	TOTAL
	← PER CENT				→
Auto Driver	9.1	67.7	83.6	80.8	77.2
Auto Passenger	15.2	17.7	7.5	7.0	11.1
Bus Passenger	42.4	5.7	2.9	2.4	4.0
Walk	9.1	4.8	2.8	4.0	3.7
Not Specified	24.2	4.1	3.2	5.8	4.0
TOTAL	100	100	100	100	100

DISTRIBUTION BY DESTINATION

The work trips of St. Albert are unevenly distributed not only by travel modes but by trip destinations as well. Edmonton alone accounts for approximately 75% of all St. Albert work trip destinations. More precisely, the O-D survey results are as follows:

Work trips to Edmonton:	72.8%
Work trips within St. Albert:	19.1%
Other Provincial destinations:	2.9%
Destinations not specified:	5.2%

By discarding the "not specified" destinations in the percentage computation, the distribution by destination results in 76.8% for Edmonton, 20.2% within St. Albert, and 3.0% for other Provincial destinations.

By comparing with past work trip destination distribution, the change in the dormitory patterns (if any) of a "bedroom" community can be studied. Information obtained on the work trip distribution by destinations of St. Albert work trips in 1967 shows a very remarkable congruence to the 1974 patterns. The 1967 O-D survey results give the following distribution:

Work trips to Edmonton:	78.5%
Work trips within St. Albert:	20.8%
Other Provincial destinations:	0.7%

To ascertain the stability of the work trip distribution patterns in the time series between 1967 and 1974, reference is made to the 1972 O-D survey data on St. Albert work trips. The January 1972 survey reported a total St. Albert trip production of 4,320 work trips (note again that this also included student trips to Edmonton). Out of this total, 981 had destinations occurring within St. Albert. Translated into percentage distribution, this gives a 22.7% for work trips within St. Albert and a 77.3% for work trips to Edmonton and other Provincial destinations. This third point within the two points in the time series 1967 - 1974 shows that the stability of the dormitory patterns of St. Albert had been steadily maintained.

Table IV - 4 compares the relative changes in the dormitory patterns of St. Albert over the seven-year period. The doubling of population (growth factor of 1.9) over the period has not altered the dormitory patterns. Since there are no major employment centres (e.g. industries) located in St. Albert, quite seemingly employment in local retail stores, banks, teaching and the like pretty much takes care of the 20% local non-commuting workers that surprisingly have stayed constant. A satellite town as it is, St. Albert has remained very much dependent on the much larger community of Edmonton for major employment, with about three quarters of the labour force employed in Edmonton. Doubling of the population has merely affected a very insignificant change (a difference of only about 2%). That the dormitory patterns of St. Albert have been very stable despite an increase in population by a growth factor of close to two in seven years is clearly revealed in this finding.

TABLE IV - 4: 1967 - 1974 CHANGES IN DORMITORY PATTERNS

	JAN.1967 PATTERNS	JAN.1972 PATTERNS	JAN.1974 PATTERNS	1967 - 1974 RELATIVE CHANGES	
				RATIO	DIFFERENCE
POPULATION	9828	12637	18395	1.9	-
WORK TRIPS WITHIN ST. ALBERT	20.8%	22.7%	20.2%	-	- 1.7%
WORK TRIPS TO EDMONTON	78.5%)	77.3%	76.8%	-	- 0.6%
WORK TRIPS TO OTHER DESTINATIONS	0.7%)		3.0%	-	+ 2.3%

Since Edmonton attracts a very significant percentage of St. Albert work trips, distribution of these trips within Edmonton is further analysed. To begin with, the north side of the City (north of the North Saskatchewan River) accounts for most of the Edmonton-bound work trips - 84% to be precise. The main areas of attractions in Edmonton are:

Edmonton C.B.D.:	27%
University of Alberta:	7%
N.A.I.T. and Industrial Airport:	8%
Area just North of Downtown:	9%
Bremner Industrial (West of 142 St. and North of 111 Ave.):	8%

The 1967 distribution of St. Albert work-trip ends in Edmonton was grouped in regional areas as shown in Figure IV - 3. The numbers in brackets are the percentage figures for the respective areas obtained in 1967 while the corresponding unbracketted figures refer to the 1974 percentage distribution. It is apparent from Figure IV - 3 that the percentage distribution has not altered to any considerable degree. Notably, St. Albert work trips have continued to concentrate in the major employment area within the C.B.D. (27.8% in 1967 and 27.3% in 1974). In this instance, the stability of dormitory patterns St. Albert has been in is further brought to light. However, the truth that some 40% of the trips are concentrated within the C.B.D.,

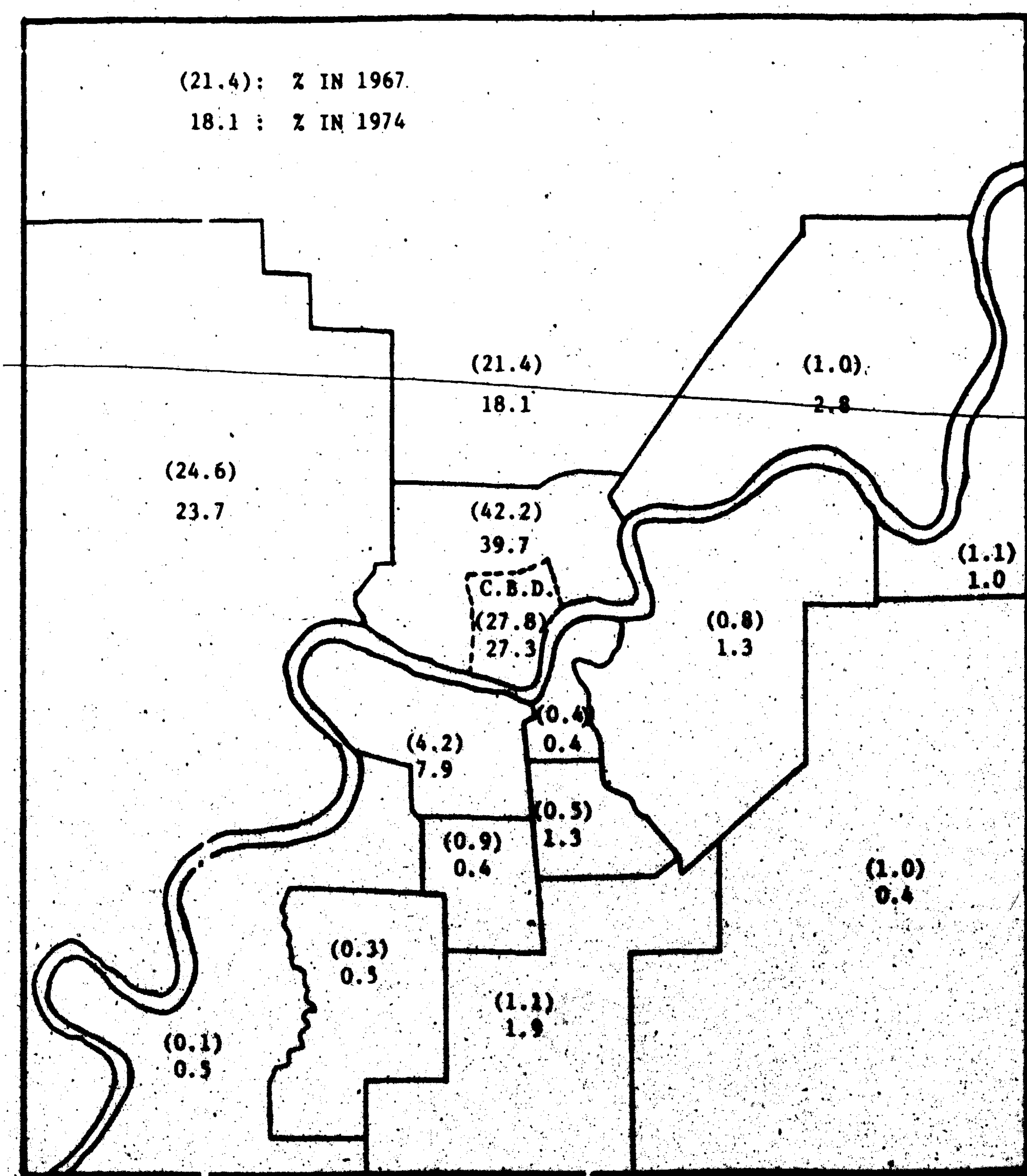

FIGURE IV - 3: PERCENTAGE DISTRIBUTIONS OF ST. ALBERT WORK TRIP DESTINATIONS IN EDMONTON (1967 & 1974) and vicinity suggests two points: (1) that the rapid growth of St. Albert work trips to this area could significantly contribute to the seriousness of traffic congestion in the area, and (2) that the concentration of these trip ends should enable more efficient implementation of public transit to cater to the needs of this mass group of commuters.

DISTRIBUTION BY TIME

From the response given in the O-D survey it was possible to analyse the distribution of work trips by time of departure from home. This bit of data is essential in the correlation of work trips with the actual traffic movement in the field as will be done in a later section. The distribution has been worked out in percentage per time interval. Figure IV - 4 gives the percentage distribution per half-hour interval for the time between 5.30 and 9.30 in the morning with other departure times collectively grouped in the "other time" category. A word of information, this result was worked out solely for those work trips of St. Albert whose trip distinations located within the City of Edmonton. In simple terms, the figure implies that of the total Edmonton-destined work trips originating from St. Albert 85.5% leave their homes for work between 6.30 to 8.30 A.M., with 54.9% clustered in the peak hour between 7.00 and 8.00 A.M. and 34.[illegible]% for the half hour between 7.00 and 7.30 A.M. Irrespective of their modes of transportation, such is the peaking characteristic the figure reveals. The 5.3% in the "other time" category are those work trips whose work journey begins at other than the specified time intervals.

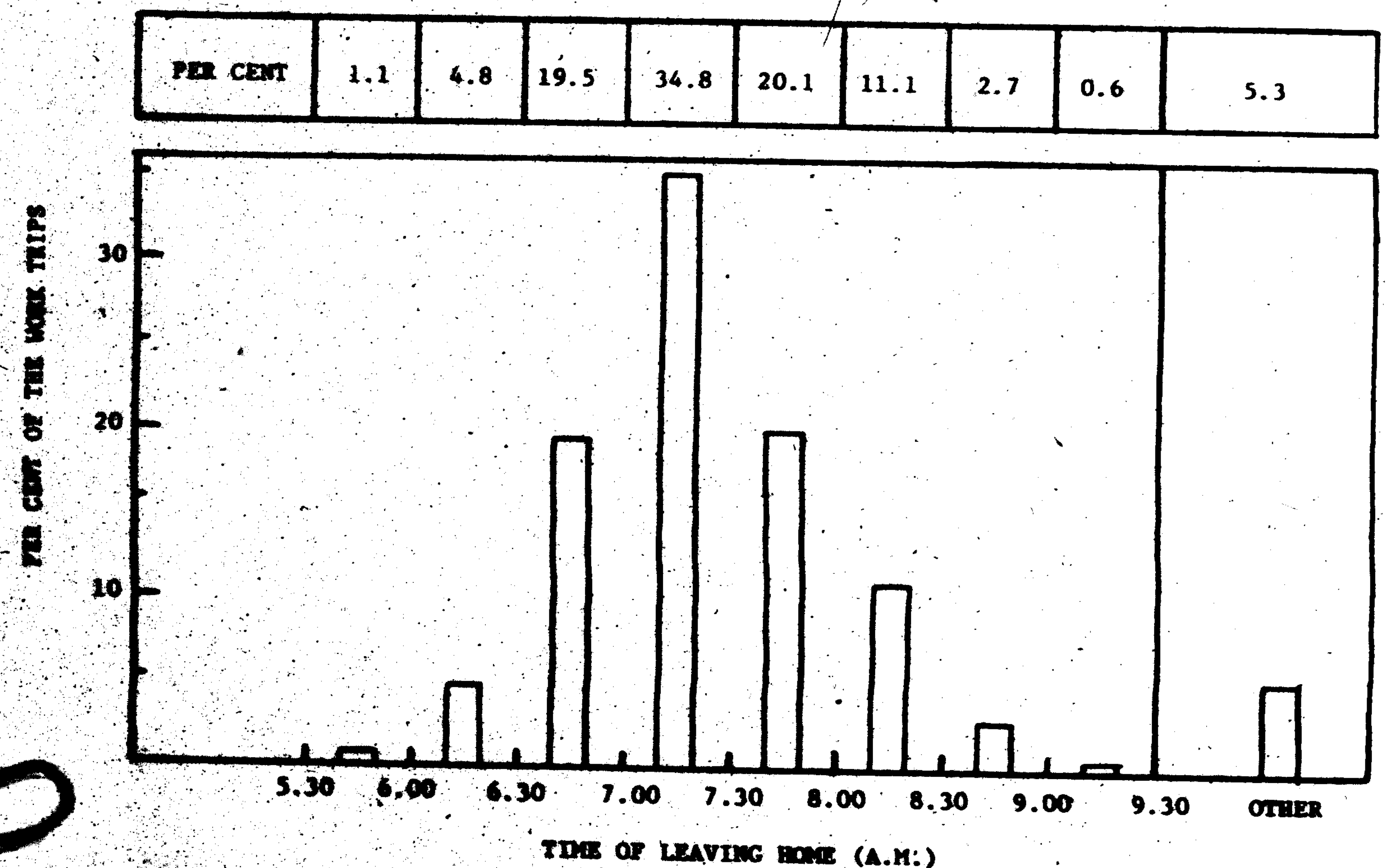

FIGURE IV - 4: PERCENTAGE DISTRIBUTION OF ST. ALBERT WORK TRIPS TO EDMONTON RELATED TO LEAVE-HOME TIMES of 5.30 to 9.30 A.M., or those whose work times are irregular.

For these individuals who reported both their leave-home and start-work times, further analysis was attempted to study the nature and magnitude of their work-journey times. Table IV - 5 shows the percentage distribution of Edmonton-bound work trips as related to the time difference between leaving home and starting work for the three modes of transportation. In this table alone, it is quite evident how different modes of travel are affecting travel times as can be deduced from comparing the percentage distribution related to time difference for all three modes concerned. The weighted average journey time (difference between leave-home and start-work times) per trip for each mode can be computed as has been performed in Table IV - 6. Such means of calculation produce trip times of 42 minutes per trip for auto drivers, 47.5 minutes per trip for auto passengers and 66 minutes per trip for bus passengers. In view of the nature and method of the analysis, the reliability and accuracy of these journey times may be somewhat questionable. Nevertheless, the results serve well for comparing purposes of the relative travel time differences for any two modes of transportation. That the average journey time of an auto passenger exceeds that of an auto driver by 5.5 minutes should come as expected since a passenger is often bound by the schedule of the driver and must allow for extra time in some cases. The table also indicates that auto drivers have a 24-minute (66 - 42) time advantage over the bus patrons (c. f. Chapter VI.3, the travel time difference for St. Albert work trips to the C.B.D. of

TABLE IV - 5: PERCENTAGE DISTRIBUTION OF ST. ALBERT WORK TRIPS TO EDMONTON RELATED TO TIME DIFFERENCE BETWEEN LEAVING HOME AND STARTING WORK

TIME DIFFERENCE (MINUTES)	PERCENTAGE DISTRIBUTION		
	Auto Driver	Auto Passenger	Bus Passenger
26 to 45	62	48	21
46 to 75	22	36	47
76 to 120	0	2	28
NOT SPECIFIED	16	14	4
TOTAL	100	100	100

TABLE IV – [illegible] DIFFERENCE BETWEEN LEAVING [illegible]

STARTING W[illegible] FOR ST. ALBERT WORK TRIPS TO EDMONTON

TIME DIFFERENCE (MINUTES)	Auto Driver		Auto Passenger		Bus Passenger	
	NO.OF TRIPS	AVERAGE TRIP-MINS.	NO.OF TRIPS	AVERAGE TRIP-MINS.	NO.OF TRIPS	AVERAGE TRIP-MINS.
26 to 45 (Avg. 35.5)	2533	89921	282	10011	61	2165
46 to 75 (Avg. 60.5)	899	54389	211	12766	137	8289
76 to 120 (Avg. 98)	-	-	12	1176	82	8036
NOT SPECIFIED	654	-	82	-	12	-
TOTAL (For specified time)	3432	144310	505	23953	280	18490
AVERAGE TIME DIFF. PER TRIP	42 Mins.		47.5 Mins.		66 Mins.	

Edmonton).

3. CORRELATING O-D SURVEY OF WORK TRIPS WITH SCREEN LINE COUNT

When Ng, in his thesis project, correlated the Edmonton 1967 O-D work trip data with the cordon count for traffic bound for the C.B.D. of Edmonton between the hours of 7.00 to 9.30 A.M., he contended that a +15% correction be made to the O-D data to obtain better quantitative representation of actual conditions (Ref. 1). He did, at the same time, conclude and indicate a firm belief that the 1967 O-D information only surveyed 85% of the population. The objectives, therefore, of correlating the St. Albert work trip data with actual traffic conditions on Highway 2, particularly the A.M. traffic, are twofold: (1) to assess the reliability of the O-D data as means of estimating the A.M. traffic movement south-bound on Highway 2 between Edmonton and St. Albert, and (2) to find out if other traffic generators (other than St. Albert) contribute any significant portion of the above mentioned traffic.

The specific location of interest is at the intersection of Highway 2 and 137 Avenue. A mechanical traffic counter was set up (by the City of Edmonton) just north of the intersection to measure the south-bound traffic entering the City boundary of Edmonton located thereon. It is quite unfortunate that no traffic count was conducted at this location during the month of January, 1974, to coincide with the time of taking the O-D survey, nor was there one taken the subsequent months during the regular school term of the University and

N.A.I.T. (Recall that student trips to N.A.I.T. and the University have been included as part of St. Albert work trips in the O-D data.) However, data on traffic volume count for south-bound traffic taken on Wednesday, July of 1974, are available; but in order to correlate this count with the O-D work trip data, the latter must be updated for the same time of year. Consequently, it becomes necessary to estimate from the January 1974 O-D survey results the work trips for the time when the traffic count was taken (about six months after).

The preliminary results of the January 1974 O-D survey give the following information:

Population:	18,395
Total Households	4,600
Total work trips:	7,270
Work trips to Edmonton:	5,292
Work trips within St. Albert:	1,389
Other destinations:	589

The census taken in June 1974 shows a population increase to 19,418, with the total number of occupied units reported to be in the neighbourhood of 4,900. Based on this growth and with the aid of the predicting model developed in Chapter V, the number of work trips generating from St. Albert in the mid-year of 1974 can be estimated. The total number of St. Albert work trips in the mid-year of 1974 was expected to be 7,700, with 5,600 destined for the City of Edmonton. These estimated trips can then be likewise distributed by modes of travel, trip destinations and by time of leave-home according to the January 1974 data that have just been analysed in the preceding Section 2 of this chapter.

Table IV - 7 lists the resulting A.M. half-hourly distribution of auto driver home-to-work trips destined for Edmonton according to their leave-home time. The traffic counter, as mentioned earlier, was placed just north of the intersection of Highway 2 and 137 Avenue and recorded only south-bound traffic entering the City boundary. Comparison of the screen line count with the O-D work trip data listed under column 1 shows marked discrepancy. Traffic volume is comparatively lower because when [illegible] volume count was conducted (July 3, 1974) both the University and N.A.I.T. were not in their regular school session. Consequently, student trips and trips by many of the employees of the two institutions did not take place at the time. It is only right, therefore, to omit these trips in the comparison. Survey data indicated that such trips from these two institutions together accounted for 15% of the total. When these trips are eliminated, we arrive at the results shown under column 2 in Table IV - 7, which provide better correlation with the screen line count. The two totals between 6.00 and 9.00 A.M. differ by about 6%. These two sets of data, namely the O-D work trip information in column 2 and the screen line count, will be further compared hereafter.

Figure IV - 5 plots the half-hourly distribution of both work trips obtained from the O-D survey and the screen line count, while Figure IV - 6 shows the cumulative total volumes for the same

TABLE IV - 7: COMPARISON OF WORK TRIPS TO EDMONTON OBTAINED FROM THE O-D SURVEY AND THE SCREEN LINE COUNT FOR MID-YEAR 1974

LEAVE-HOME TIME (A.M.)	AUTO-DRIVER WORK TRIPS ESTIMATED FROM O-D DATA		TRAFFIC VOLUME BY SCREEN LINE COUNT
	1	2	
6:00 to 6:30	206	175	143
6:30 to 7:00	837	710	398
7:00 to 7:30	1493	1266	800
7:30 to 8:00	862	731	722
8:00 to 8:30	476	404	682
8:30 to 9:00	116	98	436
9:00 to 9:30	-	-	(400)
TOTAL (6:00 to 9:00)	3990	3384	3181

1: Trips by students and employees of N.A.I.T. and U. of A. included
2: Trips by students and employees of N.A.I.T. and U. of A. omitted

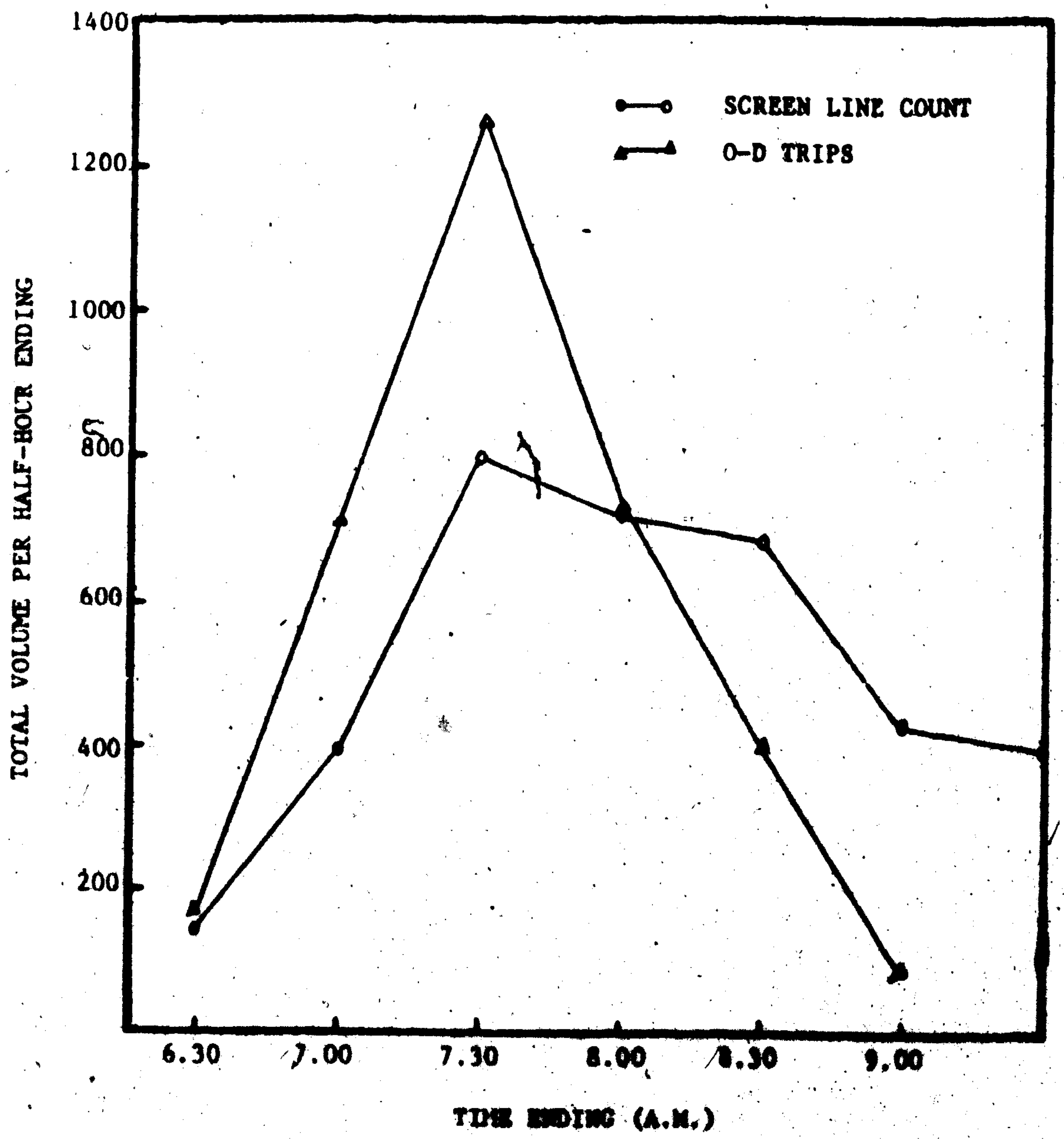

FIGURE IV - 5: HALF-HOURLY DISTRIBUTION OF O-D AUTO-DRIVER WORK TRIPS BY LEAVE-HOME TIME AND THE SCREEN LINE COUNT (MID-YEAR 1974) sets of data. In Figure IV - 6, if a lateral shift of 18 minutes is applied to the O-D curve it will roughly coincide with the position of the screen line curve. This simply means that theoretically in the morning peak an auto driver spends an average of 18 minutes time to get to the City boundary (location of the count) from the moment he leaves his home. However, eighteen-minute time appears to be somewhat longer than the regular user of the highway will expect. Reasons for the longer time as obtained in the graphical method of correlation will be cited.

(1) A glance at Figure IV - 5 will clearly show the mis-correlation of the half-hourly distribution of the two sets of data. The "distortion" in the distribution could well have originated from the survey reporting. For instance, a person who starts his journey at 7.05 is very likely to report 7.00 as his leave-home time. This person will, in our distribution analysis, be assigned in the time interval of 6.30 - 7.00 instead of the interval 7.00 - 7.30. Another person whose actual leave-home time is at 7.35 may report as 7.30, and hence will be assigned in the 7.00 - 7.30 interval instead of the succeeding one.

(2) Recall that the analysis of the percentage distribution of work trips by leave-home time has been based on all the St. Albert work trips to Edmonton irrespective of modes of transportation, whereas we are only concerned with auto-driver work trips in the correlation. Since travel times for auto passengers and bus passengers are longer than that of auto drivers, average travel time for

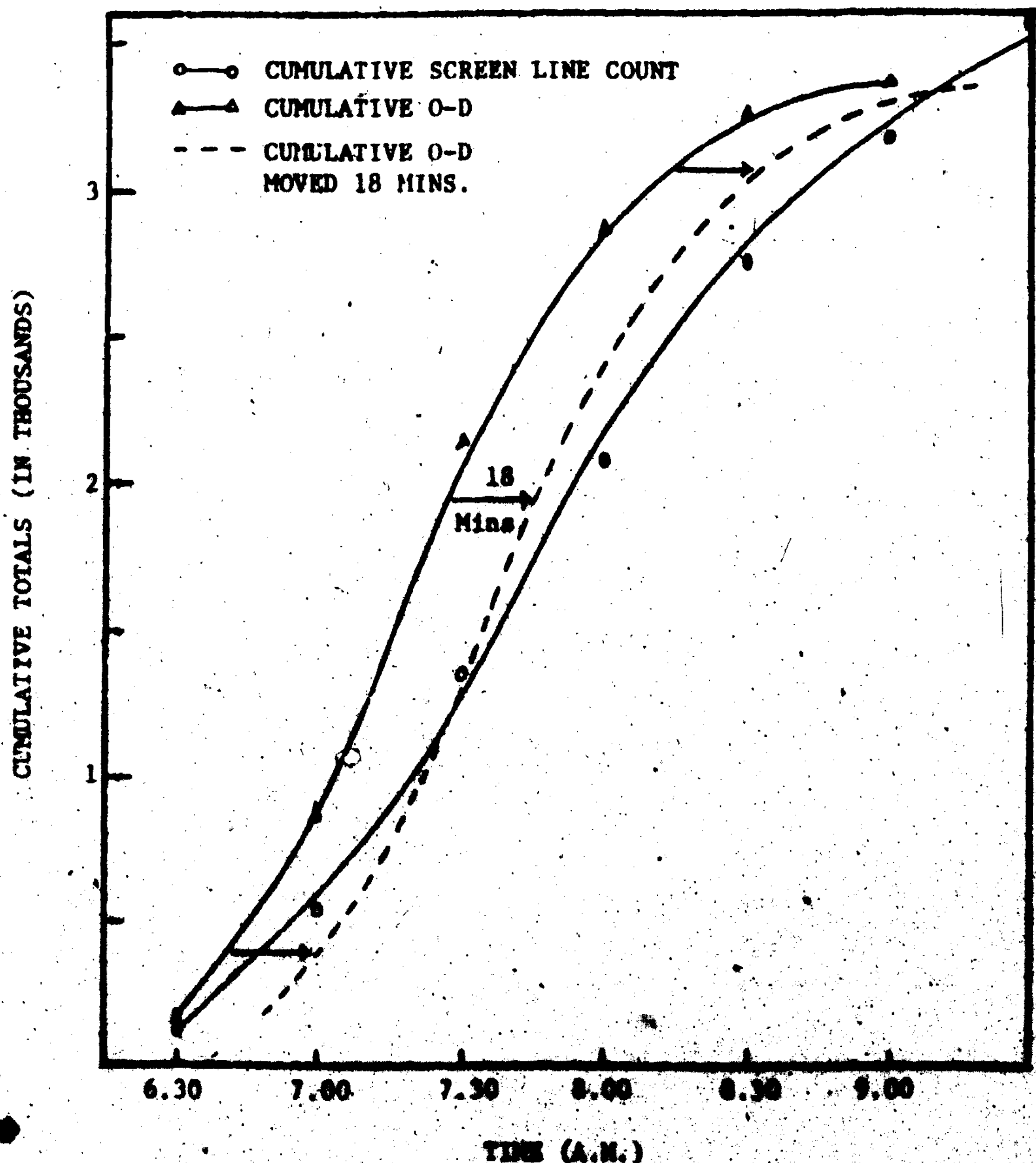

FIGURE IV - 6: CUMULATIVE TOTALS OF O-D AUTO DRIVER WORK TRIPS AND THE SCREEN LINE COUNT (MID-YEAR '74) all three modes combined naturally exceeds that of auto-driver mode alone. The following simple calculation shows the derivation of the weighted average travel time for the three modes combined (see also Table IV - 6 for the original figures):

MODE	NO. OF TRIPS	TOTAL AVERAGE TRIP MINUTES
Auto Driver	3,432	144,310
Auto Passenger	505	23,953
Bus Passenger	280	18,490
TOTAL	4,217	186,753

Weighted average travel time aggregated for all three modes is 186,753 ÷ 4,217 = 44.5 minutes. Since average trip time for an auto driver was figured to be 42 minutes (see Table IV - 6), this results in a difference of 2.5 minutes (44.5 - 42). This, in part, accounts for the longer-than-expected auto-driver travel time (18 minutes) to the City boundary as obtained by the graphical correlation method.

(3) Two conditions are cited which affect a reduction in the volume of the screen line count or, what in relative term amounts to the same thing, give a somewhat larger number of auto-driver work trips in the O-D results. Firstly, the screen line count was conducted in the summer season when more employees than usual were expected to be on vacation. It is likely, therefore, that many of

these trips did not really take place on the day of the count. Secondly, the indicated car occupancy of 1.14 persons per car in the O-D survey seems low and may have been lower than actual field conditions. Higher car occupancy rate has an effect of reducing actual traffic volume. Both the above mentioned conditions have an effect of "pulling" apart the two curves in Figure IV - 6, thus, resulting in a longer time separation.

Unfortunately, no actual car occupancy count was conducted at the time of taking the O-D survey or the screen line count; and it is difficult to ascertain the reliability of the seemingly low car occupancy of 1.14 as reported in the O-D survey. A 15-minute car-occupancy count taken in the morning peak on December 9 of 1974 for traffic bound for Edmonton indicated an average of 1.16 persons per car, while a 20-minute count taken in the evening peak on December 6 of 1974 for traffic going in the opposite direction showed an average of 1.29 per car. The graphical solution of Figure IV - 6 is quite sensitive to the car-occupancy rate being assumed. For example, if, instead of the 1.14 rate, the O-D work trip data assume a car-occupancy rate of 1.20 (which probably is more likely to be the real case), the graphical method of correlation results in that shown in Figure IV - 7. Here, the time lapse between leaving home and arriving at the City boundary for an auto driver is figured to be approximately 14 minutes, a time which is closer to being more realistic than the 18-minute time previously established for car-occupancy rate of 1.14 per car. Moreover, with car occupancy of

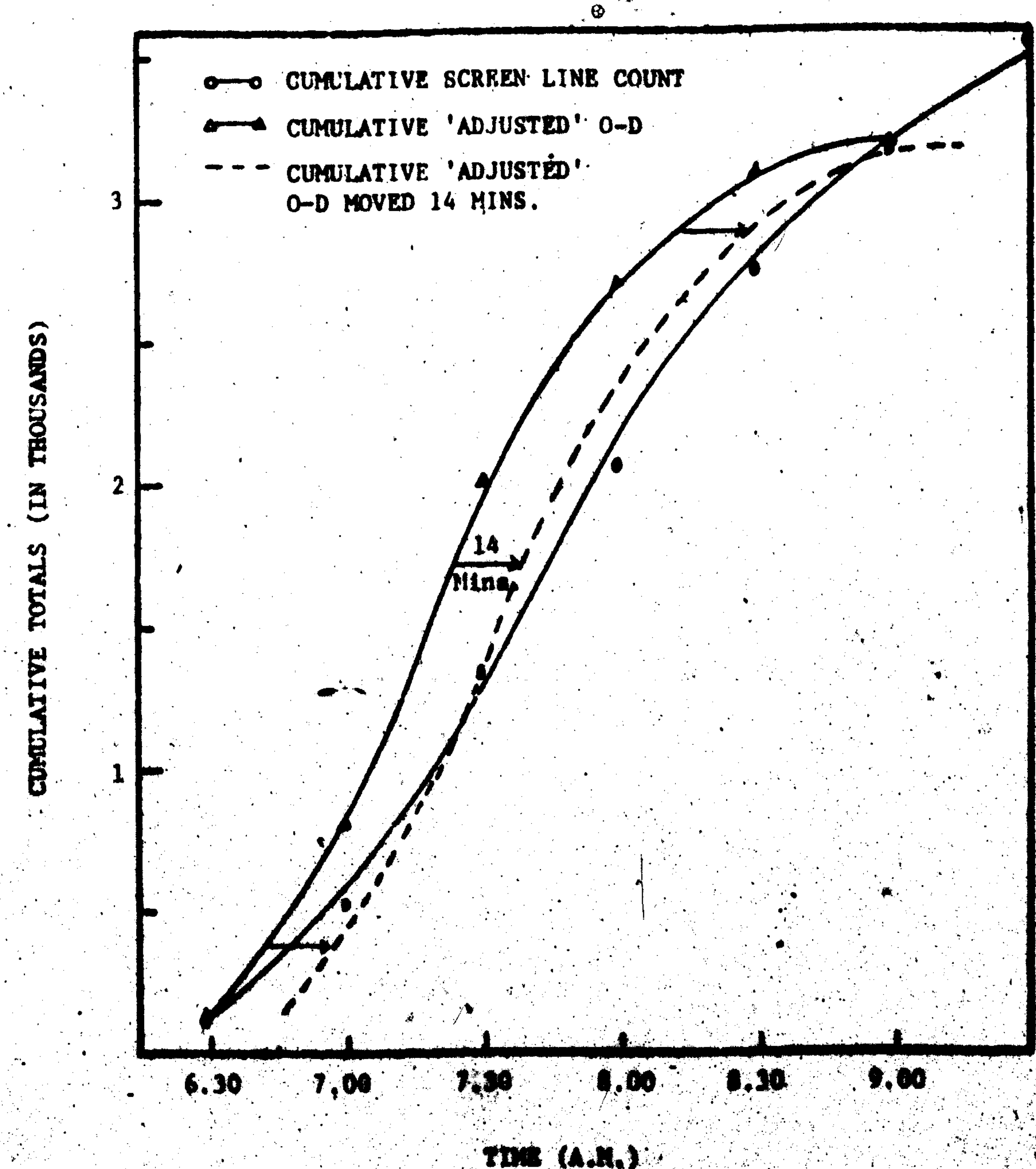

FIGURE IV - 7: CUMULATIVE TOTALS OF 'ADJUSTED' O-D AUTO-DRIVER WORK TRIPS AND THE SCREEN LINE COUNT

1.20 per car the total number of auto-driver work trips between 6.00 to 9.00 A.M. computed for the O-D is reduced to 3,214 (instead of 3,384, see Table IV - 7), which correlates much better with the total for screen line count of 3,181.

Notwithstanding all the factors mentioned above, correlation of the O-D work trip information with the screen line count suggests some noteworthy points. The close comparison of the two totals for the A.M. peak between 6.00 to 9.00 indicates that between these hours the traffic south-bound on Highway 2 between St. Albert and Edmonton for the most part is generated from St. Albert. Contribution from other traffic generators is, therefore, negligible and insignificant in magnitude. With, perhaps, minor adjustments the work trip data obtained from the O-D survey provide a good source for predicting the total A.M. peak traffic volume (between 6.00 and 9.00) for traffic movement heading towards Edmonton on the St. Albert-Edmonton corridor.

CHAPTER V

FORECASTING FUTURE WORK TRIP PRODUCTION

Trips produced from a geographical unit (zones, districts etc.) of a study area are commonly referred to as trip productions. Trips produced from the place of residence of the trip makers are classed as home-based trips. Non-home-based trips have neither end (origin or destination) at the residence of the trip maker. In this study we are interested in the journey to work of the residents of St. Albert; and for that purpose our investigation is focussed on that of the home-based work trips produced in the region.

In order to determine the future growth of these trip productions and its implications for transportation facilities, it becomes necessary to establish basic techniques to this end. Statistical methodology has traditionally been heavily relied upon in estimating procedures for trip generation. One such analytical technique is the linear regression analysis, which relates trip generation to some independent variables. The underlying assumption is that between the dependent and the independent variables there exists a high degree of association. Such an analytical technique is also applied to the study in this thesis.

1. FORMULATION OF A SIMPLE MODEL

A simplified model in the form of a mathematical equation is sought for to estimate zonal work trip production. The method of least square regression analysis as applied in this study is briefly discussed in Appendix A. Attempts are made to relate zonal production of home-based work trips to other independent variables, such as zonal population and households, and the statistical validity of the equation thus derived is subsequently evaluated.

In formulating a simple regression equation to predict future zonal work trip production, two of the variables commonly used in the prediction equation have been one of population or numbers of households. It is intended here to appraise and evaluate these variables as applied specially to the prediction of work trip production of the dormitory community of St. Albert. Final indication inferred subsequently is that the variable household is a better representation of the independent variable of the simple regression equation formulated for estimating zonal production of home-to-work trips for St. Albert.

At the time of writing this thesis, the preliminary results of the 1974 O-D survey give information on only 18 of the total 24 zones into which St. Albert was partitioned. Of the 18 zones, however, 4 zones have been omitted in this analysis. It was discovered that for the 4 zones the population numbers obtained from the O-D survey and that obtained from the census data showed large discrepancies, and therefore deemed unrepresentative. Furthermore, by eliminating the 4 zones the coefficient of determination of the regression equation thus obtained does, in fact, improve appreciably.

Sources of errors associated with the data were later clarified. It was learned that while the raw data were being lodged with the Town Hall of St. Albert, part of the data were inadvertently destroyed.

The set of data on zonal households and the corresponding number of zonal home-to-work trips produced are as follows:

	(Y) HOME-TO-WORK TRIPS	(X) HOUSEHOLDS	(Z) POPULATION
1	333	222	850
2	332	222	813
3	382	259	1028
4	323	191	875
5	343	210	864
6	309	197	722
7	410	266	1087
8	301	184	766
9	363	222	946
10	271	170	746
11	435	290	1295
12	300	197	704
13	300	185	679
14	256	176	649

A least square regression line of Y on X has the form:

$$Y = a \pm bX$$

in which

Y = the number of home-to-work trips produced in a zone

X = the number of households in the same zone

a, b = constants.

The analysis of this set of data (see Appendix A) yields the following results:

$$Y = 43.619 + 1.353\,X \quad \text{-----------} \quad (V - 1)$$

Coefficient of correlation, $R = 0.9639$

Coefficient of determination, $R^2 = 0.9291$

Standard error of estimate, $S_{yx} = 14.05$

Thus, for a zonal area of St. Albert possessing similar characteristics (e.g. population composition etc.) to those from which Equation V - 1 has been derived, estimate of home-to-work trip production can be made by using the equation.

For the sample data, the sets of points (X_1, Y_1), (X_2, Y_2) - - - (X_{14}, Y_{14}) are plotted graphically in Figure V - 1; and the resulting curve (namely Equation V - 1) called the regression curve (line) of Y on X is thereby fit in.

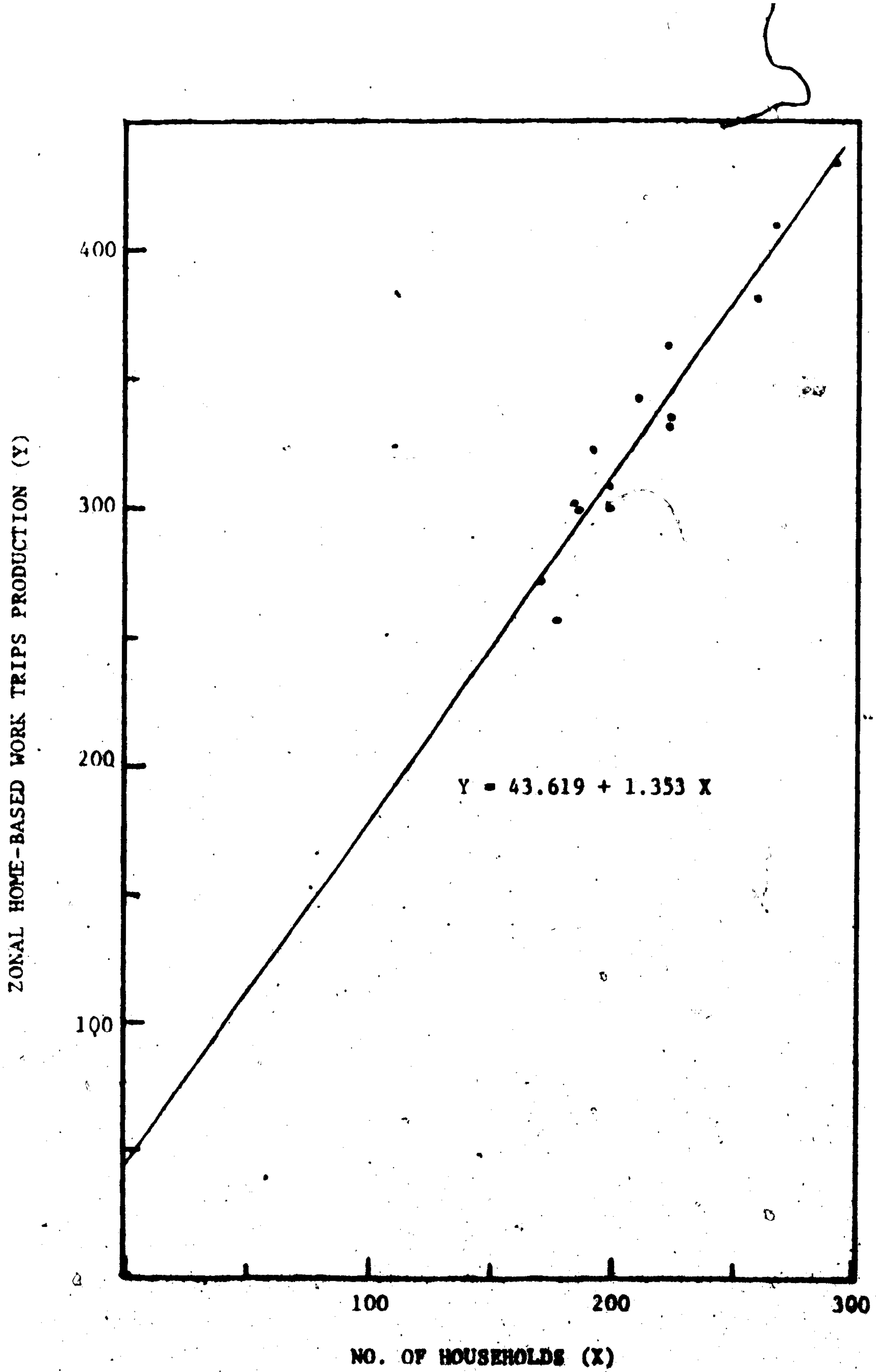

FIGURE V - 1: REGRESSION LINE OF ZONAL HOME-BASED WORK TRIPS ON HOUSEHOLDS

Now, the zonal production of work trips can likewise be related to the zonal population from the given set of data and a similar equation can be formulated. Statistical analyses produce the form of equation

$$Y = 101.696 + 0.269\ Z \qquad (V - 2)$$

The independent variable Z has in this case been represented by population instead of household. The comparison of the statistical results of the two derived equations shows the following:

PREDICTING VARIABLE

	POPULATION	HOUSEHOLD
Equation	$Y = 101.696 + 0.269\ Z$	$Y = 43.619 + 1.353\ X$
R	0.9556	0.9639
R^2	0.9133	0.9291
S_{yx}	15.53	14.05

One can infer from the above comparison of the two simple regression equations derived that viewed from the standpoint of statistics, zonal production of work trips is more closely associated to zonal households (consequently, the corresponding regression equation gives better estimate of work trips) than it is to zonal population.

Aside from the statistical arguments, by recognizing the current general trend of diminishing family (household) size we can further extend the reasoning. Consider two simple cases: Case 1 has 3 families of 4 members each (2 children in each family), making up a total population of 12 people and a total of 3 households. In light of the changing family size, Case 2 represents 4 families of 3 members each (1 child in each family), making up a total population of also 12 people but has total households increased now to 4. Speaking of probability, Case 1 group is likely to produce at the least 3 work trips and Case 2 at the least 4 work trips. So, although there is no change in total population, we can still expect an increase in work trips produced from Case 1 to Case 2 in view of the increase in the number of households. We have, in fact, already shown by the cross-classification analysis in Chapter IV - 1 that there is in reality an increase in the average work trips produced per person by decreasing household size from 4 to 3 or 2 persons. Here again is where the idea of relating work trip production to households rather than population comes into play. We will indeed show later on that St. Albert, with current average household occupancy of about 4.0 persons, has been experiencing a trend of diminishing household size.

2. APPLICATION OF THE MODEL (EQUATION) FOR FUTURE POPULATION LEVELS

The basic assumption in developing Equation V - 1 is that the total number of work trips generated in a given zone is related to the characteristics of the households in the area. To directly apply the derived relationships to a future population level will, therefore, necessitate the presumption that the relationships remain stable over time. Moreover, aggregated households at a future date and population level will be assumed to exhibit close similarities in household and travel (work trip) characteristics to those from which the equation has been established. Needless to say, however, perfect homogeneity is practically impossible.

As St. Albert and its population expand, and in whatever form land use development patterns will dictate, in applying Equation V - 1 to predict future work trips the further assumption is that the additional expansion will be sub-divided into zones each with population ranging from 600 to 1100. This is merely to agree with the population sizes of the zones that the derivation of Equation V - 1 has been based upon. The zones show an average population of 860 (see preceding section).

Finally, the number of households (a variable in the predicting model) must be known or estimated for a population level. To accomplish this, one simple and direct method would be to first determine the average household size (number of persons per household) at a particular level and thereupon obtain the approximate number of households for that population level. It is evident that in the last decade or so there has been a general trend of diminishing average household size throughout Canada. In January 1974 household size for St. Albert averaged at 4.0 persons (it was at 4.4 three years before and 4.8 some ten years before), but this, too, is expected to follow the same trend as has been in the past. Past data are available but, unfortunately, to this date no work has yet been carried out on future household estimate related to population increase for St. Albert. In this respect, the author has simply to resort to the mechanical method of forecasting in which to assume that "future experience is a direct function of past experience".

Table V - 1 shows past figures of the number of households at various population levels and from which average household occupancy is obtained. Average household occupancy is plotted against population in Figure V - 2. The resulting curve is projected forward by visual fit in a continuation of the apparent trend through the forecast period. It is probably not misleading to assume that the lower limit of this value (average household occupancy) stands at somewhere in the neighbourhood of 3.3, at least within the next generation or so.

3. RESULTS

Before future projection of work trips is attempted with the prediction model (Equation V - 1), "backward" projection with the model is tried out. Predicted number of work trips by backward projection are then compared with actual past volume of work trips to see how well they agree.

The Town of St. Albert has supplied past work trip information for the months of January in 1971, 1972 and 1973, at which times populations were 11,249, 12,637 and 13,[illegible] respectively. The information, however, gives only the number of local work trips.

TABLE V - 1: POPULATION RELATED TO HOUSEHOLDS

DATE	POPULATION	NO. OF HOUSEHOLDS	PERSONS PER HOUSEHOLD
JUNE 1974	19418	4917	3.95
JAN. 1974	18395	4600[a]	4.0[a]
JAN. 1973	15088	*	4.1
JAN. 1972	12637	*	*
JUNE 1971	11800	2688	4.39
JAN. 1970	10530	*	*
JAN. 1969	10191	*	*
JAN. 1968	10243	2191	4.67
JAN. 1967	9828	2098	4.68
JAN. 1966	9426	2009	4.69
JAN. 1965	9070	1900	4.73

a: Preliminary results

*: Figures not available

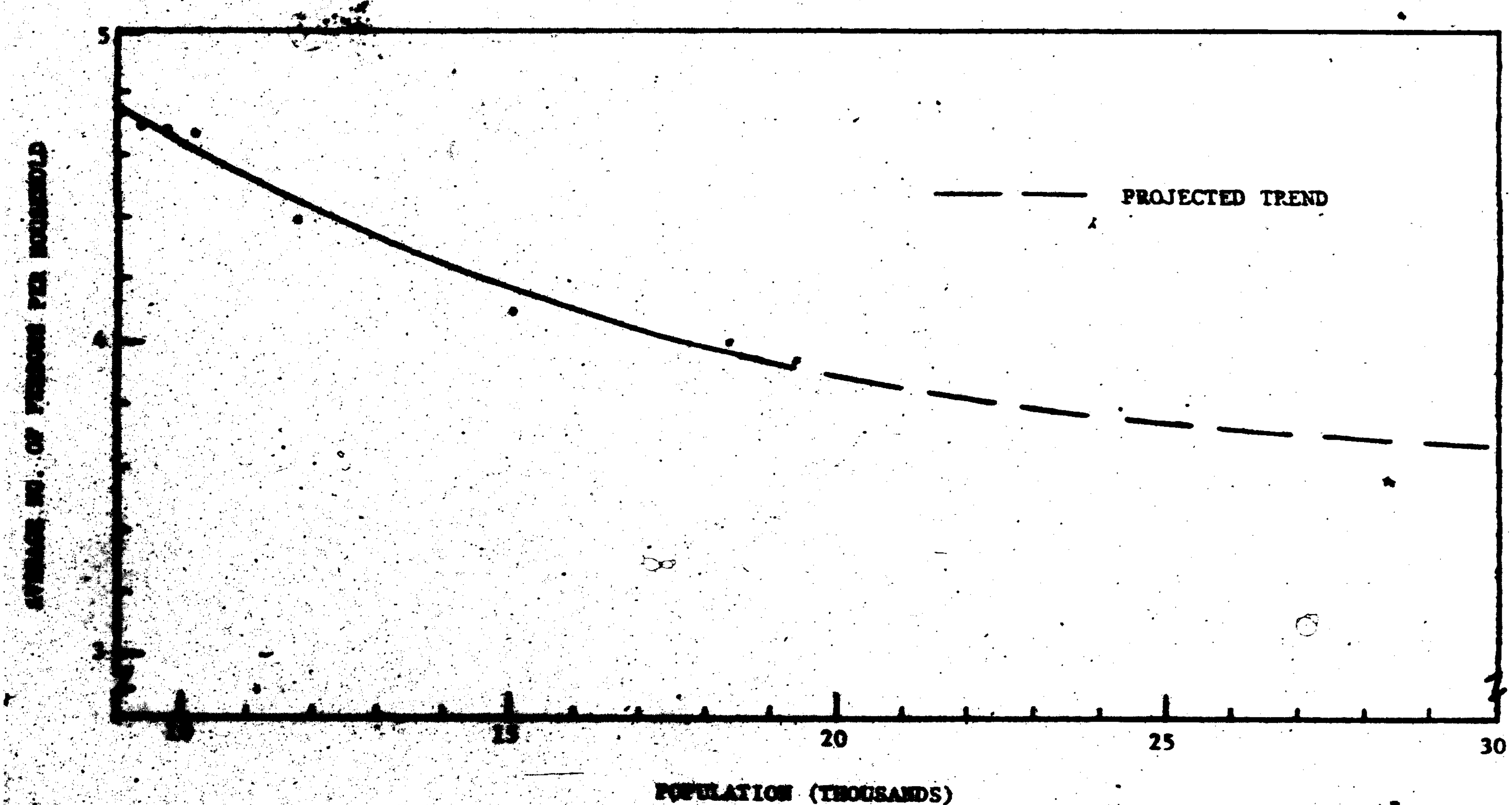

FIGURE V – 2: AVERAGE HOUSEHOLD SIZE RELATED TO POPULATION FOR THE TOWN OF ST. ALBERT

That is, only those St. Albert work trips that had destinations located within St. Albert. To obtain the total St. Albert work trips in those years, the assumption will be made that the local work trips constituted 20% of the total St. Albert work trips. Previous analysis in Chapter IV.2 has, in fact, shown that the proportion of St. Albert work trips occurring within St. Albert had remained steady at 20% of the total from the year 1967 to 1974. Total work trips having been computed by the prediction model, Table V - 2 shows the comparison of the two sets of total work trip volumes thus obtained. The percentage difference between the two gives us an idea of how reliable the model is in work trip prediction. Comparison of the work trip data for 1971 (at which time population was a little more than half the population in January 1974) shows a discrepancy of only 7%.

Backward projection of work trip production by means of Equation V - 2 gives rise to much larger discrepancies in percentage differences. With Equation V - 2, the predicted total of work trips in January 1973 is 5,850 and in January 1971 the predicted total is 4,350 work trips. Thus, when compared with the estimated actual total work trips of St. Albert, this gives percentage differences of + 7% for 1973 and + 18% for 1971. The predicted number of total work trips (using this equation) for January 1972 is 4,[illegible]0, the results of which indicate a percentage difference in total work trips of [illegible] when compared with the actual total of 4,320 work trips in January 1972. Equation V - 2, as can be recalled, has been established by

TABLE V - 2: 'BACKWARD' PROJECTION OF WORK TRIPS BY THE MODEL

YEAR (JANUARY)	POPULATION	NO. OF WORK TRIPS (a) ST. ALBERT	(b) TOTAL	BY PREDICTION MODEL HOUSEHOLD SIZE	TOTAL WORK TRIPS	% DIFF. IN TOTAL WORK TRIPS
1971	11249	736	3700	4.5	3950	+ 7%
1972	12637	981	4900*	4.4	4550	- 7%
1973	[illegible]	1090	5450	4.2	5650	+ 4%

a: Internal work trips within St. Albert.

b: Estimated from the known work trips within St. Albert as 20% of total.

*: Actual total was 4320, which gives a difference of 5% when compared with the predicted total.

associating work trip production with population. For this reason, and other reasons cited previously, Equation V - 1 (in which work trips have been associated with households instead of population) is preferred over Equation V - 2 for prediction of work trip production.

The prediction model of Equation V - 1 is then applied at future levels of population by "forward" projection. The January 1974 level of population is used as a base for estimating the increase. The base level has a population of 18,395, total households numbering 4,600 and home-to-work trips of 7,270 (estimate from preliminary results of January 1974 O-D survey). The three levels of population being chosen for study and the estimated household size are shown in Table V - 3. Estimate of average household size and the addition of zones due to the expansion of population have already been discussed in the preceding section of this chapter.

The results of the prediction are shown in Table V - 4. It is again stated here that the predicted number of home-to-work trips includes students going to school in Edmonton, because of the origin of the equation. As can be expected, it is noted here that the percentage increase in work trips exceeds that of population at every level. Once again, this is accounted for by the fact that we have related work trip production to household number and the assumption that average household size decreases over time.

TABLE V - 3: POPULATION LEVELS AND THE ESTIMATED AVERAGE HOUSEHOLD SIZE

	BASE LEVEL*	LEVEL 1	LEVEL 2	LEVEL 3
TOTAL POPULATION	18395	30,000	40,000	50,000
INCREASE IN POPULATION*	-	11,605	21,605	31,605
INCREASE IN NO. OF HOMES	-	14	25	36
ESTIMATED AVERAGE HOUSEHOLD SIZE	4.0	3.7	3.5	3.4

* Using January 1974 as base.

TABLE V - 4: POPULATION LEVELS AND PREDICTED NO. OF WORK TRIPS

	BASE LEVEL*	LEVEL 1	LEVEL 2	LEVEL 3
TOTAL POPULATION	18,395	30,000	40,000	50,000
PREDICTED NO. OF HOME-TO-WORK TRIPS[1]	7,270	12,100	16,700	21,400
PERCENTAGE INCREASE IN POPULATION*	-	63%	117%	172%
PERCENTAGE INCREASE IN NO. OF HOME-TO-WORK TRIPS*	-	66%	130%	194%

* Using January 1974 as base.

1 Include trips by students going to school in Edmonton.

CHAPTER VI

TRAVEL DEMAND IN THE FUTURE

1. LEVEL OF SERVICE AND SERVICE VOLUMES STUDY OF THE EXISTING CONDITIONS OF HIGHWAY 2

The concepts of level of service and service volumes are discussed in great detail in the "HIGHWAY CAPACITY MANUAL" (Ref. 14). The Manual defines "level of service" as a term which denotes the different operating conditions that occur on a given lane or roadway when accommodating various traffic volumes. It is a qualitative measure of the effect (directly or indirectly) of a number of factors, such as speed, travel time, traffic interruptions, freedom to manoeuver, drivers' comfort and convenience, safety and operating costs. There are six levels of service established, and are designated by the letters A (the best) through F (the worst).

In the Manual, the term "service volume" is defined as "the maximum number of vehicles that can pass over a given section of a lane or roadway in one direction of multilane highways (or in both directions on a two- or three-lane highway) during a specified time period while operating conditions are maintained corresponding to the selected or specified level of service".

In the study here, the same concepts are applied. The computation of service volumes at different levels of service for the existing Highway 2 are performed by employing the established formula:

$$SV = 2000\, N\, (v/c)\, W\, T_e \quad \text{- - - - - - - - - - - -} \quad (VI - 1)$$

where

SV = service volume (mixed vehicles per hour, total for one direction);

N = number of lanes (in one direction);

v/c = volume-capacity ratio, obtained from Table B - 1 in Appendix B;

W = adjustment for lane width and lateral clearance, obtained from Table B - 2 in Appendix B;

T_e = truck factor, obtained from Table B - 3 in Appendix B.

For the section of Highway 2, linking St. Albert and Edmonton, it can be described as an undivided multilane rural highway with the following pertinent factors used in assessing its service volumes:

Roadway factors:

Lane width: two lanes of twelve feet each in each direction.

Lateral clearance: no restricted lateral clearance within six feet from edge of traffic lane.

Shoulders: adequate shoulders of approximately ten feet in width.

Grade: approximate level terrain.

Traffic factors:

Average highway speed: 50 m.p.h.

Percentage of trucks: 8%

The results of computation using Equation VI - 1 for Highway 2 are shown in Table VI - 1. Under the prevailing conditions of Highway 2, level of service A and B is not attainable. Its upper limiting service volumes for levels of service C, D and E are shown to be 930, 2600 and 3700 vehicles per direction respectively.

In a level-of-service evaluation, desirably such factors as speed, comfort, convenience, economy and safety should all be incorporated. Depending on the quality of a roadway, service volumes vary. It is difficult to set a minimum standard of the quality of operating conditions under which a person journeying to work will be willing to accept and tolerate. Of particular interest in this study, however, is the level D service. A maximum service volume based on rural operation of level D has been adopted as the limiting ceiling in the travel demand study that will follow. The Manual describes the conditions as follows:

TABLE VI - 1: SERVICE VOLUMES OF HIGHWAY 2
RELATED TO LEVELS OF SERVICE

LEVEL OF SERVICE	OPERATING SPEED (M.P.H.)	v/c RATIO	W FACTOR	T_e FACTOR	SERVICE VOLUME
C	≥ 45	≤ 0.25	1.00	0.93	930
D	≥ 35	≤ 0.70	1.00	0.93	2600
E	30	≤ 1.00	1.00	0.93	3700

"Level of Service D approaches unstable flow, with tolerable operating speeds being maintained though considerably affected by changes in operating conditions. Fluctuations in volume and temporary restrictions to flow may cause substantial drops in operating speeds. Drivers have little freedom to manoeuver, and comfort and convenience are low, but conditions can be tolerated for short periods of time."

One major obstacle to the capacity of Highway 2, however, is the signal timing at the at-grade intersection of 137 Avenue and Highway 2. The question arises as to whether the intersection capacity is able to handle the level D service volume (2600 per hour) of Highway 2 as figured in Table VI - 1.

Computation of at-grade intersection capacity is also covered in the "HIGHWAY CAPACITY MANUAL". Our concern here, of course, is the accommodation of the southbound traffic. The nature of the calculation of the intersection capacity has the form of equation given by:

SERVICE VOLUME = ASV x G/C x PF x [illegible] x T

where

ASV = approach service volume per hour of green time, obtained from Figure C - 2 in Appendix C.

G/C = ratio of green time (for the approach) to the total cycle time of the signal timing;

PF = adjustment for peak-hour factor, obtained from Figure C - 2 in Appendix C;

RT = adjustment for right-turn traffic, obtained from Table C - 1 in Appendix C;

T = adjustment factor for truck, obtained from Table C - 1 in Appendix C.

The geometric configuration and the traffic composition at the intersection is shown in Figure C - 1 in Appendix C. For level of service D (load factor of ≤ 0.7) and with the present timing of G/C = 0.45 (45 seconds out of 100 seconds) for the approach, computation shows service volume capacity to be approximately 1200 vehicles per clock hour plus about 100 left-turn movements, giving a total of 1300 vehicles per hour. This is far short of the level D service volume of Highway 2 of 2600 vehicles per hour. It can be figured out that in order to meet this demand, a G/C ratio of approximately 0.90 must be available to the approach. To attempt to provide a G/C value of 0.9 to one approach is not possible because of the traffic load on 137 Avenue. Level D is, therefore, governed by the intersection at 137 Avenue and Highway 2 (also at 125 Avenue and at 118 Avenue).

In order to handle level D service volume of Highway 2, therefore, the capacity at the intersection at 137 Avenue must first be increased. This can, perhaps, be accomplished by widening of the approaches at the intersection, or by constructing overpass facilities should the need arise.

2. APPLICATION OF THE CONGESTION THEORY

To approach to the study of the implications of population growth on transportation demand on the St. Albert-Edmonton corridor by means of the CONGESTION THEORY developed in Chapter III, the stepwise discussions will proceed in the following order:

- Characteristics of the Town
- Limiting service volume
- Mode split
- Peak travel patterns
- The need for public transportation

CHARACTERISTICS OF THE TOWN

Basically two alternatives will be considered. The first postulates a balancing employment condition in which St. Albert creates employment, the idea being to lessen commuting work trips to Edmonton and thereby reducing travel demand. The second alternative assumes St. Albert to remain principally a bedroom (dormitory) community. The two alternatives will hereinafter be referred to as the BALANCED situation and the DORMITORY situation respectively.

For the BALANCED alternative we will assume 50% work trips destined for Edmonton (presently 75%), and the work trips to Edmonton for the DORMITORY situation will presumably remain at 75%. In Chapter IV.2, we have already seen that the doubling of population from 1967 to 1974 did not change the dormitory patterns of St. Albert which had kept a steady 75% (approximately) commuting work trips to Edmonton over those years. A sudden drastic change in the dormitory pattern is, therefore, not expected - at least not in the near future. The idea of assuming 50% Edmonton-destined work trips in the BALANCED condition is purely to see how this situation would affect a change in the travel demand as compared to the 75% dormitory situation. It is realised that any employment opportunities created in St. Albert may not necessarily be filled by St. Albert residents.

LIMITING SERVICE VOLUME

Based on the limited roadway approach (here meaning no major improvements on Highway 2 as regards to its carrying capacity), it is desired to study the capability of Highway 2 to accommodate the ever increasing home-to-work traffic with the rapid population growth. Level of Service D (comfort limit) is set as the basic desirable requirement. As has previously been shown, the upper limiting service volume for the existing Highway 2 is at 2600 vehicles per hour in each direction, or at 1300 vehicles per half hour in each direction. Beyond this volume the quality of service will tend to the E level (unstable flow conditions). As has previously been computed, the present intersection service volume for level D at 137 Avenue (City boundary) is only 1300 vehicles per hour. In order to absorb into the City the level D service volume of Highway 2, it becomes absolutely necessary to increase the intersection service volume. To apply the CONGESTION THEORY to study the capability of Highway 2 to accommodate future growth of St. Albert home-to-work traffic, therefore, a major assumption is that improvements will be made on the intersection so that the level D service volume of Highway 2 is not governed by the intersection capacity.

The CONGESTION THEORY can also be applied to the study if the intersection at 137 Avenue remains the bottleneck. Alternatively, therefore, level of service D at the intersection could be set as a limit, in which case the level of service on Highway 2 would be at a higher quality. Or one could also relate the quality of service on Highway 2 to a limit somewhat better than level of service D, with the resulting service volume lower than the upper limiting value for level of service D.

MODE SPLIT

Present mode split for work trips of St. Albert stands at a relatively small percentage of 4% by public transit, but the anticipation is that transit patronage will increase in time to come. Since it is intended here to evaluate the future potential demand for public transportation, the analysis that follows will be based on a zero percent transit mode split and then attempts are made to show this effect on the home-to-work travel demand.

The 1974 O-D survey indicated an average car occupancy for the home-to-work trips of approximately 1.15 persons per vehicle. In our analysis this same rate has been taken, although it is uncertain as to whether the car occupancy will go up or down at a later date and time.

PEAK TRAVEL PATTERNS

The present distribution by time of all home-to-work trips destined for Edmonton and the peak patterns on Highway 2 have previously been discussed in Chapter IV (see Figure IV - 5). If roadway capacity can keep pace with travel demand, ideally similar peak patterns will prevail in the future, since starting times of work are quite inflexible and do not alter much. This peak travel pattern will, for our subsequent study, be referred to as the FREE-CHOICE pattern. With limited roadway capacity, however, there is every reason to expect the patterns to alter. For as traffic volume increases, so also will the level of service of a roadway deteriorate; and besides encumbering a number of other factors qualitatively and quantitatively, this deterioration will result in increased travel time. In order to "beat" the traffic and to arrive at work on time, trip makers will simply elect to start their work journey earlier. The accompanying effect to this is a noticeable [illegible] and [illegible] peak period. These, in actuality, are the underlying concepts of the CONGESTION THEORY developed in Chapter III.

Based on the so-named FREE-CHOICE travel pattern established on the knowledge of the present patterns, the proportioning by time of the home-to-work trip pattern will be tested for various population levels. It is then possible to show if level of service D is exceeded at any time intervals. Schematically, the phenomenon of the increase in travel time and longer staggered peak period due to increased traffic volume can subsequently be shown.

The time interval specially of interest in this study is between 6.00 A.M. and 9.30 A.M. during which time an expected 95% of all home-to-work trips will be assumed to take place. The 1974 O-D survey indicated that 94.6% of the Edmonton-bound work trips left home between these times. Note, however, that this does not take into account the situation when work trips are not made because employees are absent, on holiday, sick etc., which could possibly amount to as high as 10% per day.

THE NEED FOR PUBLIC TRANSPORTATION

As discussed in Chapter III, the COMPETITION THEORY does not overlook the ideas that the demand for transit is in part a function of not only the relative travel time (to the private automobile) but also the level of passenger comfort offered by the transit. A relatively promising transit travel time must be guaranteed and an acceptable level of service in passenger comfort in terms of volume of space per passenger carried should be [illegible] (see Chapter III).

The hypothetical approach by which the need for public transportation is evaluated has been presented in the THEORY section in Chapter III. A smooth curve representing the DESIRED traffic flow is hand-fitted and superimposed with the FREE-CHOICE flow on a volume - vs - time graph. The number of vehicles (hence the number of people) that have to be removed and replaced instead by public mass transit in order to achieve the DESIRED flow of traffic can then be computed; and, similarly, the required mode splits necessary to attain this level of service can be evaluated thereon.

2.1. RESULTS AND DISCUSSIONS

HOME-TO-WORK TRAVEL PATTERNS

The ideal FREE-CHOICE home-to-work trip patterns for both the DORMITORY and BALANCED situations are shown in Tables IV - 2, IV - 3 and IV - 4. The stages and time horizons under consideration correspond to the population levels of 30,000, 40,000 and 50,000 respectively. It can be seen that except for the BALANCED situation at population 30,000, the limiting service volume of level D cannot be maintained without introducing public transportation; and for both population levels of 40,000 and 50,000 the FREE-CHOICE patterns reach the stage of forced (jammed) flow (i.e. traffic volume exceeds service volume for level of service E).

As the [illegible] THEORY states, with limited roadway capacity and increasing traffic volume beyond some limits, the [illegible] patterns cannot be maintained. By [illegible] [illegible] [illegible] to the

TABLE VI - 2: HOME-TO-WORK TRIP PATTERNS AT POPULATION 30,000

(A) [illegible] SITUATION

[illegible] AUTO-DRIVER WORK TRIPS TO EDMONTON (6:00 to 9:30 A.M.) = 7500

[illegible] (A.M.)	6:00 TO 6:30	6:31 TO 7:00	7:01 TO 7:30	7:31 TO 8:00	8:01 TO 8:30	8:31 TO 9:00	9:01 TO 9:30
[illegible]	300	825	1725	1500	1425	900	825
[illegible]	-	-	425	200	125	-	-

(B) [illegible]

[illegible] WORK TRIPS (6:00 to 9:30 A.M.) = 5000

[illegible]	[illegible]	[illegible]	1150	1000	950	600	550

TABLE VI - 3: HOME-TO-WORK TRIP PATTERNS AT POPULATION 40,000

(A) DORMITORY SITUATION

TOTAL AUTO-DRIVER WORK TRIPS TO EDMONTON (6:00 to 9:30 A.M.) = 10347

TIME (A.M.)	6:00 TO 6:30	6:31 TO 7:00	7:01 TO 7:30	7:31 TO 8:00	8:01 TO 8:30	8:31 TO 9:00	9:01 TO 9:30
FREE-CHOICE PATTERN	414	1138	2380	2069	1966	1242	1138
NO. EXCEEDING LEVEL D	-	-	1080	769	666	-	-

(B) BALANCED SITUATION

TOTAL AUTO-DRIVER WORK TRIPS (6:00 to 9:30 A.M.) = 6898

TIME (A.M.)	6:00 TO 6:30	6:31 TO 7:00	7:01 TO 7:30	7:31 TO 8:00	8:01 TO 8:30	8:31 TO 9:00	9:01 TO 9:30
FREE-CHOICE PATTERN	276	759	1586	1380	1310	828	759
NO. EXCEEDING LEVEL D	-	-	286	80	10	-	-

TABLE VI - 4: HOME-TO-WORK TRIP PATTERNS AT POPULATION 50,000

(A) DORMITORY SITUATION

TOTAL AUTO-DRIVER WORK TRIPS TO EDMONTON (6:00 to 9:30 A.M.) = 13258

TIME (A.M.)	6:00 TO 6:30	6:31 TO 7:00	7:01 TO 7:30	7:31 TO 8:00	8:01 TO 8:30	8:31 TO 9:00	9:01 TO 9:30
FREE-CHOICE PATTERN	530	1458	3050	2652	2519	1591	1458
NO. EXCEEDING LEVEL D	-	158	1750	1352	1219	210	158

(B) BALANCED SITUATION

TOTAL AUTO-DRIVER WORK TRIPS (6:00 to 9:30 A.M.) = 8839

TIME (A.M.)	6:00 TO 6:30	6:31 TO 7:00	7:01 TO 7:30	7:31 TO 8:00	8:01 TO 8:30	8:31 TO 9:00	9:01 TO 9:30
FREE-CHOICE PATTERN	354	972	2033	1768	1679	1061	972
NO. EXCEEDING LEVEL D	-	-	733	468	379	-	-

standard of not lower than level of service D, the resulting effects can be explained in Figure VI - 1. This figure shows the DORMITORY situation for population level of 30,000. The CONFINED flow curve shows what is likely to happen if traffic flow is confined to level D conditions. A total of 750 (425 + 200 + 125) auto drivers indicated by the numerical sum of c, d and e can be expected to leave home earlier than they otherwise would in FREE-CHOICE situation. This same number of people (now designated by a and b) would now fall within the time intervals between 6.00 and 7.00 A.M. Theoretically, the relationship (a + b) = (c + d + e) should hold. An increase in average travel time and a staggered and longer duration of peak period that accompany the CONFINED flow pattern of Figure VI - 1 are the resulting phenomena of the CONGESTION THEORY as presented in Chapter III. It should be realized, however, that as travel time by car becomes relatively and unreasonably long in terms of delay, public transit can become more attractive and be placed in a better competition with the private automobiles if transit is provided with exclusive facilities to render a highly competitive standard of level of service.

ASSESSING PUBLIC TRANSPORTATION MODE SPLIT

In employing the CONGESTION THEORY to assess the desired mode split by transit, reference is made to Figure VI - 2. The figure plots the curve of the previously established FREE-CHOICE travel pattern for the DORMITORY conditions at population 30,000, and in addition the DESIRED traffic flow curve has been superimposed.

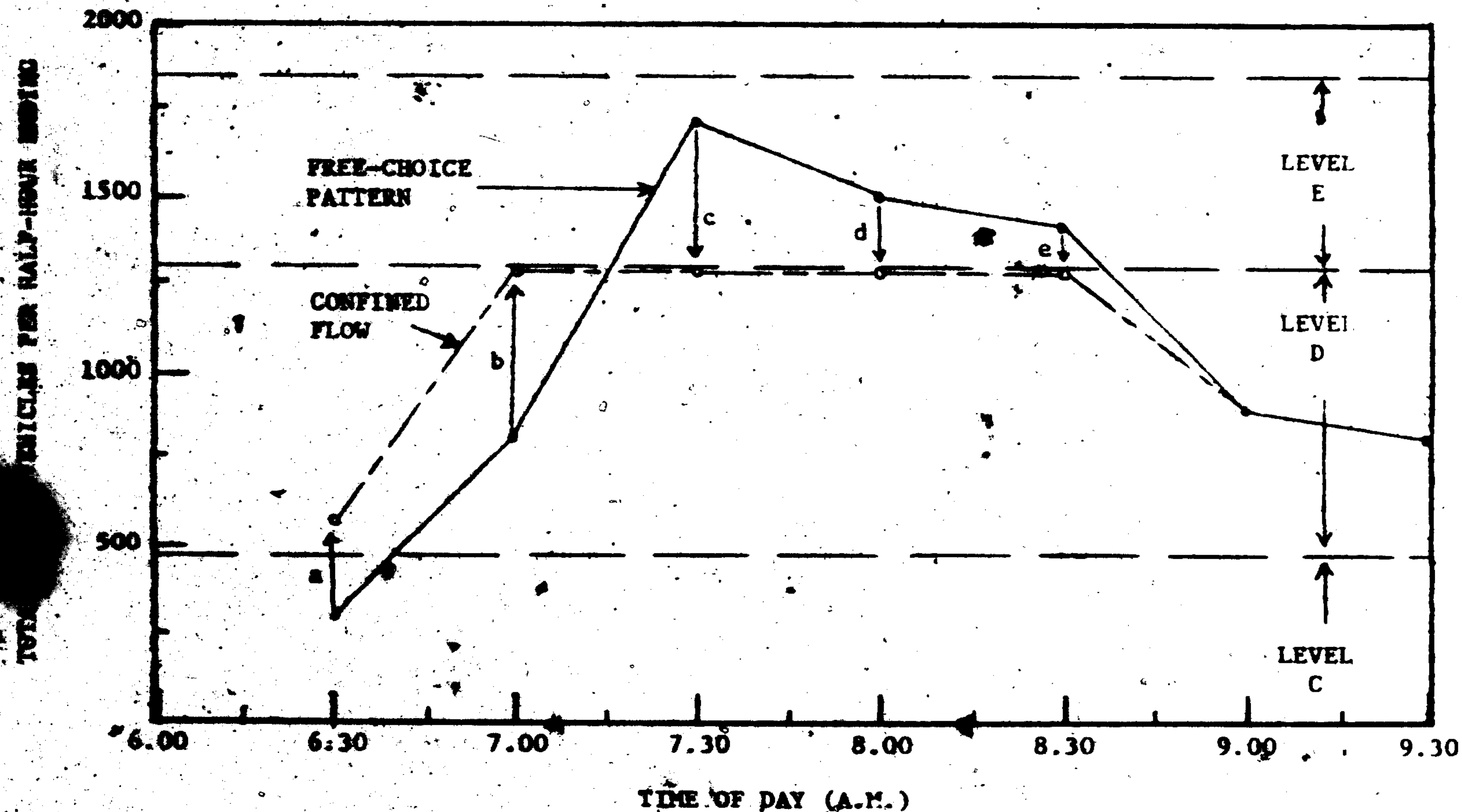

FIGURE VI - 1: HOME-TO-WORK TRIP PATTERNS AT POPULATION 30,000

The choice of a DESIRED flow pattern is purely a matter of personal judgment The higher the quality of service desired, the smaller is the volume of traffic a given roadway can service. The following is an outline of the standard based on which the chosen DESIRED pattern has been established for the A.M. home-to-work travel:

(a) Before 6.30 A.M., level of service is to be at C.

(b) Between 6.30 and 7.00 A.M. and after 9.00 A.M., the service volume is not to exceed 880 vehicles per half hour in each direction of travel; this volume being the average of the service volumes of the upper and lower limiting conditions for level D, and thus lies midway of the two limits.

(c) During peak hours between 7.00 and 9.00 A.M., the service volume approaches (but not to exceed) the maximum upper limiting volume for service level D.

With these requirements being met, the DESIRED flow pattern curve is superimposed on the graph as in Figure VI - 2. The shaded area shows were and when the FREE-CHOICE traffic exceeds the DESIRED volume. Thus, in order to meet the standard of the DESIRED pattern, the number of auto drivers that has to be moved by some form of public mass transit is

$$c + d + e = 480 + 220 + 305 = 1005$$

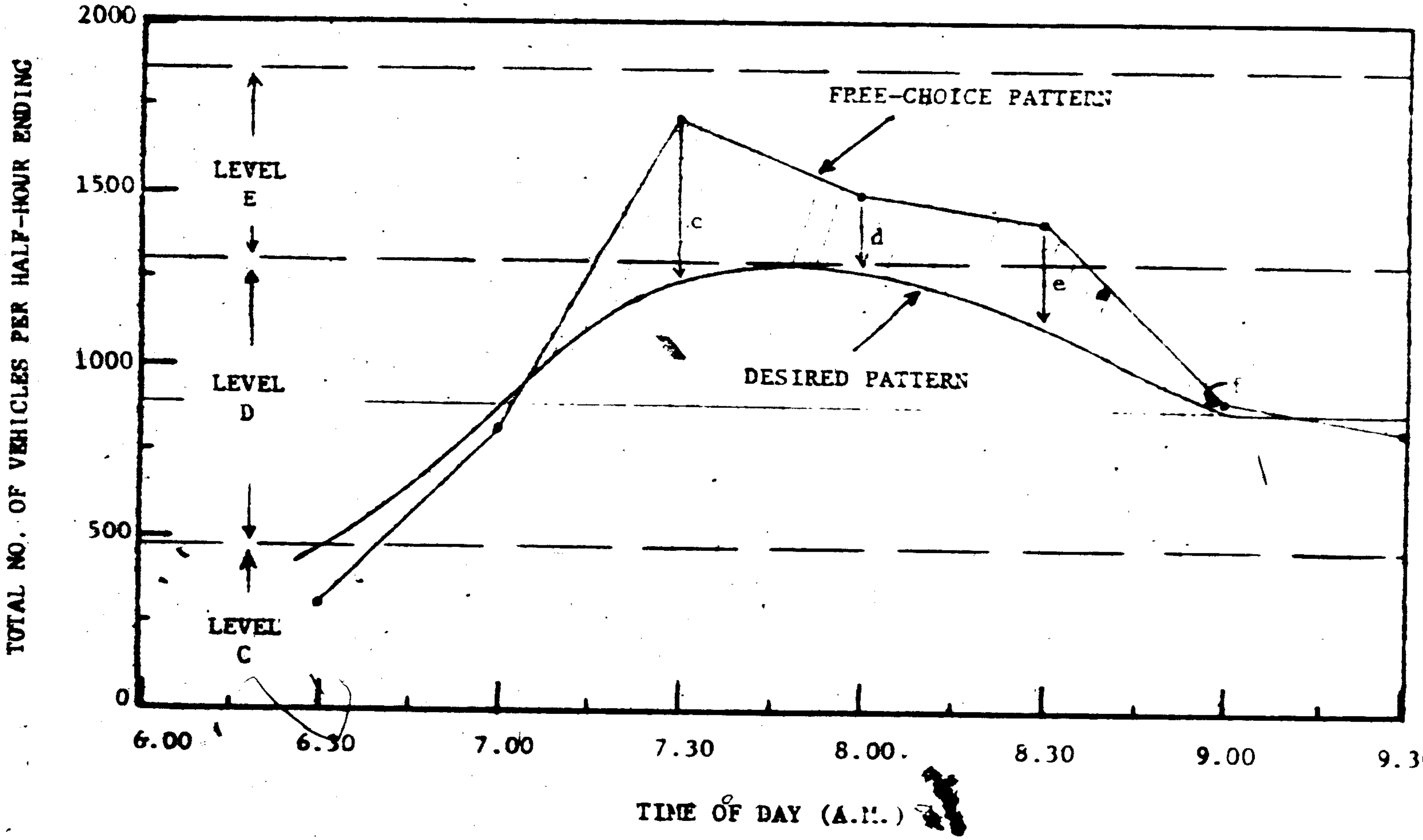

FIGURE VI - 2: HOME-TO-WORK TRIP PATTERNS AT POPULATION 30,000

or, in other words, a total of

1005 x 1.15 = 1156 people,

with car occupancy figured at 1.15 persons per vehicle.

Thus, for the Edmonton-bound work trips, the desired distribution by modes of the A.M. home-to-work trips for the DORMITORY situation at population level of 30,000 is as follows:

Total person trips:	7500 x 1.15	= 8625
Transit passenger:	1005 x 1.15	= 1156
Auto driver:	7500 - 1005	= 6495
Auto passenger:	8625 - 1156 - 6495	= 974

And the approximate percentage mode splits lead to the following:

Transit passenger:	14%
Auto driver:	75%
Auto passenger:	11%

The same procedures can also be applied at other population levels. Figure VI - 3 shows the DORMITORY case for population level of 40,000. While keeping the standard of the DESIRED flow pattern the same as before, the figure indicates the need to carry by public mass transit the following number of auto drivers:

$$b + c + d + e + f + g = 258 + 1135 + 789 + 846 + 362 + 258$$
$$= 3648$$

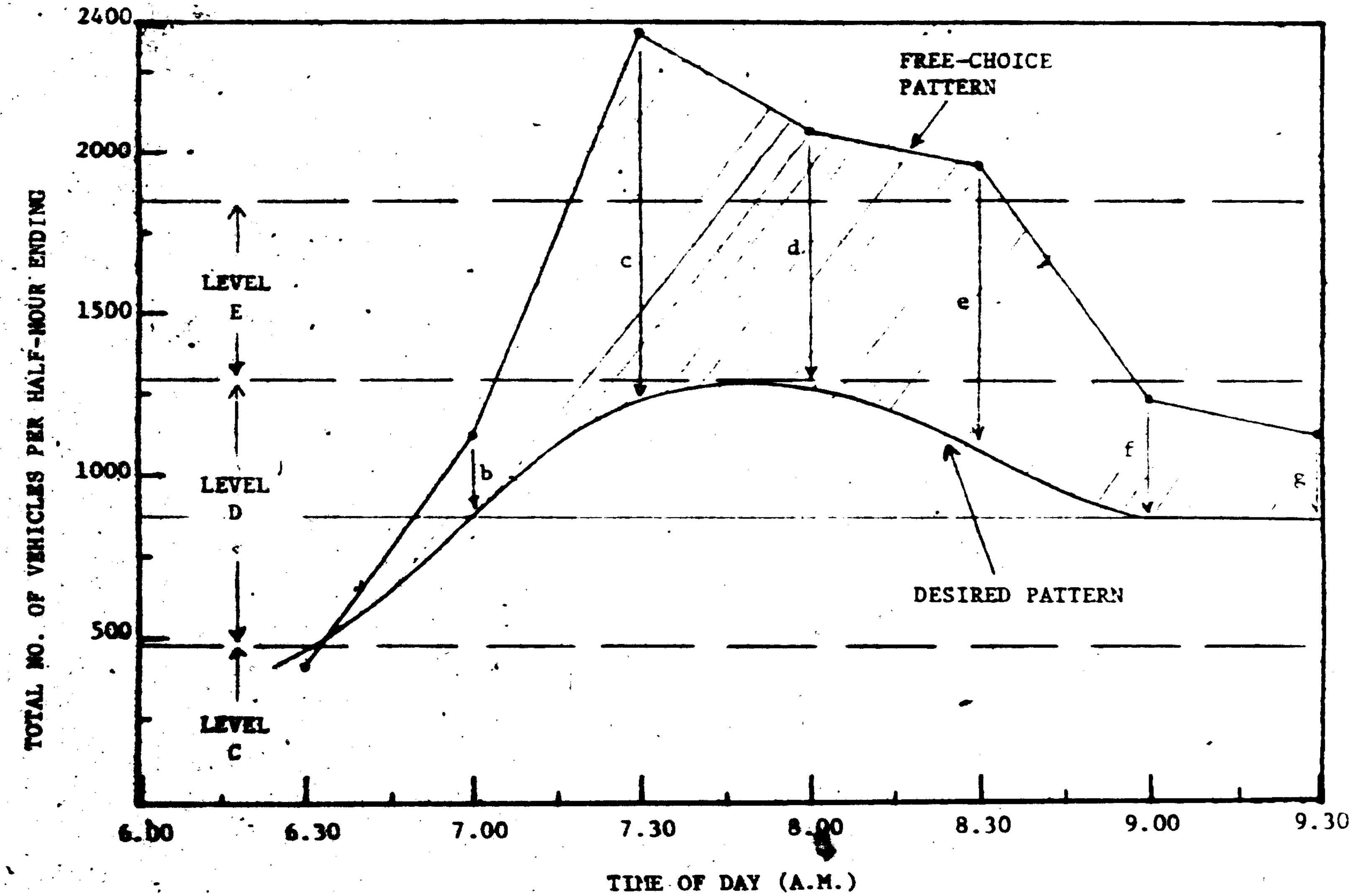

FIGURE VI - 3: HOME-TO-WORK TRIP PATTERNS AT POPULATION 40,000

which, in subsequent calculations leads to the percentage mode splits as:

Transit passenger: 35%

Auto driver: 56%

Auto passenger: 9%

These analytical procedures have demonstrated that if St. Albert is to remain a dormitory community, there is a need to increase the Edmonton-bound work-trip mode split by transit from 14% at population 30,000 to 35% at population 40,000 if the operating conditions on Highway 2 and the level of service is to be maintained at the standard outlined previously. It is to be noted that these are the mode splits of only the St. Albert work trips destined for Edmonton for the A.M. time concerned, as distinguished from total St. Albert work trips. Thus, such transit mode split to be attained at population 30,000 is roughly three times the present figure and at population 40,000 an increase to seven or eight times the present percentage is desired. Translated into number of person trips by transit, at population 30,000 the figure is 1200 transit trips and at population 40,000 it is 4200 trips by public transit. These numbers of trips all occur between the hours of 6.00 and 9.00 A.M. of the home-to-work (St. Albert to Edmonton) journey. The above derivation has assumed no improvements on roadway capacity of Highway 2, but a better and likely approach will probably entail a combination of both improved roadways and transit systems.

3. POTENTIAL MODE SPLIT FOR ST. ALBERT

The factors influencing mode choice include, among others, the following: (a) travel time, (b) travel costs (including parking), (c) comfort and convenience, (d) car necessity, (e) parking availability and (f) economic status of the trip makers. In his thesis (1967) Rhyason concluded that for the City of Edmonton economic status and relative travel time were the chief factors affecting mode choice (Ref. 19). Further work by Gill (1969) showed that travel time ratio and travel time difference were the only two factors to form a statistically significant relationship with mode split (Ref. 20).

The St. Albert-Edmonton transit service was relatively unattractive judging from the 1974 O-D survey response. The majority of the transit patrons are believed to be captive riders. For the sake of comparison it is interesting to note that some of the Edmonton areas with approximately equal relative travel times to the Edmonton C.B.D. have far better mode split by transit. These areas have transit mode splits for work trips destined for the C.B.D. ranging from 30% to 50% and transit mode split for overall total work trips of 14% to 19%, whereas for St. Albert the transit mode split of work trips to the Edmonton C.B.D. is near 10% and only 4% for total work trips. In either case, the difference is about four times. The factors influencing mode choice for St. Albert work trips may be varied, but if relative travel time (transit vs. car times) is a good measure for comparison with Edmonton, then the evidence is that the present mode split by transit for St. Albert work trips has fallen far short of its potential.

In 1969 Gill established the relationships between mode splits and travel time factors for Northern Edmonton by using the linear regression technique (Ref. 20). The two factors that are of particular interest here are namely the travel time ratio and the travel time difference. These are shown in Figures VI - 4A and VI - 4B. The reasons for the choice of these figures to assess potential mode split for St. Albert are:

(a) The relationships established were for the Northern Edmonton regions (North of 127 Avenue) whose travel times to the C.B.D. are comparable to that of St. Albert to the Edmonton C.B.D.

(b) The established relationships represented a wide range of economic status of the trip makers (economic status was measured by house sale value).

(c) It is desired to predict the potential mode split of St. Albert work trips to the Edmonton C.B.D. and these figures were established on the basis of mode split of work trips to the centre of downtown Edmonton.

Average total travel time to downtown Edmonton is computed in the following manner:

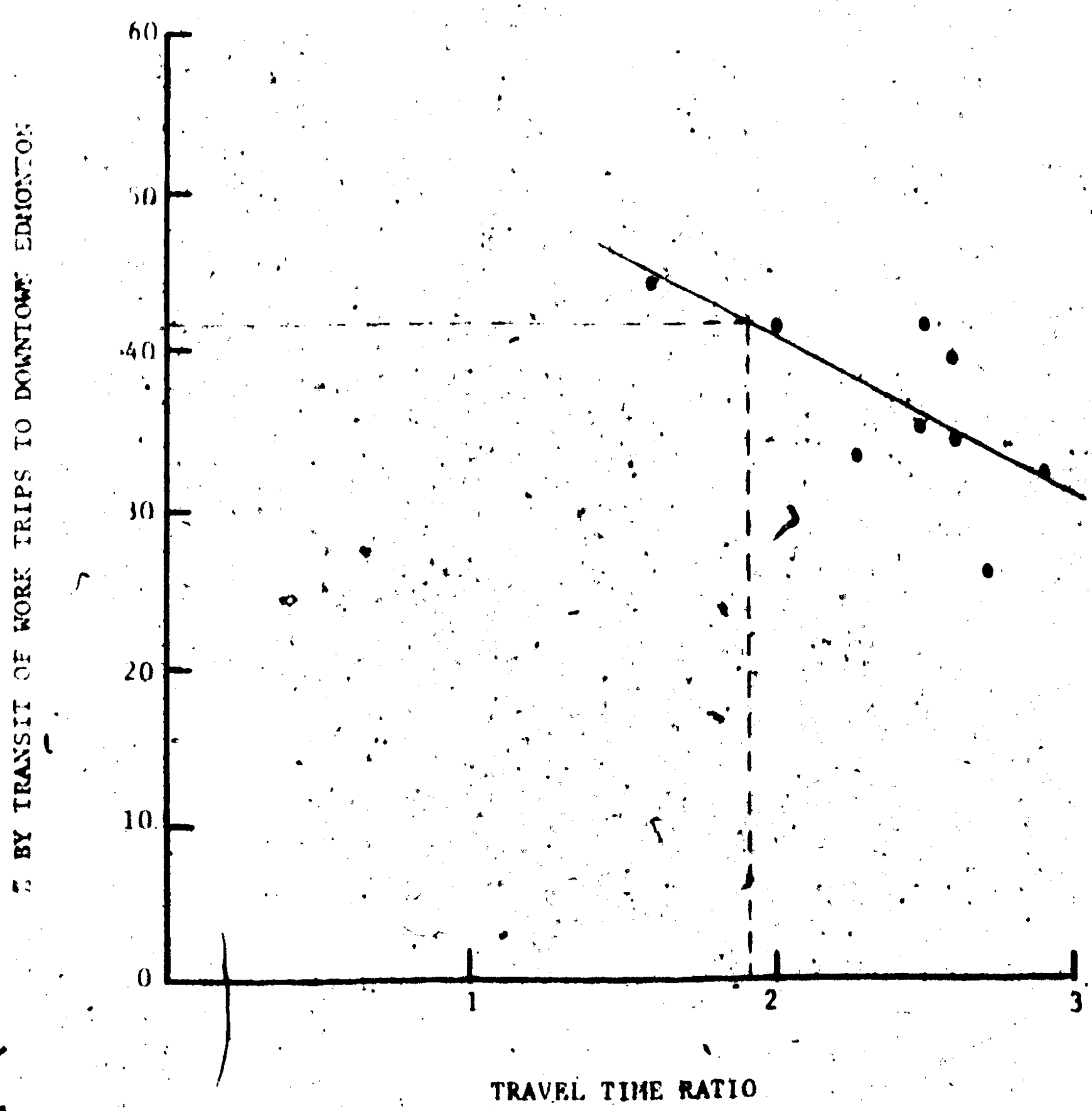

FIGURE VI - 4A: MODE SPLIT RELATIONSHIPS FOR N. EDMONTON

(Source: Ref. 20)

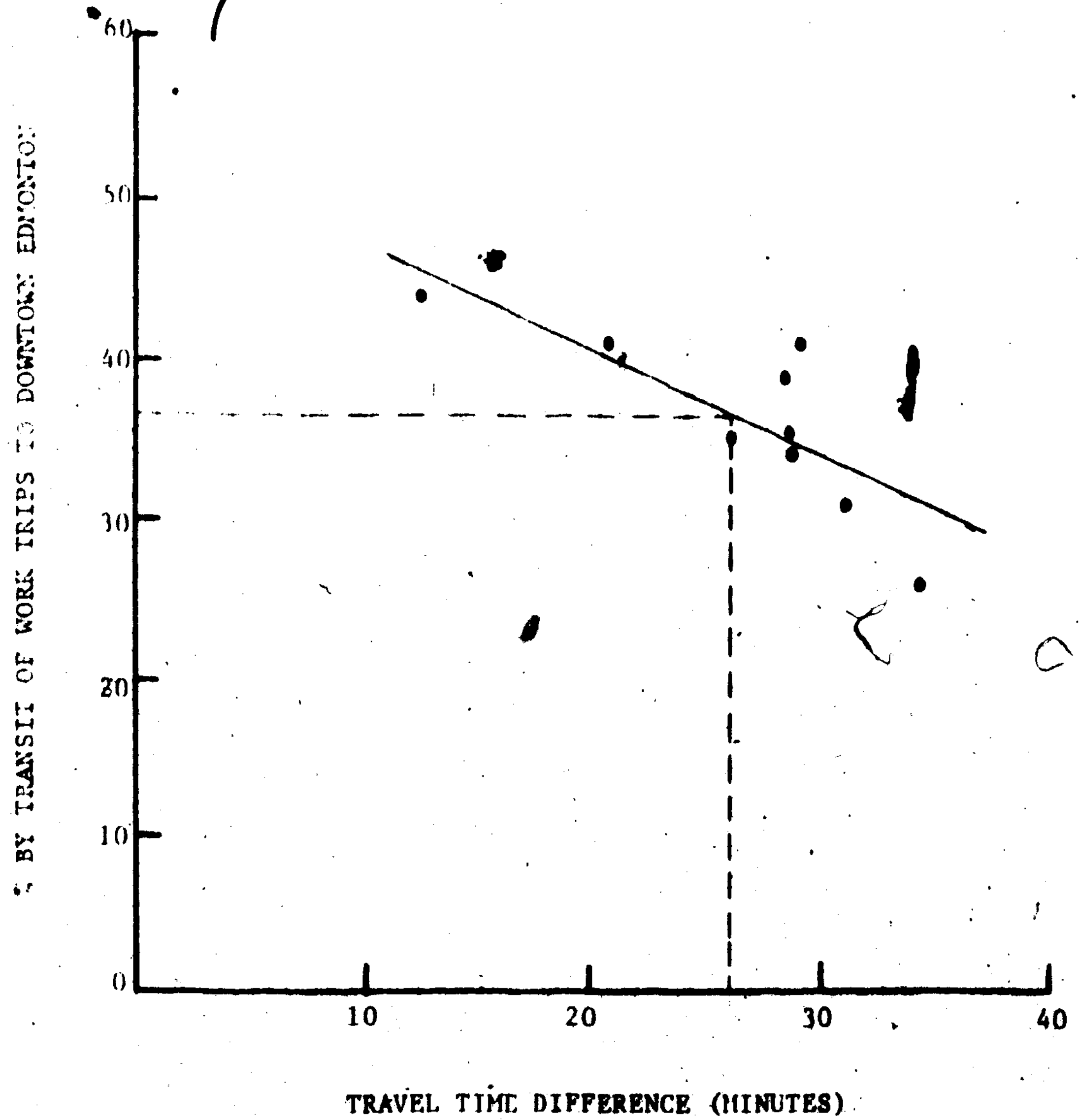

FIGURE VI - 4B: MODE SPLIT RELATIONSHIPS FOR N. EDMONTON

(Source: Ref. 20)

Travel time by bus:

Home to bus stop:	3 minutes
Waiting time:	5 minutes
Avg. bus time to station:	13 minutes
Transfer time:	2 minutes
Avg. bus time to downtown Edmonton	28 minutes
Walk to final destination:	4 minutes
TOTAL TIME:	55 minutes

Travel time by car:

Avg. driving time to downtown Edmonton:	25 minutes
Park and walk to destination:	4 minutes
TOTAL TIME:	29 minutes

This will produce a travel time ratio of 55/29 = 1.90, and a travel time difference of 55 - 29 = 26 minutes. If these are figured out on the appropriate derived relationship of Figure VI - 4A and Figure VI - 4B, the mode splits obtained in each case will be 41% and 37% respectively.

If such comparison between St. Albert and the Northern Edmonton areas can be made, then the inference is that the mode split by transit of St. Albert work trips to the Edmonton C.B.D. has a potential attainment of about four times what it presently is. Although it is unlikely that a mode split of this range can be achieved within a short time period (it takes time to change people's habits or to develop and finance a service), it does reveal the potentials of St. Albert transit system that should be exploited as a possible alternative (perhaps) to roadway expansion.

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

1. CONCLUSIONS

The chief aims of this thesis have been to study the commuting patterns and the features related to commuting work trips especially of a community that is "dormitory" in nature. A typical case in point chosen for this study is the Town of St. Albert, a dormitory community characterized as such by its overwhelming number of commuting work trips (more than 75% of total) whose trip destinations are located outside of the town. The Origin-Destination survey data on work trips have been a valuable aid in this study. Partly to try to determine the future commuting patterns of the dormitory town, the so-called CONGESTION THEORY has been presented. The investigation has been confined to the Town of St. Albert only and conclusions that have been drawn may, therefore, not be applicable to situations of other dormitory towns.

1. Based on the study of the percentage distributions of work trip destinations, it was discovered that the dormitory patterns of St. Albert have been very stable. From the year 1967 to January of 1974 population had approximately doubled, yet the dormitory patterns had remained unaltered. It appears, therefore, that mere population growth per se has little (if any) effect

on the dormitory patterns of the Town of St. Albert.

2. In developing a work-trip prediction model by the simple regression analysis method, the superiority of the variable household over the commonly used population was established as being a more reliable basis for predicting future work trip production of St. Albert. It was maintained that the general trend of diminishing family (household) size (which St. Albert is undergoing) is one factor that renders the correlation of future work trip production to population growth less dependable. Cross-classification analysis indicated an inconsistency in the relationship of work trip to family size. For household sizes of 4, 3 and 2 it showed that the average number of work trips made per person increased with decreasing household size, whereas the relationship was inconsistent for other household sizes.

3. Correlation of the O-D survey information on work trips and the actual screen line count of traffic on Highway 2 for the A.M. time between 6.00 and 9.00 showed close quantitative agreement in the cumulative total. Based on the correlation procedures, it was believed that for the A.M. time studied, other than that of St. Albert work trips, the traffic on Highway 2 bound for Edmonton composed of no significant portion from other traffic generators. It would, therefore, seem possible to get

a good quantitative estimate of the cumulative total of actual traffic based on the O-D data. The mis-match of the half-hourly distributions, however, seemed to suggest that the people tended to report in the survey questionnaire their leave-home time for work earlier than actual. By rough averaging calculations, the work-journey time (from leave-home till start-work time) to Edmonton for various modes of work trips was figured to be 42 minutes for auto drivers, 47.5 minutes for auto passengers and 66 minutes for bus passengers.

4. Application of the CONGESTION THEORY to the Town of St. Albert showed that as population grows the future commuting patterns of the dormitory town are very much dictated by the kind of transportation facilities that will be made available. Assuming the capability of the intersection at 137 Avenue to absorb St. Albert traffic into the city, the "limited roadway" approach based on level D standard showed the need to increase transit mode split of St. Albert work trips to Edmonton (for 6.00 to 9.00 A.M.) to 14% at 30,000 population and 35% at population of 40,000. Highly competitive transit service should, therefore, be implemented in order to attract these commuters who will eventually have to count on public transportation. From the standpoint of the CONGESTION THEORY, at some stage the further

growth of dormitory towns will be very much dependent upon the availability and the expansion of transportation facilities.

5. Based on comparison by relative travel times of St. Albert and her Edmonton counterparts, it indicated that the transit mode splits of both St. Albert total work trips and St. Albert work trips to the Edmonton C.B.D. were four times lower than those of her Edmonton counterparts.

2. RECOMMENDATIONS

Through the investigation carried out in this thesis, the following points have been proposed as recommendations:

1. That actual field count of car occupancy be conducted concurrent with any future Origin-Destination survey in order to ascertain the reliability of the seemingly low car occupancy rate usually reported in the survey.

2. That screen line count on Highway 2 for southbound traffic be conducted on "normal" weekdays (rather than during summer vacation) that best represent the normal traffic conditions on the highway. If possible, one such count should be conducted to concur in time with an Origin-Destination survey of work trips so that more meaningful correlation between the two can be had.

3. That attempts should be made to separate student trips from actual work trips in the analysis of the O-D survey data. This is all the more significant especially when the portion of student trips becomes sizable since characteristics involving these two trip purposes differ somewhat.

4. That, if possible, detailed study be undertaken to find out the various factors that influence mode choice of commuting workers of St. Albert, since transit usage of St. Albert work trips is comparatively very low.

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APPENDIX A

A BRIEF DISCUSSION ON LEAST SQUARE REGRESSION ANALYSIS

Given a sample of data in which Y is related to X, say we wish to form an equation that will best estimate the value of the dependent variable Y corresponding to a given value of the independent variable X. This can be accomplished by the method of simple regression analysis (Ref. 18). The so-called least square regression line of Y on X has the form

$$Y = a + bX \qquad \text{(A - 1)}$$

where a and b are constants.

If plotted on a graph, the least square line thus obtained approximates the sets of points (X_1, Y_1), (X_2, Y_2), - - - (X_n, Y_n) for n number of observations. The constants a and b of Equation A - 1 are obtained from the formulas

$$a = \frac{(\Sigma Y)\ (\Sigma X^2) - (\Sigma X)\ (\Sigma XY)}{n\Sigma X^2 - (\Sigma X)^2}$$

$$b = \frac{n\Sigma XY - (\Sigma X)\ (\Sigma Y)}{n\Sigma X^2 - (\Sigma X)^2}$$

The magnitudes of the standard error of estimate of Y on X (S_{yx}) and the coefficient of determination (R^2) are criteria commonly used to measure the validity of a regression equation. These values are computed from the expressions

$$S_{yx} = \sqrt{\frac{\Sigma\,(Y - Y_{est})^2}{n - 2}}$$

$$R^2 = \frac{\Sigma\,(Y_{est} - \bar{Y})^2}{\Sigma\,(Y - \bar{Y})^2}$$

in which

Y_{est} = the value of Y for a given value of X as estimated from Equation A - 1.

$\bar{Y}$ = the mean value of Y observations.

n = number of observations.

The standard error of estimate (S) has the properties that within a band of plus and minus one S on either side of the regression line, 68.3% of the original observations may be expected to fall. Within ± 2S and ± 3S, we can expect confidence of 95% and 99.7% respectively.

The coefficient of determination (R^2) assumes a magnitude between 0 and 1. A value of $R^2 = 1$ implies that there would be no variation remaining unexplained by the independent variable used in the regression equation. In the other extreme when $R^2 = 0$, the independent variable (X) would not explain any of the dependent variable (Y). Hence, we may say that the R^2 indicates the amount of improvement (in terms of reducing the total error) brought about by fitting the regression line. Theoretically, therefore, R^2 should be close to one for best estimate from a regression equation.

The square root of the coefficient of determination is termed the coefficient of correlation (R). R is a measure of the linear correlation between two variables. Its values vary between 0 and +1 or between 0 and -1.

APPENDIX B

TABLES FOR FACTORS USED IN THE

SERVICE VOLUMES COMPUTATION

(SOURCE: Ref. 14)

TABLE B - 1: LEVELS OF SERVICE RELATED TO VOLUME-CAPACITY RATIO

TABLE 10.1—LEVELS OF SERVICE AND MAXIMUM SERVICE VOLUMES FOR MULTILANE HIGHWAYS, UNDIVIDED AND/OR WITHOUT ACCESS CONTROL, UNDER UNINTERRUPTED FLOW CONDITIONS (NORMALLY REPRESENTATIVE OF RURAL OPERATION)

LEVEL OF SERVICE	TRAFFIC FLOW CONDITIONS: DESCRIPTION	TRAFFIC FLOW CONDITIONS: OPERATING SPEED[a] (MPH)	SERVICE VOLUME/CAPACITY (v/c) RATIO: BASIC LIMITING VALUE[a] FOR AHS OF 70 MPH	APPROXIMATE WORKING VALUE FOR RESTRICTED AHS OF 60 MPH	APPROXIMATE WORKING VALUE FOR RESTRICTED AHS OF 50 MPH	MAXIMUM SERVICE VOLUME UNDER IDEAL CONDITIONS, INCLUDING 70-MPH AHS (TOTAL PASSENGER CARS PER HOUR, ONE DIRECTION): 4-LANE HWY. (2 LANES ONE DIRECTION)	6-LANE HWY. (3 LANES ONE DIRECTION)	EACH ADDITIONAL LANE
A	Free flow	≥60	≤0.30	—[b]	—[b]	1200	1800	600
B	Stable flow (upper speed range)	≥55	≤0.50	≤0.20	—[b]	2000	3000	1000
C	Stable flow	≥45	≤0.75	≤0.50	≤0.25	3000	4500	1500
D	Approaching unstable flow	≥35	≤0.90	≤0.85	≤0.70	3600	5400	1800
E[c]	Unstable flow	30[d]	≤1.00			4000	6000	2000
F	Forced flow	<30[d]	Not Meaningful[e]			Widely variable (0 to capacity)		

[a] [illegible] and basic v/c ratio are independent measures of level of service; both limits must be satisfied in any determination of level.
[b] [illegible] for this level is not attainable even at low volumes.
[c] [illegible]
[d] [illegible]
[e] [illegible] volume/capacity ratio may well exceed 1.00, indicating overloading.

TABLE B - 2: ADJUSTMENT FACTOR FOR LANE WIDTH AND LATERAL CLEARANCE

TABLE 10.2—COMBINED EFFECT OF LANE WIDTH AND RESTRICTED LATERAL CLEARANCE ON CAPACITY AND SERVICE VOLUME OF UNDIVIDED MULTILANE HIGHWAYS WITH UNINTERRUPTED FLOW

DISTANCE FROM TRAFFIC LANE EDGE TO OBSTRUCTION (FT)	ADJUSTMENT FACTOR,ᵃ W, FOR LATERAL CLEARANCE AND LANE WIDTH							
	OBSTRUCTION ON RIGHT SIDE ONLY, OF ONE-DIRECTION TRAVELED WAY (INCLUDES ALLOWANCE FOR OPPOSING TRAFFIC ON LEFT)				OBSTRUCTIONS ON BOTH SIDES OF ONE-DIRECTION TRAVELED WAY[b,c]			
	12-FT LANES	11-FT LANES	10-FT LANES	9-FT LANES	12-FT LANES	11-FT LANES	10-FT LANES	9-FT LANES
(a) 4-Lane Undivided Highway, One Direction of Travel								
6	1.00	0.95	0.89	0.77	N.A.	N.A.	N.A.	N.A.
4	0.98	0.94	0.88	0.76	N.A.	N.A.	N.A.	N.A.
2	0.95	0.92	0.86	0.75	0.94	0.91	0.86	N.A.
0	0.88	0.85	0.80	0.70	0.81	0.79	0.74	0.66
(b) 6-Lane Undivided Highway, One Direction of Travel								
6	1.00	0.95	0.89	0.77	N.A.	N.A.	N.A.	N.A.
4	0.99	0.94	0.88	0.76	N.A.	N.A.	N.A.	N.A.
2	0.97	0.93	0.86	0.75	0.96	0.92	0.85	N.A.
0	0.94	0.90	0.83	0.72	0.91	0.87	0.81	0.70
(c) Divided Highways, One Direction of Travel								
Use adjustment factors from Table 9.2								

ᵃ Same adjustments for capacity and all levels of service.
ᵇ Appropriate for use only where normally undivided roadway is temporarily separated into two roadways by obstructions such as centerline barrier, bridge structural elements, piers, and the like, which are closer than would be the opposing traffic.
ᶜ N.A. = Not applicable; use adjustment for obstruction on right side only. (In these cases, clearance is temporarily greater than the usual separation from opposing traffic, but adjustment for this temporary improvement is not feasible).

TABLE B - 3: ADJUSTMENT FACTOR FOR TRUCKS

TABLE 10.3b—AVERAGE GENERALIZED ADJUSTMENT FACTORS FOR TRUCKS[a] ON ORDINARY MULTILANE HIGHWAYS, OVER EXTENDED SECTION LENGTHS

PERCENTAGE OF TRUCKS, P_T	FACTOR, T, FOR ALL LEVELS OF SERVICE		
	LEVEL TERRAIN	ROLLING TERRAIN	MOUNTAINOUS TERRAIN
1	0.99	0.97	0.93
2	0.98	0.94	0.88
3	0.97	0.92	0.83
4	0.96	0.89	0.78
5	0.95	0.87	0.74
6	0.94	0.85	0.70
7	0.93	0.83	0.67
8	0.93	0.81	0.64
9	0.92	0.79	0.61
10	0.91	0.77	0.59
12	0.89	0.74	0.54
14	0.88	0.70	0.51
16	0.86	0.68	0.47
18	0.85	0.65	0.44
20	0.83	0.63	0.42

[a] Not applicable to buses where they are given separate specific consideration; use instead Table 10.3a in conjunction with Table 10.6.

APPENDIX C

FACTORS USED IN THE COMPUTATION OF INTERSECTION SERVICE VOLUMES

(SOURCE: Ref. 14)

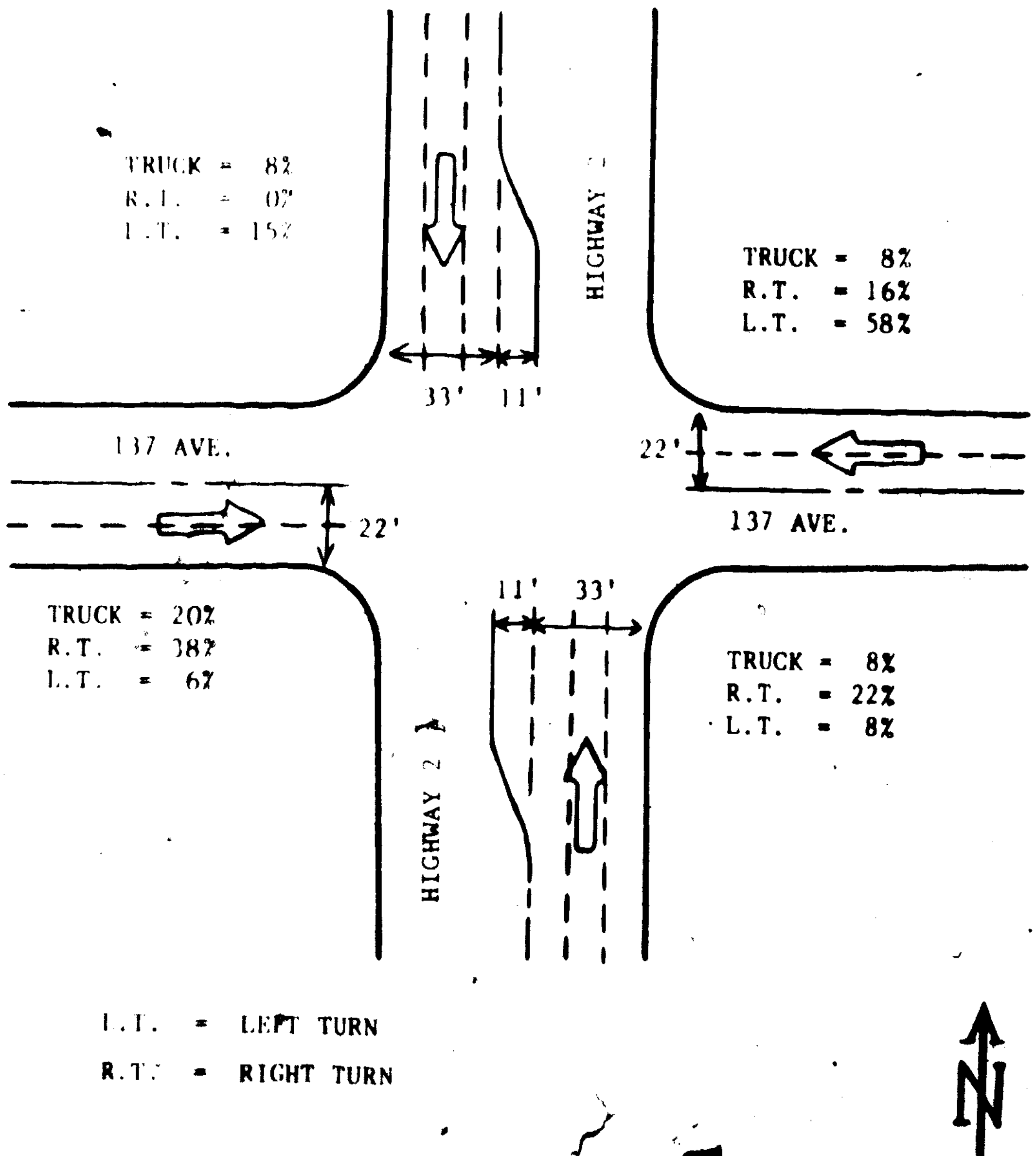

FIGURE C - 1: TRAFFIC MOVEMENTS AND GEOMETRIC CONFIGURATION AT INTERSECTION OF 137 AVE. AND HIGHWAY 2

TABLE 6.3 LEVELS OF SERVICE AND MAXIMUM SERVICE VOLUMES FOR INDIVIDUAL ISOLATED INTERSECTION APPROACHES

LEVEL OF SERVICE	TRAFFIC FLOW DESCRIPTION	LOAD FACTOR
A	Free flow	0.0
B	Stable flow	≥0.1
C	Stable flow	≥0.3
D	Approaching unstable flow	≥0.7
E[a]	Unstable flow	≥1.00
F	Forced flow	—[b]

[a] Capacity.
[b] Not applicable.

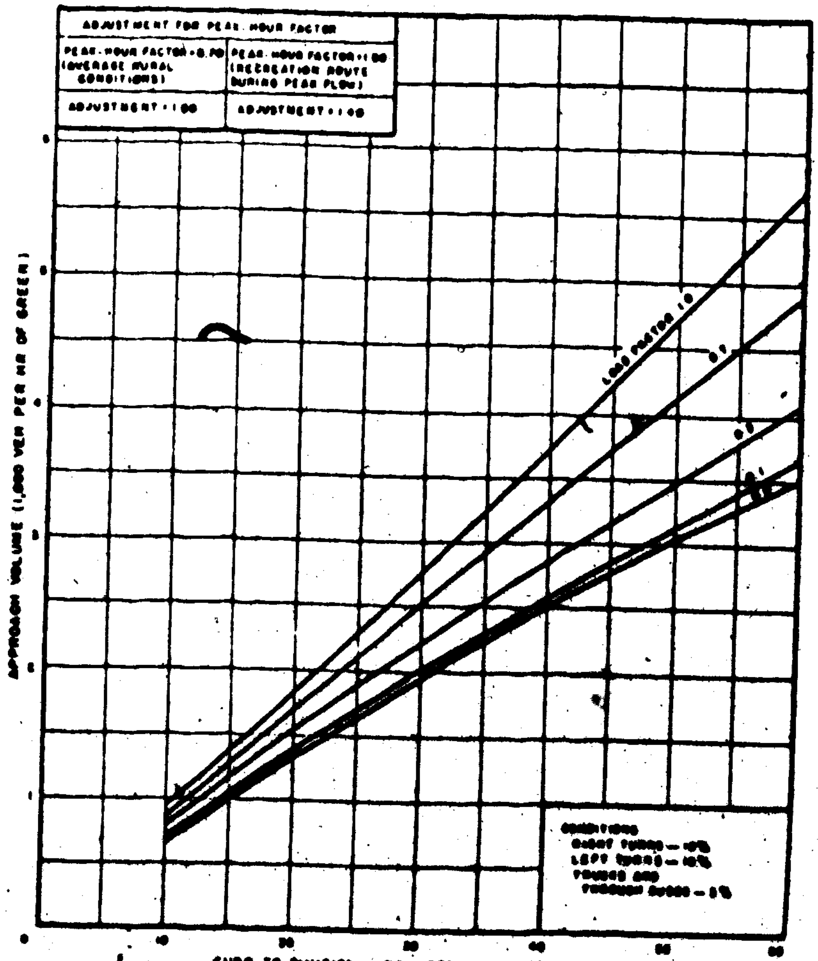

Figure 6.10. Rural intersection approach service volumes, in vehicles per hour of green signal time, for two-way highways with no parking on the traveled way.

FIGURE C - 2: INTERSECTION APPROACH SERVICE VOLUMES

TABLE C - 1: ADJUSTMENT FACTORS FOR TURNING MOVEMENTS

TABLE 6.6—TRUCK AND THROUGH BUS ADJUSTMENT FACTORS

TRUCKS AND THROUGH BUSES (%)	CORRECTION FACTOR	TRUCKS AND THROUGH BUSES (%)	CORRECTION FACTOR	TRUCKS AND THROUGH BUSES (%)	CORRECTION FACTOR
0	1.05	7	0.98	14	0.91
1	1.04	8	0.97	15	0.90
2	1.03	9	0.96	16	0.89
3	1.02	10	0.95	17	0.88
4	1.01	11	0.94	18	0.87
5	1.00	12	0.93	19	0.86
6	0.99	13	0.92	20	0.85

TABLE 6.4—ADJUSTMENT FACTORS FOR RIGHT TURNS ON TWO-WAY STREETS,[a] RIGHT TURNS ON ONE-WAY STREETS,[a] AND LEFT TURNS ON ONE-WAY STREETS[a]

TURNS[b] (%)	ADJUSTMENT FACTOR					
	WITH NO PARKING[c]			WITH PARKING[d]		
	APPROACH WIDTH ≤15 FT	APPROACH WIDTH 16 TO 24 FT	APPROACH WIDTH 25 TO 34 FT	APPROACH WIDTH ≤20 FT	APPROACH WIDTH 21 TO 29 FT	APPROACH WIDTH 30 TO 39 FT
0	1.20	1.050	1.025	1.20	1.050	1.025
1	1.18	1.045	1.020	1.18	1.045	1.020
2	1.16	1.040	1.020	1.16	1.040	1.020
3	1.14	1.035	1.015	1.14	1.035	1.015
4	1.12	1.030	1.015	1.12	1.030	1.015
5	1.10	1.025	1.010	1.10	1.025	1.010
6	1.08	1.020	1.010	1.08	1.020	1.010
7	1.06	1.015	1.005	1.06	1.015	1.005
8	1.04	1.010	1.005	1.04	1.010	1.005
9	1.02	1.005	1.000	1.02	1.005	1.000
10	1.00	1.000	1.000	1.00	1.000	1.000
11	0.99	0.995	1.000	0.99	0.995	1.000
12	0.98	0.990	0.995	0.98	0.990	0.995
13	0.97	0.985	0.995	0.97	0.985	0.995
14	0.96	0.980	0.990	0.96	0.980	0.990
15	0.95	0.975	0.990	0.95	0.975	0.990
16	0.94	0.970	0.985	0.94	0.970	0.985
17	0.93	0.965	0.985	0.93	0.965	0.985
18	0.92	0.960	0.980	0.92	0.960	0.980
19	0.91	0.955	0.980	0.91	0.955	0.980
20	0.90	0.950	0.975	0.90	0.950	0.975
22	0.89	0.940	0.980	0.89	0.940	0.980
24	0.88	0.930	0.985	0.88	0.930	0.985
26	0.87	0.920	0.990	0.87	0.920	0.990
28	0.86	0.910	0.995	0.86	0.910	0.995
30+	0.85	0.900	1.000	0.85	0.900	1.000

[a] No separate turning lanes or separate signal indications.
[b] Handle right turns and left turns separately in all computations; do not sum.
[c] No adjustment necessary for approach width of 35 ft or more; that is, use factor of 1.000.
[d] No adjustment necessary for approach width of 40 ft or more; that is, use factor of 1.000.

APPENDIX D

1974 ST. ALBERT O-D SURVEY FORM

1974 ST. ALBERT TRAVEL QUESTIONNAIRE

POLLING DIV NO 6

NO. OF PERSONS IN HOUSEHOLD [ ] (5 6)

NO. OF CARS AVAILABLE IN HOUSEHOLD [ ] (7)

LENGTH OF RESIDENCE IN ST. ALBERT (8) [1] LESS THAN 1 YEAR [2] 1-3 YRS [3] 3-5 YRS [4] 5-10 YRS [5] MORE THAN 10 YEARS

THE FOLLOWING TO BE FILLED OUT FOR EVERY PERSON OVER 16 YEARS OF AGE

FORM NO. ________

(9)	(10) SEX	(11) OCCUPATIONAL STATUS	(12-15) ADDRESS OF EMPLOYMENT	(16) MODE OF TRANSPORTATION	(17-21) TIME LEAVE HOME	(22-26) TIME START WORK
PERSON 1 [1]	[1] MALE [2] FEMALE	[1] EMPL [2] H.W. [3] UNEMPL [4] RET [5] H.SCH [6] OTHER STUDENT [7] RET [8] UNEMP [9] OTHER	STREET & AVENUE	[1] AUTO DRIVER [2] AUTO PASS [3] BUS PASS [4] WALK [5] OTHER	HOURS : MINUTES [A] [P]	HOURS : MINUTES [A] [P]
PERSON 2 [1]	[1] MALE [2] FEMALE	[1] EMPL [2] H.W. [3] UNEMPL [4] RET [5] H.SCH [6] OTHER STUDENT [7] RET [8] UNEMP [9] OTHER	STREET & AVENUE	[1] AUTO DRIVER [2] AUTO PASS [3] BUS PASS [4] WALK [5] OTHER	HOURS : MINUTES [A] [P]	HOURS : MINUTES [A] [P]
PERSON 3 [1]	[1] MALE [2] FEMALE	[1] EMPL [2] H.W. [3] UNEMPL [4] RET [5] H.SCH [6] OTHER STUDENT [7] RET [8] UNEMP [9] OTHER	STREET & AVENUE	[1] AUTO DRIVER [2] AUTO PASS [3] BUS PASS [4] WALK [5] OTHER	HOURS : MINUTES [A] [P]	HOURS : MINUTES [A] [P]
PERSON 4 [1]	[1] MALE [2] FEMALE	[1] EMPL [2] H.W. [3] UNEMPL [4] RET [5] H.SCH [6] OTHER STUDENT [7] RET [8] UNEMP [9] OTHER	STREET & AVENUE	[1] AUTO DRIVER [2] AUTO PASS [3] BUS PASS [4] WALK [5] OTHER	HOURS : MINUTES [A] [P]	HOURS : MINUTES [A] [P]
PERSON 5 [1]	[1] MALE [2] FEMALE	[1] EMPL [2] H.W. [3] UNEMPL [4] RET [5] H.SCH [6] OTHER STUDENT [7] RET [8] UNEMP [9] OTHER	STREET & AVENUE	[1] AUTO DRIVER [2] AUTO PASS [3] BUS PASS [4] WALK [5] OTHER	HOURS : MINUTES [A] [P]	HOURS : MINUTES [A] [P]

THE FOLLOWING TO BE FILLED OUT FOR EVERY PERSON UNDER 16 YEARS TRAVELLING OUT OF ST. ALBERT

(9)	(10) SEX	(11) OCCUPATIONAL STATUS	(12-15) ADDRESS OF EMPLOYMENT	(16) MODE OF TRANSPORTATION	(17-21) TIME LEAVE HOME	(22-26) TIME START WORK
PERSON 1 [2]	[1] MALE [2] FEMALE	[1] EMPL [2] UNEMPL [3] H.SCH [4] OTHER STUDENT [5] UNEMP [6] OTHER	STREET & AVENUE	[1] AUTO DRIVER [2] AUTO PASS [3] BUS PASS [4] WALK [5] OTHER	HOURS : MINUTES [A] [P]	HOURS : MINUTES [A] [P]
PERSON 2 [2]	[1] MALE [2] FEMALE	[1] EMPL [2] UNEMPL [3] H.SCH [4] OTHER STUDENT [5] UNEMP [6] OTHER	STREET & AVENUE	[1] AUTO DRIVER [2] AUTO PASS [3] BUS PASS [4] WALK [5] OTHER	HOURS : MINUTES [A] [P]	HOURS : MINUTES [A] [P]
PERSON 3 [2]	[1] MALE [2] FEMALE	[1] EMPL [2] UNEMPL [3] H.SCH [4] OTHER STUDENT [5] UNEMP [6] OTHER	STREET & AVENUE	[1] AUTO DRIVER [2] AUTO PASS [3] BUS PASS [4] WALK [5] OTHER	HOURS : MINUTES [A] [P]	HOURS : MINUTES [A] [P]
PERSON 4 [2]	[1] MALE [2] FEMALE	[1] EMPL [2] UNEMPL [3] H.SCH [4] OTHER STUDENT [5] UNEMP [6] OTHER	STREET & AVENUE	[1] AUTO DRIVER [2] AUTO PASS [3] BUS PASS [4] WALK [5] OTHER	HOURS : MINUTES [A] [P]	HOURS : MINUTES [A] [P]

FIGURE D - 1: 1974 ST. ALBERT O-D SURVEY FORM

APPENDIX E

DIRECTIONAL TRAFFIC VOLUMES ON THE ST. ALBERT-EDMONTON CORRIDOR

TABLE E - 1: TRAFFIC COUNT NORTH OF INTERSECTION OF HIGHWAY 2 AND 137 AVENUE

HOUR ENDING	JULY 3, 1974 WEDNESDAY		JULY 4, 1974 THURSDAY		JULY 5, 1974 FRIDAY	
	NORTH	SOUTH	NORTH	SOUTH	NORTH	SOUTH
6.00	*	73	67	92	79	83
7.00	*	541	355	531	332	538
8.00	*	1522	562	1613	502	1763
9.00	*	1118	603	1090	572	1251
10.00	*	710	560	718	569	758
11.00	580	741	649	673	513	740
12.00	771	649	658	750	643	793
13.00	621	782	701	769	845	852
14.00	*	767	703	819	726	837
15.00	*	620	724	720	854	855
16.00	826	672	891	680	935	789
17.00	1339	726	1457	749	1664	786
18.00	1768	664	1540	758	1849	802
19.00	1134	756	943	900	1231	903
20.00	777	815	765	882	978	*
DIRECTIONAL PEAK-HOUR VOLUME	1768	1522	1540	1613	1849	1763

* Not recorded. (DATA SOURCE: CITY OF EDMONTON)

TABLE E - 2: THROUGH TRAFFIC AT INTERSECTION OF HIGHWAY 2 AND 156 STREET

THURSDAY, JANUARY 3, 1974

HOUR ENDING	NORTH	SOUTH
7.00	95	422
8.00	344	1465
9.00	495	1088
10.00	353	473
11.00	333	451
12.00	396	480
13.00	459	506
14.00	437	563
15.00	419	363
16.00	644	451
17.00	1152	548
18.00	1580	431
19.00	627	402
20.00	380	463
21.00	206	336
22.00	207	207
DIRECTIONAL PEAK-HOUR VOLUME	1580	1465

(DATA SOURCE: ALBERTA HIGHWAYS AND TRANSPORT)