TRANSPORTATION

A SUBSTUDY OF THE REGIONAL OFFICIAL PLAN

REPORT NUMBER 3

DEVELOPMENT OF A TRAVEL FORECASTING MODEL

THE PLANNING AND DEVELOPMENT DEPARTMENT OF
THE REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH

OCT.'76

THE REGIONAL MUNICIPALITY OF
HAMILTON
WENTWORTH

October 25th, 1976

MEMORANDUM NO. 423

To: The Chairman and Members
Regional Planning and Development Committee

Subject: Regional Official Plan Study -
Travel Forecasting

Background

One of the major tasks of the Regional Official Plan Study is to determine the location and type (road/transit) of transportation facilities required for each alternative development plan. To accomplish this task, future travel demands associated with each alternative development plan have to be forecasted. The attached report describes the computerized travel forecasting model developed by the Regional Plan Division for this purpose.

In addition to its usefulness in the Regional Official Plan Study, the model provides the Region with a valuable "continuing planning" tool for determining the impact of future major development proposals on the Regional Transportation system.

Since the model enables forecasts of future travel to be made quickly and accurately for any area of the Region, such travel forecasts can be made available for use by the area municipalities on request.

Recommendation

1. Copies of the report to be provided to the area municipalities for information.
2. The Regional Plan Division make travel forecasts available for use by the area municipalities on request.

Respectfully submitted,

D. A. Lychak, M.C.I.P.
Commissioner of Planning and Development.

GMMcC:KP

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1.0 SUMMARY

A computer-based travel forecasting model was required in order to assist in the development of transportation - related impacts of future growth options for the Regional Municipality of Hamilton-Wentworth. This report describes the complete development of such a simulation model including,

(1) documentation of the input data requirements,

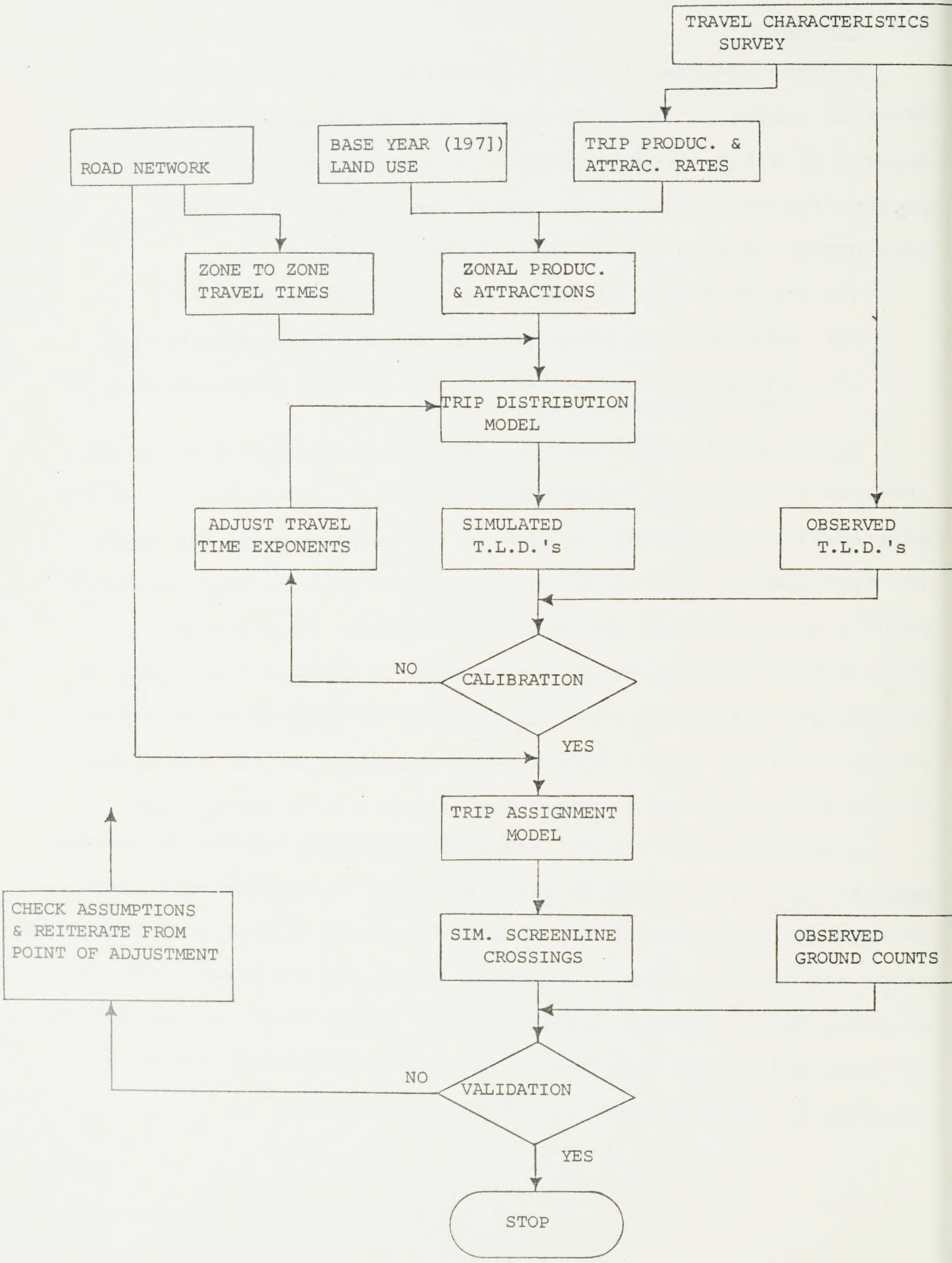
(2) calibration - refinement of the model parameters, and

(3) validation - comparison of the model's simulated results with observed data.

Figure 1-1 illustrates the sequence of activities which are involved in the model calibration-validation procedure. A series of iterative adjustments is made to the parameters of the model. The magnitude of each adjustment is gauged by comparing simulated results against actual observed travel data. This process is continued until an acceptable agreement is reached (in a base or present year) at which time the model is considered to be representative of the actual travel characteristics of the population in the study area and is ready for use as a forecasting tool.

A comprehensive traffic prediction package, PMPMOD (a version modified by M.T.C. staff to allow select link analyses and input of external trip tables) was obtained from the Ministry of Transportation and Communications. In order to provide relevant input for planning future transportation facility requirements it was decided to model all person trip travel (excluding commercial vehicles) occuring in the P.M. peak hour (4:30-5:30 P.M.).

FIGURE 1-1 MODEL CALIBRATION & VALIDATION



The study area, which consists of the Regional Municipality of Hamilton-Wentworth and the City of Burlington, was divided into 148 traffic zones. These became the basic unit for collection of the required land use data, that is, employment (by type), area and population.

Travel within the study area (internal) was simulated using three trip types; home based work (HBW), other home based (HBO), and non-home based (NHB). The two classifications of home based trips, which together accounted for approximately 87% of total P.M. peak hour internal travel, were generated on a zonal basis and distributed using a gravity model concept. NHB trips were simulated using a corridor factoring technique based on observed corridor travel characteristics.

Estimates of 1971 P.M. peak hour external travel ie. (trips whose origin and/or destination are outside of the study area) were obtained from the Ministry of Transportation and Communications in the form of an origin-destination (O-D) table. Several modifications were made to this data on a corridor movement basis by comparing assigned volumes to base year ground counts. The only corridor requiring major adjustment (assigned volumes reduced) was the Brantford-Hwy 403-Toronto Corridor.

A travel characteristics survey* of area residents, conducted in the Fall of 1974, provided much of the background information required for development and eventual calibration of

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* Travel Characteristics Survey, Regional Municipality of Hamilton-Wentworth: Transportation, Report Number 2, October 1975.

the travel forecasting model. In particular, the following base year data were extracted from survey results (for each trip purpose):

(1) trip generation/attraction rates,

(2) directional split of travel,

(3) temporal variations in demands,

(4) proportional importance of trip purpose by corridor,

(5) mean and distribution of trip lengths and,

(6) pattern of trip movements on an O-D basis.

Calibration of the model was accomplished by varying the travel time exponents in the friction function of the trip distribution phase until an acceptable agreement was reached between the shape and mean of the simulated versus observed trip length frequency distributions.

The final calibrated exponents and resultant simulated mean trip lengths (MTL) were 0.125/0.205 and 14.1/11.6 (min.) for the trip purposes of HBW/HBO respectively. Differences between the simulated versus observed MTL's were well within the $\pm$3% standard and the shapes of the trip length distributions closely matched each other when compared visually (see Figures 4-1 and 4-2).

Validation of the model's simulation results was achieved primarily through comparison of total person trip travel assigned to various corridors. In total, simulated estimates of P.M. peak hour person trip movements were compared to observed ground count data across twenty-five(25) different corridors or screenlines which represented all major intra- and inter- Regional travel movements.

Overall, the simulated results compared favourably with the corresponding ground count data (see Table 5-1). Most of the corridor differences were within ±15% and more importantly, the magnitude of deviations were generally less than 1,000 peak direction person trips.

In general, simulated results tended to be higher than the ground counts by approximately 10%. This was considered to be an appropriate adjustment for more meaningful comparison purposes due to the following:

(1) ground (observed) counts were not available for minor roads crossing the screenlines

(2) increase in the activity rate ie. (effective work trip generation rate) between the base year (1971) and the year in which the trip rates were calculated (1974-5).

(3) absence of simulation estimates for commercial vehicle movements.

On the basis of validation checks such as the above it was concluded that base year (1971) travel patterns had been adequately simulated and that the model was thus capable of producing reasonable forecasts of future P.M. peak hour corridor travel movements.

2.0 INTRODUCTION

As part of the transportation - related input to Hamilton-Wentworth's Regional Official Plan it was necessary to estimate the future transportation system facility requirements and resultant impacts of alternative growth strategies for the Region. To facilitate the above and provide input for other transportation system planning activities it was decided to implement a computer-based transportation (travel) forecasting model.

A computer package, PMPMOD (a version modified by M.T.C. staff to allow select link analyses and input of external trip tables) was obtained from the Ministry of Transportation and Communications and utilized to simulate total person trip travel occurring in the P.M. peak hour (4:30-5:30 P.M.).

Before travel can be simulated with any degree of accuracy it is necessary to adjust the parameters of the model to reflect the trip making characteristics of the people within the study area. This process of fine-tuning of the model, commonly referred to as model CALIBRATION and VALIDATION, is carried out in a base or present year so that simulated results (at each iteration) can be compared to an already documented situation.

Once the model has been calibrated and validated in the base year, that is the model adequately simulates base year travel patterns, future land use scenarios can be input and thus future travel demand forecasts can be made.

One of the most important sources of information in the development of the simulation model was a travel characteristics survey* conducted by the Regional Plan Division in the fall of 1974.

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* Travel Characteristics Survey, Regional Municipality of Hamilton-Wentworth, Planning and Development Department, Oct. 1975.

This survey was a one percent, random sample of all households within the study area (Regional Municipality of Hamilton-Wentworth and the City of Burlington) and provided base year information on trip making characteristics such as trip generation rates, distribution of trip lengths and directional split of travel.

Figure 1-1 is a flow diagram of the complete model calibration - validation process and related inputs which will be further documented in the body of this report.

3.0 DEVELOPMENT OF BASE YEAR (1971) DATA

This chapter documents the sources and derivation of the major input requirements for the development (calibration and validation) of a travel forecasting simulation model.

3.1 The Study Area

The internal study area, within which a detailed travel simulation was carried out, incorporates the entire Hamilton-Wentworth Region and the City of Burlington. The City of Burlington was included due to the significant inter-action between it and the City of Hamilton.

Trips to/from places outside this area are relatively few in number and were handled separately under the classification of external travel.

3.1.1 Zone System

The zone system that was employed is illustrated in Figures 3-1 and 3-2. There are 174 traffic zones in all; 148 internal zones ie. (within the internal study area) and 26 larger external zones covering the rest of the Province of Ontario.

Of the internal zones, 135 are located in the Hamilton-Wentworth Region and are geographically compatible with both the T.A.R.M.S. system and the one used to code the travel characteristics survey. The remaining 13 internal zones cover the City of Burlington and are a direct aggregation of the T.A.R.M.S./ survey zones.

For ease of comparison and presentation a superzone system was formed (within the Region) consisting of 30 districts.

Figure 3 - 1

INTERNAL TRAFFIC ZONES

Figure 3-2 EXTERNAL TRAFFIC ZONES

These superzones are direct aggregations of the traffic zones and correspond to the Region's Planning Districts.

3.1.2 Road Network

A road network consisting of approximately 649 nodes was utilized to simulate the transportation network in the P.M. peak hour. All highways, arterials and a number of collector roads are represented in the network. Speeds were coded which reflect actual driving conditions in the P.M. peak hour. Much of the road link information was extracted from the report, Transportation Inventory, Regional Municipality of Hamilton-Wentworth Planning and Development Department, October 1975.

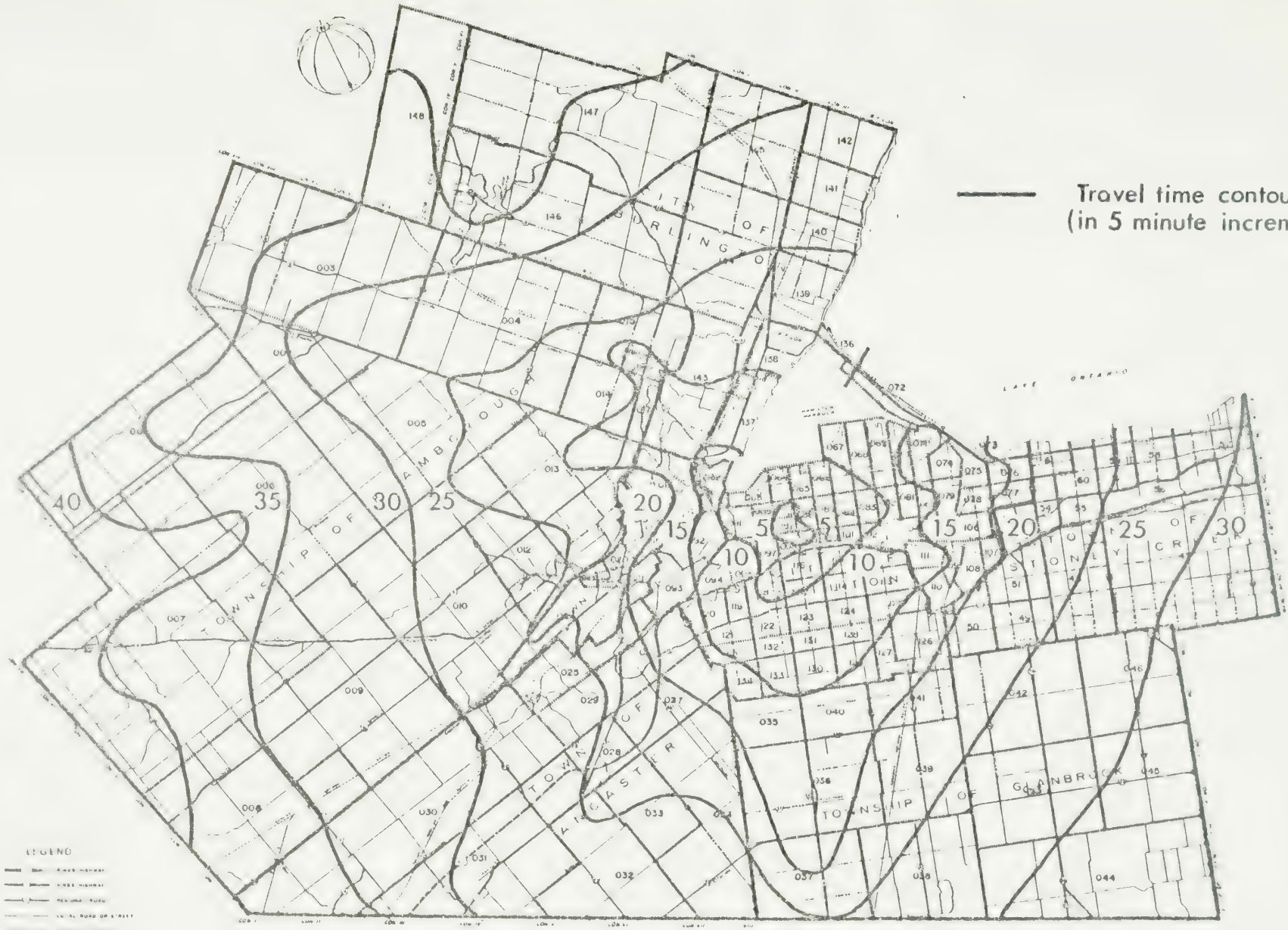
The consistency of the network was initially checked by comparing simulated network travel times with actual or known driving conditions in the P.M. peak hour. Travel time contour maps, which show the travel time (in minutes) required to reach all points in the study area from selected key origins, were used to display simulated conditions. Figure 3-3 is one such example showing the contours resulting when downtown Hamilton is used as the focal point. Other contour maps from downtown Stoney Creek and Dundas can be found in the Appendix.

3.1.3 Screenline Selection

Screenlines or corridors were selected as a basis for summarizing and comparing travel demands. Twenty-five (25) screenlines in all were utilized, eight encircling the Region and seventeen intersecting various movements within the Region (see Appendix).

Figure 3-3

SIMULATED TRAVEL TIME CONTOURS FROM DOWNTOWN HAMILTON (P.M. PEAK HOUR)



Screenlines located in the City of Hamilton closely approximate those used in the Hamilton Transportation Strategy Study of 1973 so that corridor information could be collected and compared on a consistent basis.

Where possible screenlines were located so as to follow major physical and/or jurisdictional boundaries and intersect distinct corridor travel movements. A complete description of each screenline along with a listing of all major and minor roads crossing it can be found in the Appendix.

3.2 Internal Travel

Internal trips are defined as those which both start and end within the study area. Three trip purposes were used to simulate internal travel; namely home based work (HBW), other home based (HBO) and non-home based (NHB). As mentioned previously, a detailed discussion of the derivation of internal travel characteristics eg. (trip rates) can be found in the report, Travel Characteristics Survey - Reg. Mun. of Hamilton-Wentworth, October 1975.

3.2.1 Home Based Work Trips

In the P.M. peak hour home based work trips account for only about 51% of total internal travel. This survey result is significant due to the relatively low observed proportion of 'essential' trips ie. (work related) in the P.M. peak hour, a characteristic which is significantly different from the overall average used for the T.A.R M.S. area.

Analysis of the directional split of travel indicated that 94% of all home based work trips (in the P.M. peak hour) were destined for the residential end.

The final HBW trip rates which were used to simulate P.M. peak hour travel are shown below in Table 3-1. The trip production and attraction rates are disaggregated by population and employment density categories respectively.

TABLE 3-1

P.M. PEAK HOUR HOME BASED WORK TRIP RATES

Trips Produced = Rate * Population

Population Density (persons/acre)	Rate
0-10.0	.104
10.1-20.0	.119
20.1-30.0	.122
30.1-40.0	.115
> 40.0	.165

Trips Attracted = Rate (1) * Wholesale & Manfuacturing Emp.
+ Rate (2) * Retail Employment
+ Rate (3) * Service Emp.
+ Rate (4) * Other Emp.

Employment Density (employees/acre)	Wholesale/Man. Rate(1)	Retail Rate(2)	Service Rate(3)	Other Rate(4)
0-4.0	.330	.309	.309	.309
4.1-10.0	.318	.308	.308	.308
10.1-30.0	.307	.272	.314	.314
> 30.0	.343	.218	.405	.405

There was one area of exception to the above trip rates and that was for the City of Burlington. Analysis of existing travel data indicated that the proportion of external trips (as compared to total travel) generated by the City of Burlington

was significantly higher than the average for the whole study area (due to Toronto bound commuter trips). Since the trip rates are representative of internal travel only this difference made it necessary to reduce the internally generated travel (trip rates) for the City of Burlington accordingly.

Using the results of Table 3-2 (below) a correction factor of 0.82 was calculated and applied to the HBW trip production rates for all zones located in the City of Burlington.

TABLE 3-2

PROPORTIONS OF EXTERNAL TRAVEL

	Total Study Area* (incl. City of Burl.)	City of Burlington**
% external work trips of total	7%	23%

source: * Travel Characteristics Survey, 1975
** 1971 Census - Place of Work - Place of Residence and Journey to Work Survey- Burlington, 1972

3.2.2 Other Home Based Trips

Home based trips for purposes other than work (HBO) account for approximately 36% of all internal travel in the P.M. peak hour. The purposes included (in relative order of importance) are shopping and personal business, social - recreation, and school.

Table 3-3 lists the P.M. peak hour HBO trip rates. The trip production rates are disaggregated by population density similar to those for home based work.

The travel characteristics survey was not originally designed to collect the level of detail of information required to generate home based other trip attraction rates. An attraction equation was synthesized, however, by utilizing information obtained from the survey on the proportional attractivity of various land use types to home based other trips. By relating the intensity of each land use type to the corresponding amount of employment or population an equation was developed in terms of variables which are easier to forecast (see Appendix for derivation of HBO trip attraction equation).

TABLE 3-3

P.M. PEAK HOUR HOME BASED OTHER TRIP RATES

Trips Produced = Rate * Population

Population Density (persons/acre)	Rate
0-10.0	.0923
10.1-20.0	.0812
20.1-30.0	.0596
30.1-40.0	.0525
> 40.0	.0431

Trips Attracted = .0103 * Manufacturing & Wholesale Emp.
+ .285 * Service Emp.
+ .285 * Retail Emp.
+ 1.719 * Other Emp.
+ .0224 * Population

3.2.3 Non Home Based Trips

Non home based (NHB) trips, which neither start nor end at a persons place of residence, account for only about 13% of total internal travel in the P.M. peak hour.

Insufficient data was available from the travel characteristics survey to produce trip generation rates for NHB trips. As a result a factoring technique was utilized to generate trips of this type. The complete survey sample was assigned to the

composite road network and summarized by travel corridor (screenline) under two categories; home based trips and non-home based trips. The observed proportions of total trips to home based trips (across each corridor) were then utilized as factors to scale up simulated home based trips (HBW plus HBO) to represent total internal travel.

A complete list of the NHB scaling factors can be found in Table 5-1.

3.3 External Travel

External trips are defined as those having one or more of their trip ends outside the study area. In order to incorporate trips of this type an O-D (origin - destination) table was obtained from the Ministry of Transportation and Communications which relected P.M. peak hour person trip travel external to the study area. Subsequent assignment of this trip table to the network resulted in the corridor volumes shown in Table 3-4*.

These external trips can then be directly added (on a corridor basis) to the internally generated trips to produce estimates of total person trip travel demand.

TABLE 3-4

EXTERNAL CORRIDOR TRAVEL
(in P.M. peak hour, pk. direction person trips)

Screenline (Corridor)	1971 External Trips
1	2,080
2	520
3	520
4	970
5	700

* Note: Several modifications (on a corridor basis) were made to the external trips as shown here. These are documented in the Appendix.

Screenline (Corridor)	1971 External Trips
6	400
7	700
8	1,960
9	40
10	850
11	460
12	210
13	270
14	190
15	930
16	90
17	200
18	1,890
19	1,150
20	1,010
21	500
22	360
23	480
24	2,080
25	850

3.4 Land Use

Specifically, the land use requirements for operation of the model are: population and employment by type (wholesale and manufacturing, retail, service and other) for each traffic zone. The area of each zone is also required for calculating density-related measures, eg. (see Table 3-3).

The source of the 1971 data base was a publication of the Ministry of Transportation and Communications, Socio-Economic Data, 1971 (TARMS). Minor modifications were made to the above on the basis of census data for the area. A complete listing of the data base can be found in the Appendix.

3.5 Ground Counts

Representative base year (1971) ground counts in the P.M. peak hour were required for all major road facilities (at point of crossing screenline) for comparison and eventual refinement

of model simulation results. The major difficulties encountered in collecting this data were centred around,

(1) the multiplicity of data sources required to obtain all the necessary counts and,

(2) the lack of specific information on peak hour travel as opposed to daily (A.A.D.T.), 24 hour volumes.

For facilities within the City of Hamilton the City Traffic Department proved to be an excellent source of ground count data. They provided traffic volume overlay maps for both the P.M. peak hour and the 24 hour period and vehicle classification counts by time of day.

Outside the City of Hamilton little information was available on peak hour traffic volumes. Instead, 24 hour A.A.D.T. (average annual daily traffic) volumes had to be used and multiplied by a series of factors to produce estimates in terms of P.M. peak hour, peak direction person trips. A.A.D.T. volumes for county roads were obtained from the Regional Engineering Department's records while similar data for Provincial Highways came from the Ministry of Transportation and Communications.

The transformation of 24 Hour A.A.D.T. counts into equivalent volumes expressed in P.M. peak hour, peak direction person trips involved the estimation of the following parameters; vehicle occupancy factors, peak hour factors, directional split factors and truck factors. In the City of Hamilton most of this information was readily available. For roads outside the City the factors were developed from examination of City of

Hamilton data in the same cooridor, specially-requested Provincial counts on major facilities and design hour volume estimates.

Since the Hamilton Transportation Strategy Study (1973) had already documented 1971 P.M. peak hour, peak direction person trip movements in certain common corridors within the City of Hamilton it was decided to utilize this data where available. However, peak hour volumes were re-computed from A.A.D.T. data (for these corridors) as a check on the consistency of estimation of the associated transformation (peak hour) factors.

Table 3-5 lists the A.A.D.T. counts for each screenline and the related factors that were applied to produce corridor volumes in terms of P.M. peak hour, peak direction person trips. A comparison with peak hour data from the H.T.S.S. is also given where available.

TABLE 3-5

GROUND COUNTS (by Screenline)

Screenline	A.A.D.T.	Vehicle Occupancy Factor	Peak Hour Factor (Pk. hr/24 hr.)	Directional Split Factor	Truck Factor	P.M. Peak Hour Person Trips In Peak Direction	HTSS Ground Counts
1	33,543	1.38	.080	.63	.88	2,053	-
2	8,450	1.38	.094	.55	.90	543	-
3	12,370	1.38	.085	.57	.90	744	-
4	18,210	1.38	.078	.55	.90	970	-
5	12,930	1.38	.082	.53	.90	698	-
6	9,310	1.38	.089	.58	.86	570	-
7	19,910	1.38	.081	.65	.86	1,244	-
8	65,650	1.38	.104	.66	.90	5,597	-
9	6,020	1.38	.105	.59	.93	479	-
10	21,730	1.38	.092	.56	.90	1,390	-
11	17,840	1.38	.111	.64	.90	1,574	1,425
12	13,290	1.38	.093	.62	.90	952	-
13	14,940	1.38	.084	.68	.90	1,060	1,000
14	11,900	1.38	.093	.62	.90	852	1,000
15	93,272	1.38	.084	.68	.92	6,764	6,815
16	51,370	1.38	.092	.85	.92	5,100	4,590
17	17,490	1.38	.093	.61	.90	1,232	1,350
18	97,810	1.38	.102	.54	.90	6,691	7,270
19	148,290	1.38	.087	.52	.88	8,147	8,600
20	101,440	1.38	.088	.61	.88	6,613	7,050
21	28,723	1.38	.103	.73	.90	2,682	1,800
22	99,901	1.38	.090	.76	.90	8,486	8,110
23	26,375	1.38	.094	.66	.90	2,032	2,050
24	44,274	1.38	.110	.62	.90	3,750	3,750
25	28,170	1.38	.092	.68	.91	2,213	-

4.0 MODEL CALIBRATION

4.1 Calibration Process

Model calibration, in the context of this report, refers to the process of iterative adjustments that are made to the friction functions in the gravity model of the trip distribution phase. The nature and magnitude of the adjustments required are gauged by comparing simulated results with observed data at each stage. Once acceptable agreement has been reached the model is considered to be calibrated,in that the final friction functions thus obtained are considered to be indicative of the actual travel characteristics of the population in the study area.

Generally speaking, as the travel time between two zones increases the likelihood or amount of travel between those zones decreases. This relationship is expressed in the PMPMOD computer package in the form,

$$F(dij) \propto e^{-(\theta * ttij)}$$

where $F(dij)$ = represents the friction function
θ = a calibrated constant
$ttij$ = the minimum path travel time between zones i and j.

It is the exponential constant, theta (θ), which is adjusted at each iteration of the calibration process. Theta is a reflection of the sensitivity of the study area population to changes in travel time, where larger values reflect greater sensitivity to travel distance thus resulting in proportionally fewer long trips.

Comparisons between the trip length freguency distributions simulated by the model and those calculated from observed data provided the basis for adjustment of the friction function

exponents (θ). The following standards were used to define an acceptable level of agreement between the two (thus signifying a calibrated relationship):

(1) the shape and position of the trip length distribution curves should be relatively close when compared visually and,

(2) the difference between simulated and observed mean trip lengths should be within ± 3%.

4.2 Results

The final (calibrated) friction function exponents which were selected are shown below in Table 4-1. One exponent was required for each of the trip purposes distributed by the gravity model. Comparison of the observed versus simulated mean trip lengths (MTL) indicates that their difference is well within the ± 3% standard.

TABLE 4-1

CALIBRATED EXPONENTS

Trip Purpose	Observed MTL	Simulated MTL	Friction Function Exponent
HBW	14.2	14.1	0.125
HBO	11.5	11.6	0.205

Figures 4-1 and 4-2 are a comparison of the observed versus simulated trip length freguency distributions for the trip purposes of HBW and HBO respectively. As can be seen from the graphs the agreement in the shape and position of the two sets of curves is quite good.

FIGURE 4-1 SIMULATED VERSUS OBSERVED TRIP LENGTH FREQUENCY DISTRIBUTIONS (HBW)

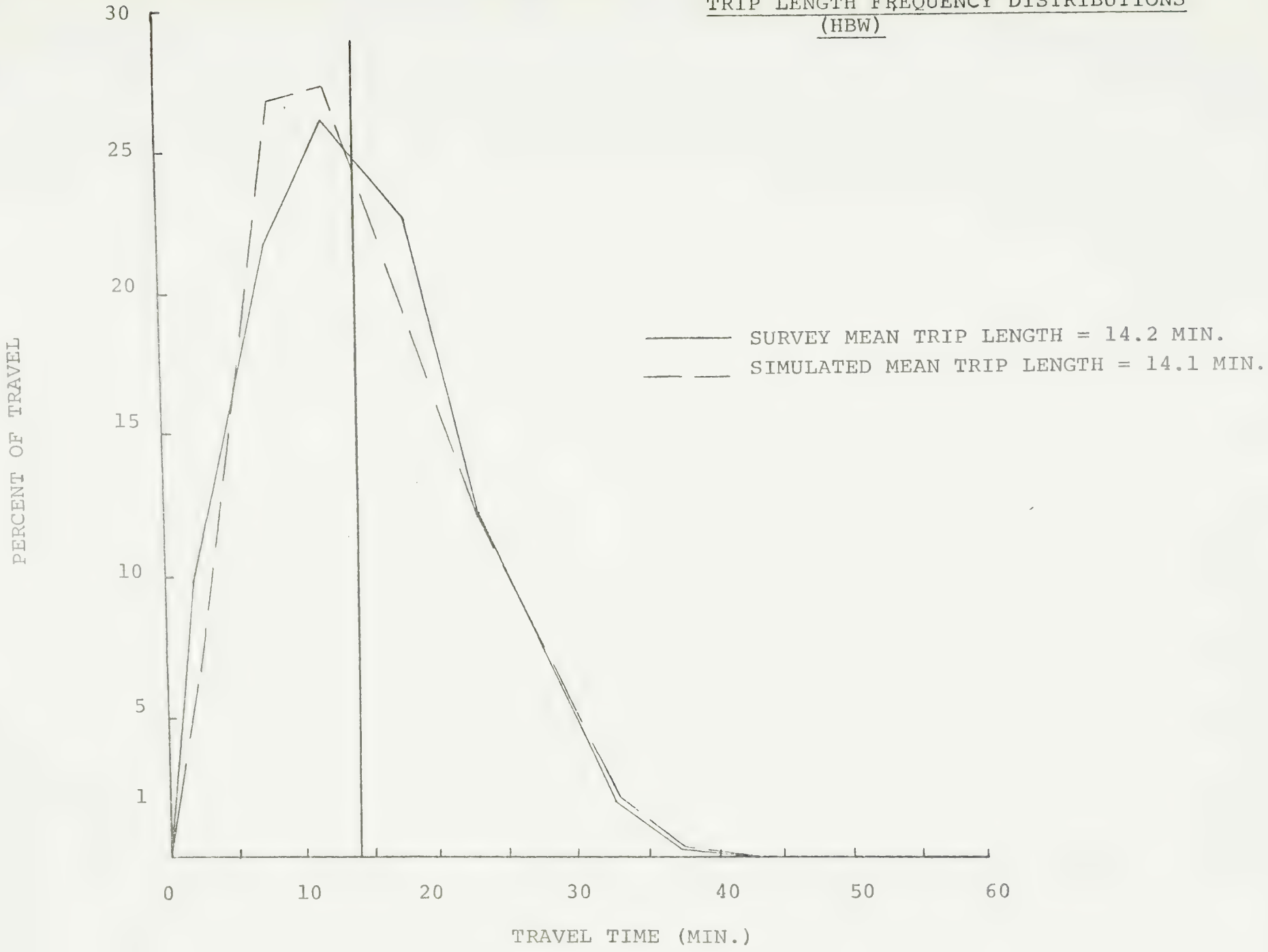
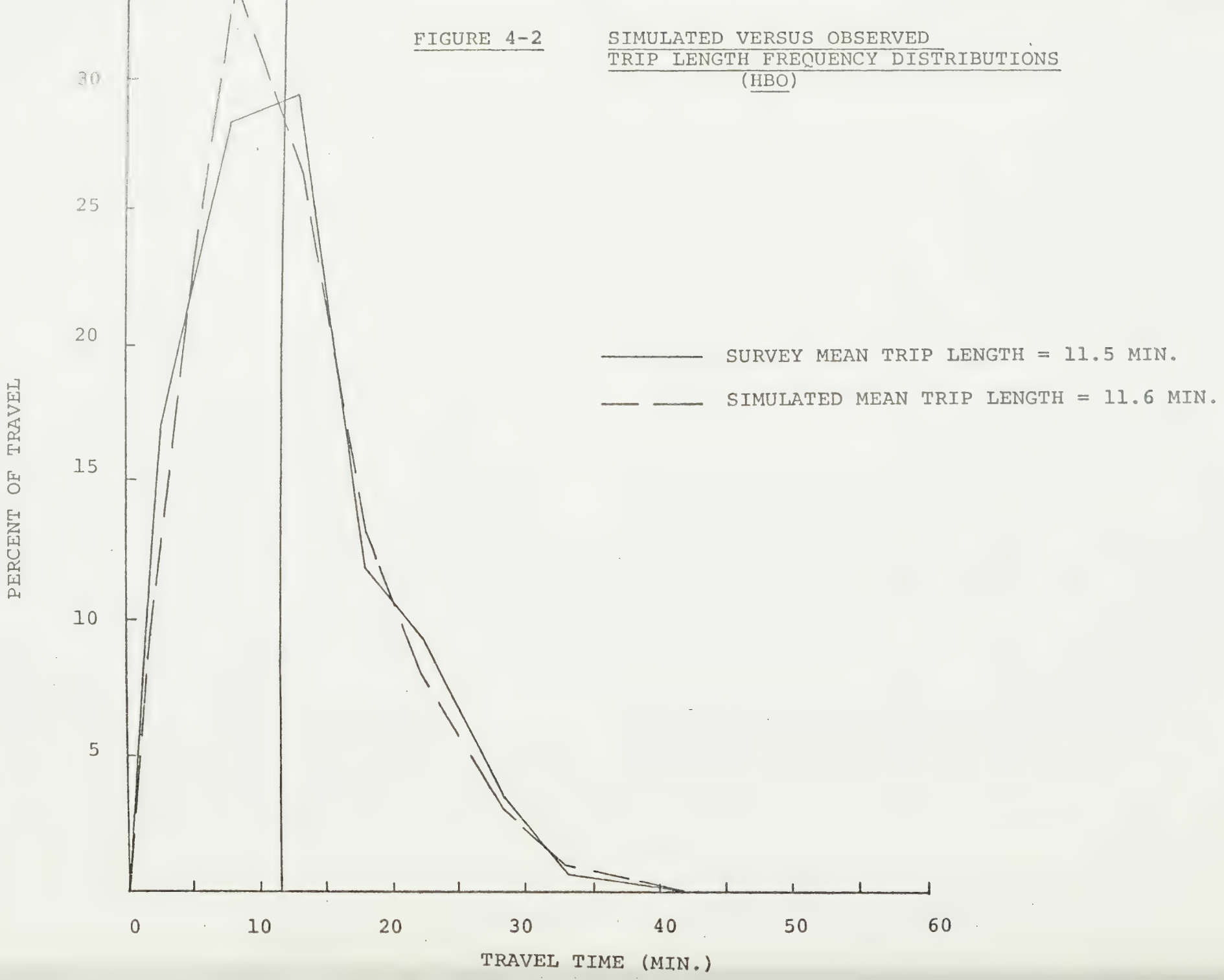


FIGURE 4-2 SIMULATED VERSUS OBSERVED TRIP LENGTH FREQUENCY DISTRIBUTIONS (HBO)



5.0 MODEL VALIDATION

5.1 Validation Process

The model validation phase is a final series of checks that are made on the simulated, base year results by comparing the model outputs with observed * data from other sources. Once the base year conditions are modeled satisfactorily then it only remains to account for any changes in the input variables eg.(population and employment growth) in order to use the model for forecasting purposes.

The potential sources of data available for validation (cross-checking) purposes included the following:

(1) Census - Place of Work - Place of Residence Matrix, 1971

(2) Travel Characteristics Survey - Trip Summaries, 1974

(3) Vehicle (Ground) Counts, 1971

No meaningful comparisons could be made between the Census - Place of Work data and simulated results because of the uncertainties involved in converting to a common unit of measure. Expressing both in terms of P.M. peak hour person trips, for example, would involve the estimation of trip rates, peak hour factors and directional split of travel on an origin - destination (interchange) basis.

P.M. peak hour trip data from the Travel Characteristics Survey was summarized in an aggregated O-D table format where each zone represented one area municipality. Unfortunately, the

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* by observed is meant non-simulated

small survey sample size and the need to extract only P.M. peak hour data left most cells in the table with an insignificant number of entries. Also, there was a time difference of approximately 3 years between the two sets of data. Therefore the survey results could only be utilized to provide a gross check on the trip distribution phase for the major, home based inter-municipal movements.

The base year ground counts (as documented in section 3.5) provided the easiest and most direct comparison for simulated versus observed results. Agreement at this level of detail provides a positive check on all aspects of simulation process from trip generation through to trip assignment.

5.2 Results

Table 5-1 compares the total simulated demand with the observed ground count (by corridor) for each of the twenty-five screenlines. The simulated demands are further disaggregated into internal and external type trips due to their different methods of derivation.

Examination of the observed versus simulated volumes indicates that the agreement overall is good. Most of the differences are within $\pm$ 15% and the magnitudes of deviation are generally less than 1,000 peak direction person trips (aggregated on a corridor basis).

In general the total simulated corridor volumes are higher than the corresponding ground counts by approximately 10%.

TABLE 5-1

VALIDATION RESULTS

Screenline	Home Based Trips	Non Home Base Factor	Total Internal Demand	External Demand	Total Simulated Demand	Total Observed Demand
1	-	-	-	2,080	2,080	2,053
2	-	-	-	520	520	543
3	-	-	-	520	520	744
4	-	-	-	970	970	970
5	-	-	-	700	700	698
6	470	1.00	470	400	870	570
7	2,069	1.19	2,462	700	3,162	1,244
8	3,487	1.30	4,533	1,960	6,493	5,597
9	661	1.13	747	40	787	479
10	1,201	1.15	1,381	850	2,231	1,390
11	1,032	1.14	1,176	460	1,636	1,425
12	814	1.12	912	210	1,122	952
13	737	1.14	840	270	1,110	1,000
14	438	1.09	477	190	667	1,000
15	6,856	1,16	7,953	930	8,883	8,600
16	5,565	1.15	6,400	90	6,490	5,034
17	1,173	1.10	1,290	200	1,490	1,407
18	6,790	1.24	8,420	1,890	10,310	8,150
19	7,197	1.21	8,708	1,150	9,858	10,000
20	6,847	1.18	8,079	1,010	9,089	7,900
21	3,839	1.25	4,799	500	5,299	2,782
22	7,917	1.16	9,184	360	9,544	8,810
23	2,702	1.15	3,107	480	3,587	2,108
24	3,086	1.14	3,518	2,080	5,598	3,750
25	1,254	1.19	1,492	850	2,342	2,213

This was considered to be an appropriate adjustment for more meaningful comparison purposes due to the following:

(1) ground (observed) counts were not available for minor roads crossing the screenlines

(2) increase in the activity rate ie. (effective work trip rate) between the base year (1971) and the year in which the trip rates were calculated (1974).

(3) absence of simulation estimates for commercial vehicle movements.

A limited comparison between simulated results and factored-up survey data showed reasonable agreement in the amount of home based travel distributed between and within the various area municipalities. Where a large number of survey observations was available, such as travel within the City of Hamilton, the simulated number of trips very closely approximated those of the survey ie. (less than 5% difference).

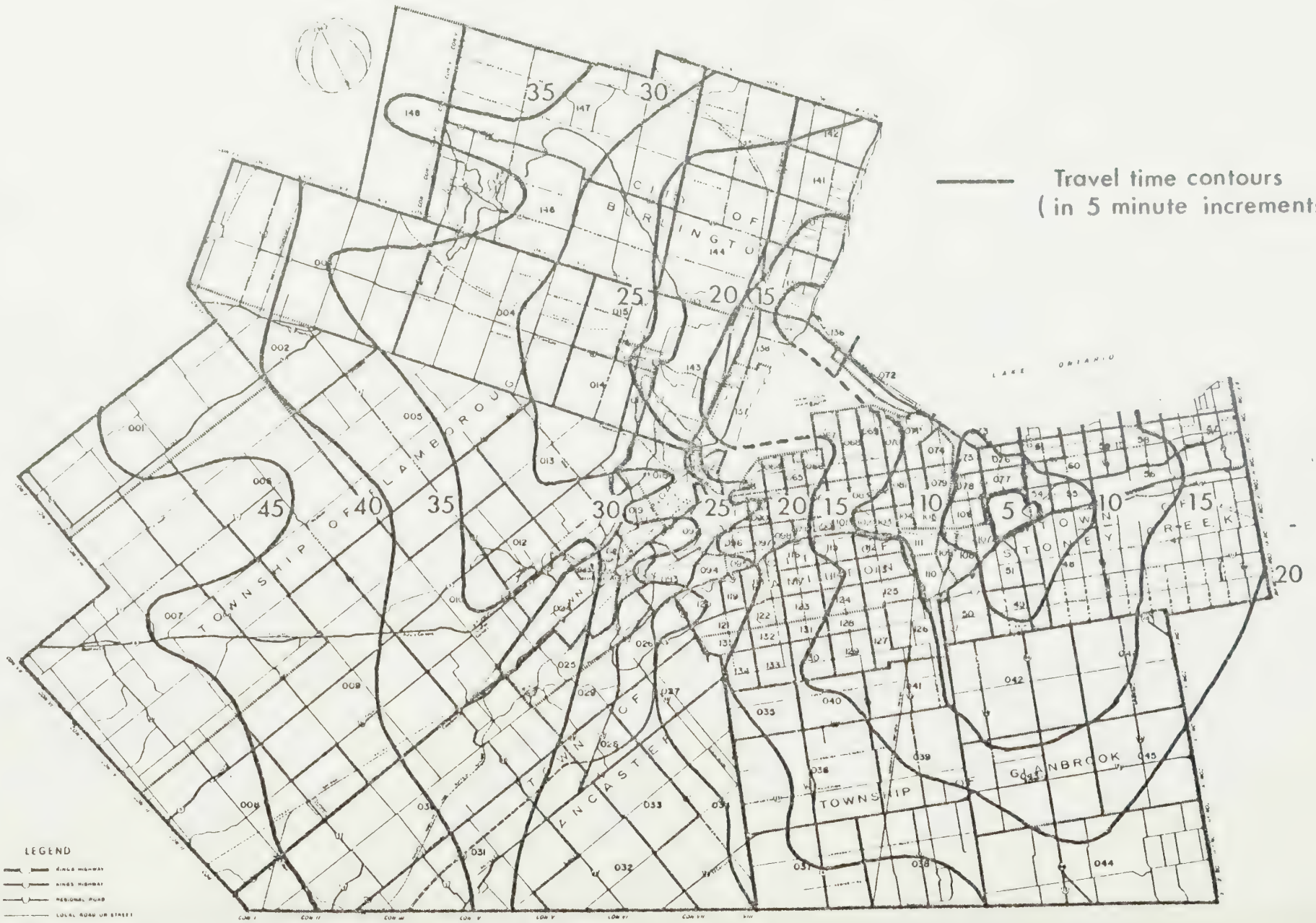
On the basis of validation checks such as described above it was concluded that the model had adequately simulated base year conditions and was ready for use as a forecasting tool.

APPENDIX A

Simulated Travel Time Contour Maps From

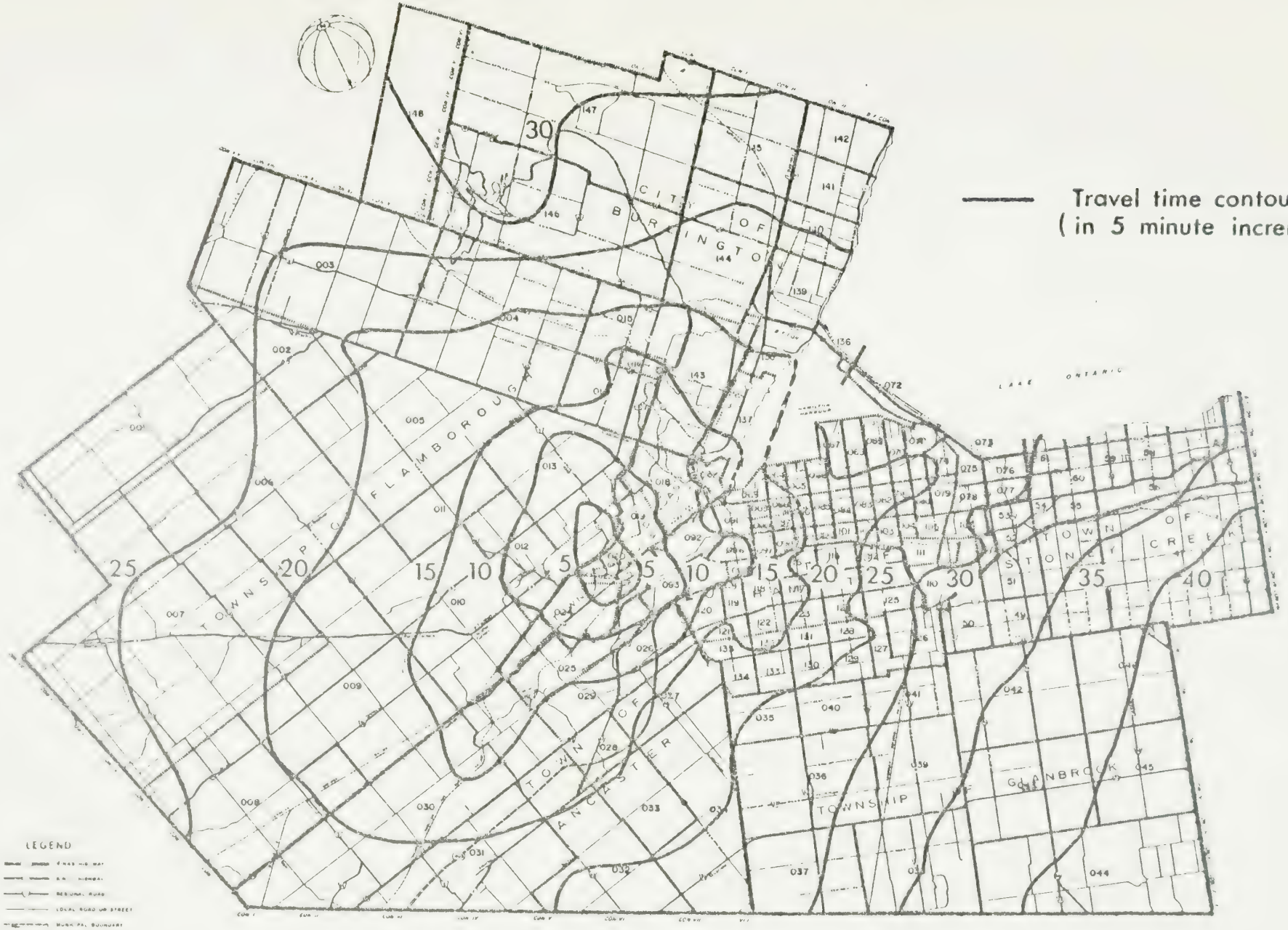
Downtown Stoney Creek & Dundas

SIMULATED TRAVEL TIME CONTOURS FROM DOWNTOWN STONEY CREEK (P. M. PEAK HOUR)



THE REGIONAL MUNICIPALITY OF HAMILTON - WENTWORTH

DOWNTOWN DUNDAS (P.M. PEAK HOUR)



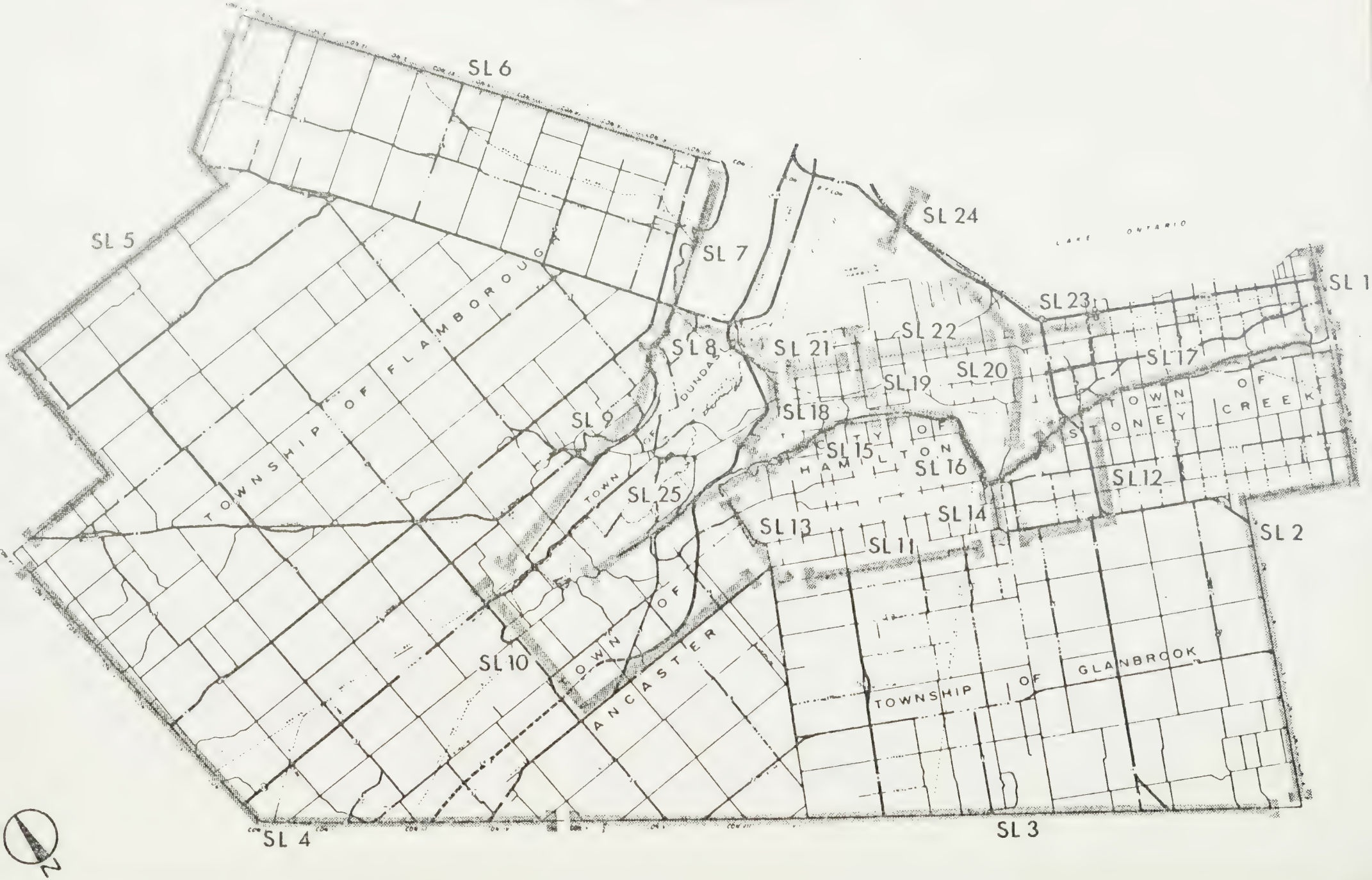
THE REGIONAL MUNICIPALITY OF HAMILTON - WENTWORTH
And The City of Burlington

PLANNING AND DEVELOPMENT DEPARTMENT
HAMILTON

APPENDIX B

Screenline Documentation

SCREENLINE LOCATIONS



Not To Scale

SCREEN LINES

SL-1

This screenline extends along the eastern boundary of the study area (below the escarpment), between Lake Ontario and the Niagara Escarpment. It intersects the Hamilton - St. Catharines corridor.

Major roads crossing are:
- Q.E.W.
- Highway #8

Minor roads crossing are:
- Base Line Road
- North & South Service Roads

SL-2

This screenline extends along the eastern boundary of the Hamilton-Wentworth Region (above the escarpment), between the escarpment and the South-East corner of the Regional Boundary.

Major roads crossing are:
- Highway #20
- Regional Road 25A
- Regional Road 11
- Regional Road 50
- Regional Road 22

Minor roads crossing are:
- Smith Road
- Highland Road
- 9th Road East
- 8th Road East
- 7th Road East
- Golf Club Road
- 2nd Concession Road
- 7th Concession Road
- 8th Concession Road
- 9th Concession Road

SL-3

This screenline follows the southern edge of the study area from the South-East corner of the Hamilton-Wentworth Region, west, to the Brantford-Onondaga Township line.

Major roads crossing are:
- Highway #56
- Highway #6
- Regional Road 13
- Regional Road 33 (Tyneside Road)
- County Road 22 (Trinity & Carluke Road)

Minor road crossings are:
- Road allowance between lots, 30 & 31.
- 28 & 29
- 24 & 25
- 20 & 21
- Trinity Church Road

Miles Road
Ferris Road
Glancaster Road
Nodsworth Road
Shaver Road
Carlduke Road
Trinity Road
Butter Road

SL-4

This screenline extends along the southern boundary of the Hamilton-Wentworth Region from the Brantford-Onondaga Township Line (just east of Highway #2), up to, but not including Highway #8. It intercepts the Hamilton-Brantford corridor.

Major road crossings are:
Highway #2
Highway #99
Highway #5
County Road 17
County Road 14

Minor roads crossing are:
Alberton Road
Book Road
Ferguson Road
Parsonage Road
Ronald Road
Misener Road
Powerline Road
Harrisburg Road
2nd Concession Road
Patric Road
5th Concession Road
6th Concession Road
7th Concession Road
Maclean Road

SL-5

This screenline extends along the northern boundary of Flamborough Township from Highway #8 (inclusive), east, to the regional boundary between Halton & Wellington. It contains the K/W-Hamilton and Guelph-Hamilton corridors.

Major roads crossing are:
Highway #8
Highway #97 & 52
Highway #52
Highway #6

Minor roads crossing are:
Studiman By-Road
Clyde Side Road
Sheffield By-Road
8th Concession Road
10th Concession Road
Foreman Side Road

Valens Side Road
Lennon Side Road
11th Concession Road
14th Concession Road
Centre Road

SL-6

This screenline extends along the eastern boundary of Flamborough Township from the corner nearest Highway #401, south-east to the Niagara escarpment.

Major roads crossing are: Highway #5
County Road 18
County Road 36

Minor roads crossing are: Mountsberg Road
11th Concession Road
10th Concession Road
9th Concession Road
8th Concession Road
7th Concession Road
6th Concession Road
5th Concession Road
4th Concession Road

SL-7

This screenline extends along the southern boundary of Flamborough (the escarpment) between King Road (inclusive) and Highway #6 (inclusive). It cuts across the Guelph-Hamilton/Burlington corridor.

Major roads crossing are: Highway #6

Minor roads crossing are: Waterdown Road
Snake Road

SL-8

This screenline runs parallel to Highway #6 (on the west side) from the Niagara escarpment down to Hamilton Harbour. It intersects the Toronto/Burlington-Hamilton corridor.

Major roads crossing are: Highway #403
Highway #2
York Road

Minor roads crossing are: Old Guelph Road
Heath Street

SL-9

This screenline extends along the escarpment i.e.(the boundary between Flamborough and Ancaster), from Highway #6 (exclusive) to Highway #99 (exclusive).

Major roads crossing are: Highway #8
Regional Road 5 (Sydenham)

Minor roads crossing are: Valley Road
Wier Side Road
Binkley Road

SL-10

This screenline runs parallel to Highway #52 (on the east side) from Highway #99 (inclusive) south to Highway #2 (inclusive), then extends east, parallel to Highway #2/53 (on the southern side), to the City of Hamilton Limits.

Major roads crossing are: Highway #99
County Road 23
Highway #2
County Road 16
County Road 48

Minor roads crossing are: Mineral Springs Road
Powerline Road
Shaver Road
Smith Road

SL-11

This screenline runs along the southern city limits immediately south of Highway 53 (Rymal Road).

Major roads crossing are: Highway #6

Minor roads crossing are: Aldercrest Avenue
Seneca Avenue
Springside Drive
Miles Road
Nebo Road
Glover Road
Trinity Church Road
Glancaster Road

SL-12

This screenline extends along Highway 53 (on the southern side) from Trinity Church Rd. (exclusive)up to, but not including First Road East (of Highway 20) in Stoney Creek, then directly north to the escarpment.

Major roads crossing are: Highway #20
Highway #56
Regional Road 11
Regional Road 40

Minor roads crossing are: Highland Road
Green Mountain Road

SL-13

This screenline runs along the western Hamilton City Limits on the mountain between Highway #53 (inclusive) and the escarpment.

Major roads crossing are: Highway #53
Mohawk Road
Proposed Mountain Freeway

Minor roads crossing are: Golf Club Road

SL-14

This screenline extends along the eastern Hamilton City Limits on the mountain from Highway #53 (inclusive) to the escarpment.

Major roads crossing are: Highway #53 (Rymal Road)
Proposed Mountain Freeway (possibly)

Minor roads crossing are: Highland Road
Mud Street

SL-15

This screenline extends along the escarpment from Highway #403 (exclusive) to just east of the Upper Wentworth Street. It includes the major wester mountain accesses.

Major roads crossing are: Beckett Drive (Queen Street access)
James Street Mountain Road
Claremont Access
Jolley Cut

SL-16

This screenline extends along the escarpment from Wentworth Street to just west of Highway #20.

Major roads crossing are: Sherman Access
Kenilworth Access
Mount Albion Road

SL-17

This screenline extends along the escarpment between Highway #20 (inclusive) and the eastern edge of the Hamilton-Wentworth Region.

Major roads crossing are:
- Highway No. 20
- New Mountain Road
- Regional Road 50

Minor roads crossing are:
- Dewitt Road
- McNeilly Road

SL-18

This screenline is located to the east of Highway #403 between Hamilton Harbour and the escarpment. It intersects the western approaches to Hamilton's CBD below the mountain.

Major roads crossing are:
- Aberdeen Avenue
- Main Street
- King Street
- York Blvd.

Minor roads crossing are:
- Fred Street

SL-19

This screenline runs parallel to Wentworth Street (on the west side) from the Harbour to the escarpment. It intersects cross-town, east-west traffic.

Major roads crossing are:
- Charlton Avenue
- Main Street East
- King Street East
- Cannon Street
- Barton Street
- Burlington Street
- Proposed Perimeter Road

Minor roads crossing are:
- Stinson Street
- King William Street
- Nightingale Street
- Wilson Street
- Century Street
- Birge Street
- Shaw Street
- Burton Street
- Ferrie Street

SL-20

This screenline intercepts the eastern approaches to Hamilton's CBD. It extends along the Red Hill Creek from the harbour

up to the escarpment.

Major roads crossing are:
- King Street East
- Queenston Road
- Barton Street
- Burlington Street

Minor roads crossing are:
- Hixon Street
- Melvin Avenue
- Brampton Street

SL-21

This screenline is located along the CN mainline between the Harbour and Wentworth Street (exclusive).

Major roads crossing are:
- James Street
- Wellington Street

Minor roads crossing are:
- Bay Street
- McNab Street
- John Street
- Mary Street
- Ferguson Avenue
- Victoria Avenue

SL-22

This screenline is located along the CN mainline between Wentworth Street (inclusive) and Red Hill Creek. It separates the Bayfront Industrial area from most of the major east-west arterial links.

Major roads crossing are:
- Wentworth Street
- Birch Avenue
- Sherman Avenue
- Gage Avenue
- Ottawa Street
- Kenilworth Avenue
- Parkdale Avenue
- Woodward Avenue

Minor roads crossing are:
- Lottridge Street
- Avondale Avenue

SL-23

This screenline is located along the CN mainline between the Red Hill Creek and the eastern edge of the Hamilton-City limits.

Major roads crossing are: Highway #20 (Centennial Parkway)

Minor roads crossing are: Nash Road
Kenora Avenue
Lake Avenue
Grays Road

SL-24

This screenline is located along the Beach Strip Canal which separates Hamilton from Burlington.

Major roads crossing are: QEW (Niagara)

Minor roads crossing are: Beach Blvd.

SL-25

This screenline is located along the western portion of the escarpment. It extends from east of Highway #403 to west of Sulphur Springs Road.

Major roads crossing are: Highway #403
Highway #2

Minor roads crossing are: Old Dundas Road
(County Road No. 32)
Sulphur Springs Road

APPENDIX C

Home Based Other (HBO) Trip Attraction Equation

Derivation of HBO Trip Attraction Equation

1. Assumptions

   (a) that the amount of land devoted to residential, manufacturing plus industrial, retail plus service and other uses is proportional to the corresponding amount of population and/or employees of a similar classification.

   (b) that future changes in the proportional mix of employment (by type) and population reflect similar changes in the relative attractivity of the corresponding type of land use.

2. Input Data (1971)

   (a) total study area manufacturing plus wholesale employment,
   Em = 81,696

   (b) total study area retail plus service employment,
   Es = 90,242

   (c) total study area other employment,
   Eo = 2,696

   (d) total study area population,
   POP = 488,294

   (e) total P.M. pk. hour HBO trips produced,
   PROD = 42,140

   (f) proportion of total HBO trips attracted (pk.hr.) as a function of land use*: - manufacturing plus wholesale,
   Am = 0.02
   - retail plus service,
   As = 0.61
   - other,
   Ao = 0.11
   - residential
   Apop = 0.26

---

* source: Travel Characteristics Survey, 1974

3. Equation Form

$$ATT(j) = Rate(1) * Em(j) + Rate(2) * Es(j) + Rate(3) * Eo(j) + Rate(4) * POP(j)$$

where ATT(j) = the number of P.M. peak hour HBO trips attracted to zone j,
Em(j) = the number of manufacturing plus wholesale employees located in zone j (and so on).

4. Derivation of Coefficients

(a) calculate scaling factors (S) to convert the unit contribution of each variable to a common basis (population was selected as basic unit):

Spop	1
Sm = POP/Em	= 5.98
Ss = POP/Es	= 5.41
So = POP/Eo	= 181.1

(b) calculate relative attraction indices (R) for the four predictor variables as the product of the unit scaling factor (S) and the relative attractivity of the variable (A) as outlined in section 2(f).

Rm = Sm * Am	= 0.119
Rs = Ss * As	= 3.30
Ro = So * Ao	= 19.9
Rpop = Spop * Apop	= 0.26

(c) calculate scaling (balancing) factor which balances total HBO attractions (as estimated from rates in (b)) to productions.

$$SF = PROD/(Rm*Em+Rs*Es+Ro*Eo+Rpop*POP)$$

$$= 0.0863$$

(d) determine final attraction co-efficients as product of the relative attraction indices (R) and the scaling factor (SF).

RATE(1) = Rm*SF	= 0.0103
RATE(2) = Rs*SF	= 0.285
RATE(3) = Ro*SF	= 1.719
RATE(4) = Rpop*SF	= 0.0224

APPENDIX D

External Travel Adjustments

Derivation of Screenline Adjustment Factors for External Travel

Adjustments to the magnitudes of external travel were made on a screenline or corridor basis if sufficient data were available. Depending on the nature of the travel in the corridor the adjustment procedure would follow one of two procedures:

(1) External Corridors (only external travel crossing):

Correction factors were computed as the ratio of ground counts (observed) to simulated data.

(2) Internal Corridors (both internal & external travel crossing)

Since no explicit data was available on the observed amount of external travel in such corridors (during the P.M. peak hour) it was only possible to adjust the external assignments to the extent that adjustments were made to external corridors (as described in 1).

The corrective action was to subtract/add a percentage of the amount by which external assignments had been reduced/increased in a related external corridor. The percentage reflected the proportion of external travel that was common to both corridors.

(See table on next page)

EXTERNAL TRAVEL ADJUSTMENTS

Corridor (Screenline)	Direction	Internal Simulated	Unadjusted External (Simulated)	Total Simulated	Ground Count (1971)	Adjustment Procedure: Multiply(1) Factor by	Subtract(2) Amount	Subtract(2) Related Corridor	Subtract(2) % From Related Corridor	Final Adjusted External Travel
1 + 2	Peak	-	2,767	2,767	2,595	0.94	-	-	-	2,600
	N-Peak	-	3,148	3,148	1,649	0.52	-	-	-	1,640
4	Peak	-	4,829	4,829	970	0.20	-	-	-	970
	N-Peak	-	4,392	4,392	794	0.18	-	-	-	790
5	Peak	-	1,255	1,255	698	0.56	-	-	-	700
	N-Peak	-	1,931	1,931	619	0.47	-	-	-	910
8	Peak	4,158	4,769	8,927	5,597	-	(.78)*(.82)*C	4:N-Peak	78%	1,960
	N-Peak	2,859	6,073	8,932	2,883	-	(.78)*(.80)*C	4:Peak	78%	3,000
10	Peak	1,329	4,235	5,564	1,390	0.20	-	-	-	850
24	Peak	3,384	3,335	6,719	3,750	-	(.77)*(.52)*C	1+2:N-Peak	77%	2,080
25	Peak	1,586	4,242	5,828	2,213	0.20	-	-	-	850

NOTE: C = the unadjusted external travel from the related (external) corridor

APPENDIX E

Land Use Data Bank
(1971)

Source: Socio-Economic Data, 1971 (TARMS)

Census, 1971 (Statistics Canada)

Population Density Analysis in Residential Neighbourhoods, 1972 (City of Hamilton)

LAND USE DATA BANK (1971)

Traffic Zone	Population	Manufacturing Construction Wholesale	Retail	Service	Other	Area (acres)
1	470	12	1	8	50	9801
2	665	24	55	119	7	3970
3	1,370	0	21	74	73	12756
4	2,475	47	97	168	138	9929
5	1,310	23	52	112	95	8993
6	620	0	2	5	31	8855
7	1,620	8	46	129	100	22448
8	1,540	26	16	33	58	7801
9	760	61	16	66	44	9968
10	1,265	39	4	10	45	8333
11	240	27	5	66	18	2492
12	2,560	88	49	204	26	2975
13	1,800	7	12	101	99	6540
14	710	0	99	71	32	1862
15	880	0	12	20	26	2522
16	2,145	187	138	73	0	404
17	545	0	26	138	6	552
18	1,080	170	12	231	20	1537
19	350	0	0	19	10	1340
20	3,605	0	39	197	0	286
21	4,160	19	320	170	0	532
22	1,420	374	193	498	0	128
23	2,570	532	27	297	45	227
24	5,450	1,015	266	96	20	2118
25	355	0	0	46	10	2069
26	2,795	4	37	178	5	1635
27	3,415	5	31	237	10	2344
28	2,710	7	106	450	35	1281
29	2,035	2	29	125	10	1950
30	1,500	0	24	55	105	12342
31	945	0	24	70	125	7456

Traffic Zone	Population	Manufacturing Wholesale Construction	Retail	Service	Other	Area (acres)
32	285	22	11	59	30	4728
33	385	5	5	11	30	2364
34	740	4	9	4	65	6462
35	765	0	13	6	9	1448
36	1,795	57	56	454	68	5644
37	750	0	25	31	23	3989
38	660	2	4	23	37	4846
39	450	0	2	2	28	3546
40	1,005	0	31	7	17	1438
41	685	4	0	19	28	1812
42	980	39	4	21	28	5516
43	985	21	154	105	38	5142
44	510	0	0	4	19	8540
45	425	6	4	6	32	3979
46	925	2	21	37	33	4147
47	1,235	70	11	7	100	8895
48	1,015	41	19	40	30	3014
49	690	23	15	8	7	1219
50	360	31	4	8	8	1292
51	800	4	8	0	10	1183
52	2,855	6	12	23	15	364
53	6,915	193	187	223	15	493
54	3,490	4	23	62	15	493
55	1,435	150	18	82	25	502
56	640	615	12	33	25	1645
57	2,380	62	48	340	35	2029
58	1,140	14	13	18	15	975
59	1,635	108	7	299	35	1015
60	2,180	722	40	203	25	739
61	600	2,190	145	339	5	621
62	0	0	0	24	0	381
63	2,280	66	39	285	16	239
64	5,075	633	50	778	0	276

Traffic Zone	Population	Manufacturing Construction Wholesale	Retail	Service	Other	Area (acres)
65	2,325	2,904	110	182	0	291
66	1,590	2,050	212	187	0	273
67	1,300	18,981	66	266	0	715
68	1,075	4,220	29	50	0	630
69	1,675	5,524	29	68	0	651
70	80	4,969	0	319	0	496
71	25	2,411	93	174	4	544
72	3,105	7	32	64	0	385
73	0	26	0	30	0	343
74	3,255	1,215	120	687	0	521
75	140	523	116	401	0	308
76	230	1,469	114	87	0	461
77	1,760	30	33	45	0	397
78	3,055	22	128	141	0	345
79	9,650	578	372	707	0	476
80	4,620	515	201	566	0	281
81	8,100	310	331	503	0	282
82	7,570	107	3,063	1,156	0	282
83	9,665	1,235	482	865	0	297
84	9,300	1,657	341	897	0	300
85	9,535	2,384	621	2,114	0	287
86	9,605	484	666	3,298	0	286
87	2,035	1,225	890	2,158	0	138
88	2,965	1,225	890	2,158	0	139
89	2,515	1,225	890	2,158	0	137
90	2,750	2,040	2,178	3,389	0	137
91	11,525	600	227	828	0	433
92	7,160	121	334	3,705	0	885
93	11,525	600	227	828	0	935
94	5	157	0	14	0	391
95	3,525	9	11	98	0	223
96	8,360	3,090	309	634	0	426

Traffic Zone	Population	Manufacturing Construction Wholesale	Retail	Service	Other	Area (acres)
97	10,005	111	293	2,396	0	274
98	7,040	602	323	5,977	0	225
99	5,395	99	95	800	0	180
100	5,470	158	39	608	0	179
101	3,940	702	43	560	0	190
102	2,845	36	27	103	0	240
103	5,535	64	75	190	0	264
104	3,940	50	248	127	3	227
105	3,810	40	50	308	0	264
106	6,995	49	585	302	0	389
107	55	0	10	9	0	262
108	2,240	178	4	7	0	485
109	150	9	0	140	0	307
110	25	0	0	26	0	688
111	5,835	64	15	40	0	388
112	7,160	20	360	371	0	400
113	11,840	82	108	258	0	539
114	9,065	17	296	519	0	416
115	12,950	61	355	2,407	0	489
116	9,040	56	179	581	0	476
117	8,200	25	661	557	0	440
118	8,660	95	319	1,979	0	688
119	3,660	17	68	98	0	296
120	3,840	9	1	1,026	0	560
121	1,670	12	22	422	0	406
122	4,375	55	93	355	0	436
123	7,590	213	248	461	0	498
124	4,445	4	40	165	0	466
125	2,975	4	46	193	0	857
126	560	108	16	63	0	1196
127	280	25	24	67	0	499
128	285	3	2	0	0	363

Traffic Zone	Population	Manufacturing Construction Wholesale	Retail	Service	Other	Area (acres)
129	1,060	13	7	108	0	642
130	740	17	58	42	9	678
131	600	55	14	56	0	389
132	1,010	5	17	11	0	365
133	1,065	9	49	77	0	650
134	335	36	0	13	0	548
135	200	2	0	0	0	410
136	735	6	12	938	0	296
137	3,253	715	385	478	0	1705
138	8,990	412	265	422	0	995
139	21,826	2,137	1,211	2,979	447	2416
140	10,596	606	1,665	718	0	1654
141	8,624	808	193	311	0	1714
142	14,132	405	253	240	0	1861
143	1,676	497	41	239	0	3644
144	12,086	2,227	283	1,010	0	5250
145	1,172	486	13	78	0	4137
146	1,662	183	27	63	95	12866
147	1,376	50	15	83	11	17744
148	916	0	4	21	17	14630