COMMONWEALTH OF KENTUCKY
DEPARTMENT OF TRANSPORTATION
Division of Research
533 South Limestone
Lexington, KY 40508

CALVIN G. GRAYSON
SECRETARY

JULIAN M. CARROLL
GOVERNOR

H-3-72

February 15, 1978

MEMORANDUM TO: G. F. Kemper
State Highway Engineer
Chairman, Research Committee

SUBJECT: Research Report 493; "Simulation of External-Internal and Through Trips for Small Urban Areas;" KYP-75-72; HPR-PL-1(13), Part III-B.

Travel patterns are synthesized in many ways and using a minimum of field observations and data when a proven, simulation model is available. A rather confounding factor is the so-called "through trips." The magnetic strength of attractors inside an urban area generates external-internal trips, and vice versa. What generates through trips is the mere fact that there is no better way to go to a destination beyond the city. Indeed, the sum "out" equals the sum "in." The sums of "ins" and "outs" minus the "through" is the "external-internal" trips. To predict the "through" kind requires some knowledge of distant attractors and alternative routes. Perhaps it would be helpful to perform checks of the sum of the predictions of external-internal and "through" trips. This process would involve subtracting the sum of all external-internal trips from the sum of AADT's at all external stations in order to obtain the total number of through trips. If the sum of "through" trips and external-internal trips is not reasonably close to the sum of AADT's, then adjustment factors could be applied as required to proportionally decrease or increase the deficient or inflated predictions.

This package of prediction models comprises an attempt to synthesize travel desires and trip-making characteristics which traditionally have been very unpredictable. Therefore, this process of checks and balances should be applied to assure reasonable predictions.

Respectfully submitted,

Jas. H. Havens
Director of Research

gd
Enc.
cc's: Research Committee

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle	5. Report Date
Simulation of External-Internal and Through Trips for Small Urban Areas	February 1978
	6. Performing Organization Code
	8. Performing Organization Report No.
7. Author(s)	493
J. G. Pigman	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Division of Research Kentucky Bureau of Highways 533 South Limestone Street Lexington, Kentucky 40508	11. Contract or Grant No. KYP-75-72
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	Final
	14. Sponsoring Agency Code

15. Supplementary Notes

Study Title: Simulation of Origin-Destination Data for Small Urban Area Transportation Studies

16. Abstract

The objective of this study was to develop models which would simulate internal-external trips and external-external (through) trips. Regression analysis and cross-classification of data were tested in an attempt to predict the number of internal-external trips and the percentage of through trips. Regression analysis was used in the development of a through-trip distribution model. Grouping data for analysis created some problems; however, trial-and-error evaluation enabled selection of variables which produced reasonable results. Variables found to be most significant in the development of internal-external models were population and employment. For through-trip models, variables used were population, functional classification, AADT at the external station, and percent trucks. In developing through-trip distribution models, variables of significance were AADT at the destination station, percent trucks at destination station, percent through trips at destination station, and ratio of destination AADT to total AADT's at all stations (value squared).

Overall, the models developed in this study appear to be adequate for planning purposes when ease of application and accuracy of the models are considered.

17. Key Words	18. Distribution Statement
Internal-external trips External-external trips Regression analysis Cross-classification Productions and attractions Socio-economic data	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Research Report
493

SIMULATION OF EXTERNAL-INTERNAL AND THROUGH TRIPS FOR SMALL URBAN AREAS

KYP-75-72; HPR-PL-1(13), Part III B

by

Jerry G. Pigman
Research Engineer Chief

Division of Research
Bureau of Highways
DEPARTMENT OF TRANSPORTATION
Commonwealth of Kentucky

February 1978

INTRODUCTION

Agencies responsible for determining when and where to construct new urban highways and streets, or to improve existing ones, must consider many factors in the decision-making process. A major factor is the travel desires and volume of traffic which can be expected to use the facilities in the future. Estimates of future traffic patterns are made by various traffic simulation models. These models are usually some mathematical expression with parameters and constants to simulate traffic flow. Alternative transportation systems can be evaluated in terms of costs and benefits to a particular area by inputing socio-economic descriptors into a simulation model in order to determine traffic patterns and volumes. Travel patterns within an urban area are divided into three categories:

1. External-External or Through Trips -- trips originating and terminating outside the area.
2. Internal-External Trips -- trips originating inside the area and terminating outside the study area, or vice-versa.
3. Internal-Internal Trips -- trips originating and terminating within the area.

The Department of Transportation's Division of Urban and Regional Planning is responsible for 37 transportation studies in small urban areas in Kentucky. The urban areas are defined as cities with populations between 5,000 and 50,000, as established by the 1970 census. The purpose of the studies is to provide sufficient information on transporation needs to develop priority listings of urban improvement projects. Surveys are usually conducted to determine trip patterns associated with a particular urban area. Costs and manpower limitations, however, make it impractical to conduct on-site surveys on each route intersecting the study area. Each transportation study typically requires origin-destination surveys at 5 to 15 external stations. The survey costs approximately $2,000 per station, including coding and factoring costs. Through June 1977, studies have been completed in 22 cities; and some work has been accomplished in three other cities.

As a result of limitations in the collection of origin-destination data for small urban areas, the Division of Urban and Regional Planning requested the Division of Research to develop a method of simulating both external-external and internal-external trips.

Historically, travel data for the three types of trips have been obtained from origin-destination surveys. The external origin-destination survey, in which drivers of vehicles are interviewed at the study area boundary, provides data for the internal-external and external-external trip types. Internal-internal trip data are generally obtained by home interview surveys, truck surveys, and taxi surveys. The collecting, coding, editing, processing, and summarizing of these data often has represented a major portion of the time and cost of conducting a transporatation study. However, review of studies completed has indicated that there are many similarities in the models developed for trip generation and trip distribution involving internal-internal trips. For this reason, it has been possible for the past several years to synthesize internal-internal trips by modeling. Many of the similarities in past and present studies involving internal-internal trips are also apparent in internal-external and external-external trips. Synthesis of the trips involves application of values from origin-destination studies to other urban areas having similar population and socio-economic characteristics. By emphasizing previously tested procedures and by selecting variables that characterize small urban areas in Kentucky, models were developed, herein, for simulating internal-external and external-external trips.

REVIEW OF LITERATURE

Differences between large urban areas and small urban areas are apparently significant enough to compel separation of them for modeling traffic. Most planners categorize those areas with less than 50,000 population as small urban areas. Several attempts have been made to develop traffic-estimating models without origin-destination surveys and to, therefore, eliminate the need for extensive data collection.

Initial work in North Carolina was directed toward simulation of internal travel using trip generation data from either a small sample of home interviews or from data obtained from another similar urban area. By 1970, a procedure for synthesis of internal travel had been perfected to the extent that its use has become standard operating procedure *(1)*. In 1970 and 1971, Modlin, working with the North Carolina Department of Transportation, was successful in synthesizing internal, external, and through travel for small urban areas *(2)*.

Another report by Modlin *(3)* dealt specifically with through trips. The estimating procedure consisted of three models. The first dealt with estimating the percentage of through trips in the AADT at each external station given the functional classification of the facility external to the cordon, the current AADT, the percentage of the facility external to the cordon, the latest AADT, the percentage of panel and pickup trucks, and the urban area population. The second was a composite model composed of distribution models for each functional classification which produced a triangular through-trip table. A third model developed estimated the percentage of total external trips by vehicles garaged inside the cordon as a function of employment available within the urban area.

An overview of the transportation planning process applicable to small urban areas and giving emphasis to estimation of travel was prepared as part of the National Cooperative Highway Research Program *(4)*. The study concluded that forecasting traffic should be customized for varying levels of analysis. It was recommended that models be used to produce networks of trips. However, the need to complement the approach with a selectively chosen small sample of home interviews was noted.

Another study, by Jones *(5)*, involved Lafayette, Indiana. Previously developed corridor growth-factor models for developing future estimates of internal traffic in small urban areas were tested and modified. Regression equations were developed to provide data usually obtained from external cordon surveys. Alternative procedures for providing external survey information, based on use of historical data from the subject city, were also developed. The completed procedure provided traffic volumes within the accuracy necessary for planning major throughfares in small urban areas.

Most studies of trip generation undertaken in the 1960's relied heavily on regression analyses. However, a recent study sponsored by the Federal Highway Administration indicated that a combination of cross-classification and rate analysis was a more efficient and straightforward procedure for forecasting trip generation *(6)*. The approach to forecasting was based upon cross-classification analysis for residential trip generation and trip rates and upon modified cross-classification for non-residential trip generation. The process was based upon developing trip productions and trip attractions as generally used for input to the gravity model trip-distribution process. Some advantages of using the combined cross-classification and rate analysis is the ease of understanding, efficient use of data, and ease of updating. The process is also valid in forecasting and base-year accuracy measures.

PROCEDURE

Transportation studies of 22 cities having populations ranging between 6,000 and 50,000 were the primary source of data for the analyses. Since an effort was being made to simulate internal-external and external-external (through) trips, it was necessary to determine which studies contained trip tabulations for both types of trips. Table 1 is a list of the 22 areas for which data were available. The table also includes the year the study was conducted, population of each urban area, number of external stations, and number of internal zones. A complete set of data was not available for Campbellsville (Study Number 10) or Frankfort (Study Number 19), and these two cities were excluded from the data base. The geographical distribution of urban areas used in this study is presented in Figure 1.

As is the case with most prediction models, the procedure followed was a trial-and-error process of selecting independent variables which were easy to predict, which met the test of reasonableness, and which produced statistically sound results. Model formulation was confined to regression analyses and cross-classification techniques.

INTERNAL-EXTERNAL MODEL DEVELOPMENT

Internal-external equations developed in the urban area transportation studies are tabluated in Table 2. Inspection of these equations reveals the types and the combinations of independent variables which were used to predict internal-external trips. The dependent variable (internal-external trips) and independent variables (various planning and socio-economic factors) were the best combination of variables to represent base-year conditions and to use to predict future trip generation. Internal-external trips were obtained from origin-destination surveys conducted at the time of the study. Population and employment data were available from censuses, and projections of these variables were considered good predictors of conditions at some point in the future. The study areas were grouped according to population, and specific variables used to predict internal-external trips are shown in Table 3.

TABLE 1. SMALL URBAN AREAS FOR WHICH TRANSPORTATION STUDIES HAVE BEEN COMPLETED

STUDY AREA NUMBER	STUDY AREA	YEAR OF STUDY	POPULATION (YEAR OF STUDY)	NUMBER OF EXTERNAL STATIONS	NUMBER OF INTERNAL ZONES
1	Murray	1967	14,713	9	21
2	Glasgow	1969	12,979	8	32
3	Paducah	1970	50,000	15	105
4	Madisonville	1968	18,224	8	50
5	Franklin	1969	7,898	6	28
6	Cynthiana	1969	6,700	6	21
7	Somerset	1968	14,031	9	21
8	Bowling Green	1970	36,553	11	78
9	Hazard	1970	6,145	4	16
10	Campbellsville	1968	11,200	7	19
11	Henderson	1971	24,965	10	82
12	Elizabethtown	1971	12,300	12	49
13	Hopkinsville	1971	26,647	12	84
14	Winchester	1970	16,205	11	32
15	Danville	1970	12,755	8	33
16	Corbin	1970	11,430	7	31
17	Mt. Sterling	1969	7,695	7	21
18	Nicholasville	1973	7,464	7	25
19	Frankfort	1970	34,506	14	55
20	Richmond	1976	23,477	7	35
21	Berea	1976	9,210	8	27
22	Mayfield	1976	13,436	12	25

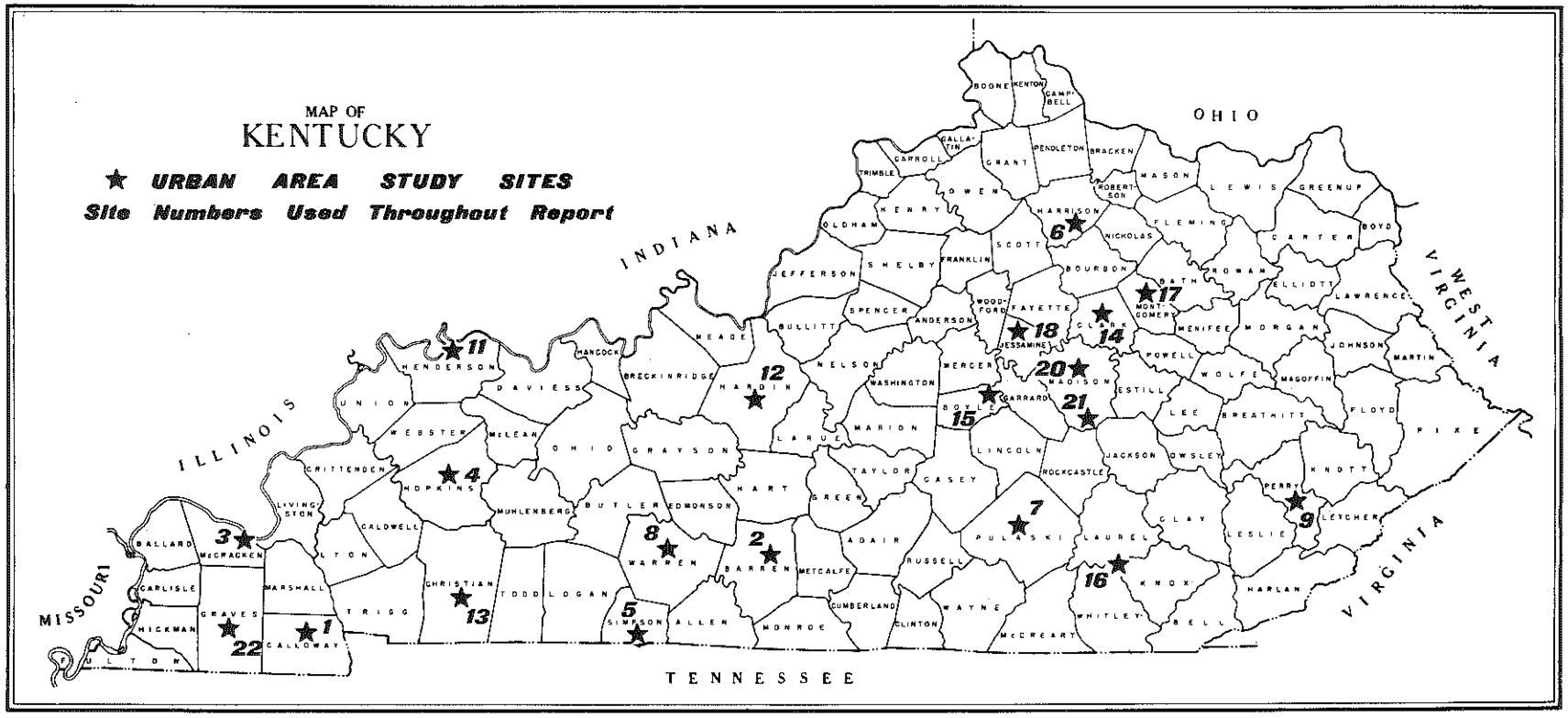

Figure 1. Geographical Distribution of Study Areas.

TABLE 2. EQUATIONS FOR INTERNAL-EXTERNAL TRIPS FOR SMALL URBAN AREAS (FROM PLANNING STUDIES)

STUDY AREA NUMBER	EQUATION
1	Y = 403.26 + 2.76 (TE)
2	Y = -123.9 + 0.60 (POP) + 0.66 (TE) + 3.48 (CE)
3	Y = 116.78 + 1.36 (CE + PE)
4	Y = -44.71 + 0.34 (POP) + 2.59 (TE)
5	Y = 45.23 + 0.21 (POP) + 6.30 (CE)
6	Y = 113.03 + 0.32 (POP) + 4.59 (CE + PE)
7	Y = 129.83 + 0.25 (POP) + 4.13 (CE) + 0.67 (IE)
8	Y = -35.51 + 0.26 (POP) + 1.06 (CE) + 0.50 (IE) + 1.73 (PE)
9	Y = 38.3 + 0.42 (POP) + 2.88 (TE)
10	Data not available
11	Y = 30.8 + 0.19 (POP) + 0.39 (TE) + 1.42 (CE)
12	Y = -12.81 + 0.74 (POP) + 1.55 (TE)
13	Y = 22.27 + 0.15 (POP) + 1.38 (CE) + 0.56 (IE) + 1.40 (PE)
14	Y = -6.65 + 0.35 (POP) + 2.87 (CE) + 3.81 (PE) + 0.78 (IE)
15	Y = 143.86 + 4.32 (CE) + 0.47 (IE)
16	Y = 2.00 + 0.41 (POP) + 0.66 (TE) + 3.36 (CE)
17	Y = 75.94 + 0.67 (POP) + 6.12 (CE) + 0.36 (IE)
18	Y = 12.59 + 0.68 (POP) + 11.0 (CE)
19	Data not available
20	Y = 26.59 + 0.43 (POP) + 2.59 (CE) + 1.61 (PE) + 0.61 (IE)
21	Y = -12.82 + 0.93 (POP) + 6.30 (CE) + 0.99 (PE) + 0.33 (IE)
22	Y = 15.77 + 0.38 (POP) + 3.35 (CE) + 2.49 (PE) + 1.10 (IE)

where Y = Internal-External Trips
POP = Population of Area
TE = Total Employment
CE = Commercial Employment
PE = Public Employment
IE = Industrial Employment

TABLE 3. EQUATIONS FOR INTERNAL-EXTERNAL TRIPS CATEGORIZED BY POPULATION AND SOCIO-ECONOMIC VARIABLE (NUMBERS REPRESENT STUDY AREA DESIGNATION)

SOCIO-ECONOMIC VARIABLES INCLUDED IN EQUATION	POPULATION (THOUSANDS)				
	5 - 10	10 - 15	15 - 20	20 - 30	30 - 50
TE		1			
POP + TE	9	12	4		
POP + TE + CE		2, 16		11	
POP + CE	5, 18				
POP + CE + IE	7	17			
POP + CE + PE	6				
POP + CE + PE + IE	21	22	14	13, 20	8
CE + PE					3
CE + IE		15			

REGRESSION ANALYSIS

Data on dwelling units, population, various types of employment, and internal-external trip attractions by zone were collected, tabulated, keypunched, and coded for computer analyses. Data used in developing internal-external models are listed in APPENDIX A. Linear regression was the first type of analysis performed to derive a prediction model. Several combinations of independent variables were tested using data available from the 20 cities. Each internal zone was considered to be a separate set of data; therefore, a total of 816 sets of data were available. The data sets were reduced from 816 to 762 because some of the data sets exhibited unusually large, or small, internal-external trips. Regression analysis using the complete data (APPENDIX A) was attempted. The result was a prediction equation which was inaccurate and unresponsive. A second regression analysis was made using the zones within each study area as a data set. These equations characterized individual areas well, but the equations were not applicable to predicting trips in other areas. It became apparent that the study areas should be combined into population groups as shown in Table 4. Regression analyses using five population groups were made, and the resultant equations are presented in Table 5.

TABLE 4. SMALL URBAN AREAS GROUPED BY POPULATION

STUDY AREA NUMBER	STUDY AREA	POPULATION	POPULATION GROUP
5	Franklin	7,898	
6	Cynthiana	6,700	
9	Hazard	6,145	5,000 - 9,999
17	Mt. Sterling	7,695	
18	Nicholasville	7,464	
21	Berea	9,210	
1	Murray	14,713	
2	Glasgow	12,979	
7	Somerset	14,031	
12	Elizabethtown	12,300	10,000 - 14,999
15	Danville	12,755	
16	Corbin	11,430	
22	Mayfield	13,436	
4	Madisonville	18,224	15,000 - 19,999
14	Winchester	16,205	
11	Henderson	24,965	
13	Hopkinsville	26,647	20,000 - 29,999
20	Richmond	23,477	
3	Paducah	50,000	30,000 - 50,000
8	Bowling Green	36,553	

TABLE 5. INTERNAL-EXTERNAL TRIP PREDICTION MODELS (REGRESSION ANALYSIS)

STUDY AREA NUMBERS	POPULATION GROUP	EQUATION
5, 6, 9, 17, 18, 21	5,000 - 9,999	Y = 10.25 + 0.53 POP + 5.41 CE + 0.81 PE + 0.57 IE
1, 2, 7, 12, 15, 16, 22	10,000 - 14,999	Y = 123.45 + 0.15 POP + 2.73 CE + 3.20 PE + 0.80 IE
4, 14	15,000 - 19,999	Y = -28.41 + 0.38 POP + 2.72 CE + 3.28 PE + 0.69 IE
11, 13, 20	20,000 - 29,999	Y = 1.78 + 0.30 POP + 1.87 CE + 1.64 PE + 0.53 IE
3, 8	30,000 - 50,000	Y = 60.76 + 0.05 POP + 1.26 CE + 0.30 PE + 0.51 IE

Y = Internal–External Trips by Zone
POP = Population of Internal Zone
CE = Commercial Employment by Zone
PE = Public Employment by Zone
IE = Industrial Employment by Zone
Note: Statistical parameters for these equations are presented as the combined equations in Table 8.

CROSS-CLASSIFICATION ANALYSIS

The second type of analysis used to obtain internal-external prediction models was cross-classification of data. Independent variables used for this analysis were zone population, total employment by zone, and dwellings by zone. The first cross-classification matrices were developed with large numbers of categories for each variable. It was found that the number of entries per cell was not sufficient to give significance to this high degree of stratification because only 816 zones constituted the data base. From regression analyses, it was found that dwellings and population exhibited characteristics of collinearity; and, therefore, one or the other should be dropped from the regression equations. Since both variables relied on the same characteristics of the urban area for prediction purposes, dwellings were omitted from the cross-classification analysis. The resulting model in its final form is presented in Table 6. Total employment by zone and population by zone are stratified into five and three groups, respectively. Due to the unusual attractors (businesses and institutions) previously mentioned, only 762 of the 816 internal zones were used for the final cross-classification analysis. The number of entries per cell in the matrix is also shown in Table 6. The report on trip-generation analysis by the Federal Highway Administration *(6)* suggested that at least 25 observations be accumulated for each cell. Only two of the 15 cells had less than 25 observations.

TABLE 6. CROSS-CLASSIFICATION PREDICTION OF INTERNAL-EXTERNAL TRIPS PER INTERNAL ZONE

TOTAL EMPLOYMENT	POPULATION		
	0 - 150	151 - 500	> 500
0 - 5	59 (87)*	87 (51)	317 (8)
6 - 50	154 (46)	185 (73)	340 (63)
51 - 100	179 (22)	222 (39)	485 (52)
101 - 300	436 (30)	464 (70)	610 (87)
> 300	945 (42	1,150 (43)	1,309 (49)

*( ) Data entries per cell for the above matrix

EXTERNAL-EXTERNAL MODEL DEVELOPMENT

REGRESSION ANALYSIS: PERCENTAGE THROUGH TRIPS

Development of a regression model to predict the percentage of through trips at an external station was influenced significantly by the North Carolina research *(3)*. Using their results as a guide, a model was tested with several independent variables to evaluate the percentage of through trips in the AADT at external stations. Independent variables in the regression analysis were AADT at the external station, percent trucks, population, functional classification of the highway at the external station, and employment. A list of data is presented in APPENDIX B. The same areas used to develop models to predict the percentage of through trips were used in developing internal-external trip models. There were 20 areas and a total of 177 external stations.

Considerable effort was devoted to collecting functional classification data for each of the routes. Of the 177 external stations, four functional classifications were represented. There were 61 external stations on primary arterials, 102 on minor arterials, 11 on collectors, and three on local routes. In the North Carolina study *(3)*, functional classification was used as a dummy variable. The method of dummy variables involves coding the data in such a manner that only selected classifications would be entered into the regression equation; others would be omitted. Functional classification, however, yielded no improvement in the statistical values for the equation. Functional classifications were also considered in an equation for each class, but this also proved unsuccessful. Employment data did not significantly improve the predictive ability of the equation. Generally, it is best that prediction equations have relatively small constants; however, equations forced to have smaller constants were not acceptable because predictions were less accurate. After several attempts at segregating the data, the simplest equation which represented all functional classifications and gave the best predicting ability was developed as shown in Table 7.

TABLE 7. EXTERNAL-EXTERNAL TRIP MODELS

REGRESSION EQUATION

$Y = 0.003\ EXSADT + 1.49\ PTADT - 0.0007\ POP + 17.43$

where Y = Percent through trips of the AADT at an external station
EXSADT = AADT at external station
PTADT = Percent trucks of AADT at external station
POP = Population of study area

CROSS-CLASSIFICATION

FUNCTIONAL CLASSIFICATION	AADT	PERCENT TRUCKS OF AADT	PERCENT THROUGH TRIPS	ENTRIES PER CELL
Primary Arterial	0 - 2,500	0 - 5	12	2
		6 - 10	31	3
		> 10	41	6
	2,500 - 5,000	0 - 5	39	2
		6 - 10	31	7
		> 10	49	15
	> 5,000	0 - 5	24	2
		6 - 10	49	10
		> 10	64	15
Minor Arterial	0 - 2,500	0 - 5	16	17
		6 - 10	20	30
		> 10	15	8
	2,500 - 5,000	0 - 5	28	9
		6 - 10	20	8
		> 10	36	18
	> 5,000	0 - 5	10	2
		6 - 10	32	4
		> 10	40	5
Collector	ALL	ALL	25	11
Local	ALL	ALL	19	3

CROSS-CLASSIFICATION ANALYSIS: PERCENTAGE THROUGH TRIPS

Recent work with cross-classification models has increased the confidence in this type of model for prediction purposes. Here, the first attempts to predict percentages of through trips using cross-classification were generally unsuccessful because too many variables and too much stratification were used. Population of the study area, functional classification of the route at the external station, AADT of the route at the external station, and percent trucks of the AADT were the variables first considered. Population of the area was dropped first because too many blanks appeared in the cross-classification matrix. Functional classification, which was not a significant variable when entered into the regression equation, was found to be a practical means of segregating data for cross-classification analysis. Cross-classification models were developed for primary arterial and minor arterial functional classifications; however, insufficient data were available to develop models for collector and local routes. The average percentage of through trips for the 11 collector routes and three local routes were used as representative of the 20 urban areas analyzed in this study.

After several attempts to develop a cross-classification model, it was decided that a small number of cells was practical for the amount of data available. The final cross-classification model used only three groups of AADT data and three groups of truck percentages for each AADT group. Therefore, for the models representating primary arterials and minor arterials, there were nine cells within each of the models. These models and the average percentage through trips representing collector and local routes are presented in Table 7, along with the regression equation model.

REGRESSION ANALYSIS: DISTRIBUTION OF EXTERNAL-EXTERNAL (THROUGH) TRIP ENDS

The distribution of external-external (through) trip ends was accomplished by developing regression equations for each of the four functional classifications. Equations were developed such that trip ends were distributed from each functional classification to all other functional classifications. External-external trip data were available for only 17 of the 20 urban areas used in the development of the other models in this study. The three urban areas for which data were not available were Somerset, Mt. Sterling, and Nicholasville. Table 8 is a summary of the data used in the development of the through-trip distribution models. Since the models were developed to distribute trip ends from one functional classification to all others within a particular urban area, a total of 1,332 combinations of trip interchange data were available for use in the analyses.

External-external trip data had to be balanced and then doubled before being input into the distribution models. This was necessary to make the distribution of trips from one external station to all other stations equal to 100 percent. For example, if the balanced number of trips from external Station A to external Station B is 10 and the number from B to A is 10, then the total number of trips between the two external stations is 20. Handling the trip tables in this manner, the volumes at the external station represent two-way traffic.

Independent variables considered for inclusion in the regression analyses are presented in Table 9. Of the 14 variables used in an attempt to predict the distribution of through trips, only four were considered significant enough to be included in the final model. To adequately represent two-way trips, it was felt that some function of both origin station and destination station be included in the model. However, results from the regression analysis indicated that variables representing the origin station were relatively insignificant; and, therefore, they were omitted from the equation. One variable, the ratio of the destination station AADT to the combined AADT at all external stations, did represent the origin station in an indirect way. The other three independent variables were AADT at the destination station, percent trucks at the destination station, and percentage through trips at the destination station. The models in their final form are presented in Table 10.

TABLE 8. SUMMARY OF ORIGIN-DESTINATION DATA USED IN DEVELOPMENT OF THROUGH-TRIP DISTRIBUTION MODELS

STUDY AREA NUMBER	STUDY AREA	AADT RANGE	RANGE OF PERCENT THROUGH TRIP ENDS	FUNCTIONAL CLASSIFICATION			
				PRIMARY	MINOR	COLLECTOR	LOCAL
1	Murray	782 - 4,195	3 - 34	3	5	1	
2	Glasgow	1,143 - 5,249	9 - 67	3	5		
3	Paducah	535 - 6,427	4 - 36	3	8	1	3
4	Madisonville	424 - 9,051	10 - 67	2	5	1	
5	Franklin	935 - 4,198	13 - 40		5	1	
6	Cynthiana	894 - 6,983	16 - 53	2	4		
7	Somerset		DATA NOT AVAILABLE				
8	Bowling Green	792 - 14,433	5 - 90	4	7		
9	Hazard	805 - 6,232	13 - 33	2	1	1	
10	Campbellsville		DATA NOT AVAILABLE				
11	Henderson	507 - 20,317	11 - 90	4	6		
12	Elizabethtown	845 - 12,981	8 - 98	5	5	2	
13	Hopkinsville	1,094 - 7,400	4 - 88	5	7		
14	Winchester	883 - 13,710	13 - 88	2	7	2	
15	Danville	1,874 - 7,068	16 - 48	4	4		
16	Corbin	2,257 - 12,951	12 - 89	4	3		
17	Mt. Sterling		DATA NOT AVAILABLE				
18	Nicholasville		DATA NOT AVAILABLE				
19	Frankfort		DATA NOT AVAILABLE				
20	Richmond	1,124 - 10,608	17 - 40	3	4		
21	Berea	359 - 9,694	10 - 28	2	6		
22	Mayfield	738 - 6,976	7 - 80	7	5		

TABLE 9. INDEPENDENT VARIABLES TESTED IN DEVELOPMENT OF THROUGH-TRIP DISTRIBUTION MODEL

1. AADT at Origin Station
2. Percent Trucks of AADT at Origin Station
3. Percent Through Trips of AADT at Origin Station
4. Functional Classification of Route at Origin Station
5. AADT at Destination Station
6. Percent Trucks of AADT at Destination Station
7. Percent Through Trips of AADT at Destination Station
8. Functional Classification of Route at Destination Station
9. Ratio of Origin AADT to Destination AADT
10. Ratio of Destination AADT to Total AADT
11. AADT at Destination Station (Squared)
12. AADT at Destination Station (Square Root)
13. Ratio of Destination AADT to Total AADT (Squared)
14. Ratio of Destination AADT to Total AADT (Square Root)

TABLE 10. EXTERNAL-EXTERNAL TRIP DISTRIBUTION MODELS

FUNCTIONAL CLASSIFICATION	EQUATION
Primary Arterial	Y = +0.0001 DADT + 0.11 DPTADT + 0.22 DPTPADT + 385.83 SQRADTOT - 2.58
Minor Arterial	Y = +0.0008 DADT - 0.08 DPTADT - 0.03 DPTPADT + 228.14 SQRADTOT + 6.20
Collector	Y = -0.00001 DADT + 0.11 DPTADT + 0.05 DPTPADT + 295.06 SQRADTOT + 3.10
Local	Y = -0.01 DADT - 0.03 DPTADT + 0.83 DPTPADT + 2704.73 SQRADTOT + 1.95

where
- Y = Percent of Trip Ends from Origin Station Distributed to Each of the Other Functional Classifications
- DADT = AADT at Destination Station
- DPTADT = Percent Trucks of AADT at Destination Station
- DPTPADT = Percent Through Trips of AADT at Destination Station
- SQRADTOT = Ratio of Destination AADT to Total AADT (Squared)

RESULTS

INTERNAL-EXTERNAL TRIP MODELS

Regression equations for internal-external trips are presented in Table 5. In the equations, internal-external trip attractions are a function of population of internal zone, commerical employment, public employment, and industrial employment by zone. Table 6 summarizes the internal-external cross-classification model. In this model, internal-external trip attractions are a function of employment by zone and population by zone. Figure 2 was prepared as a graphical representation of internal-external trip attractions as a function of employment and population by internal zone. For all three population ranges, the number of internal-external trip attractions increases with increasing total employment.

Several statistical values were used to evaluate the accuracy and reliability of the internal-external trip models. For the regression analyses, the statistical values were the squared correlation coefficient, standard error of estimate, mean of the dependent variable, and coefficient of variation. These values for each study and each group of studies are reported in Table 11. A wide range of statistical reliability was achieved by developing internal-external regression models for each of the study areas and for the combination of studies which made up the five groups. As should be expected, the statistical results for the individual study areas were better than the results for the combination of studies. Definitions of each statistical measure and equations used to calculate the values are presented in APPENDIX C.

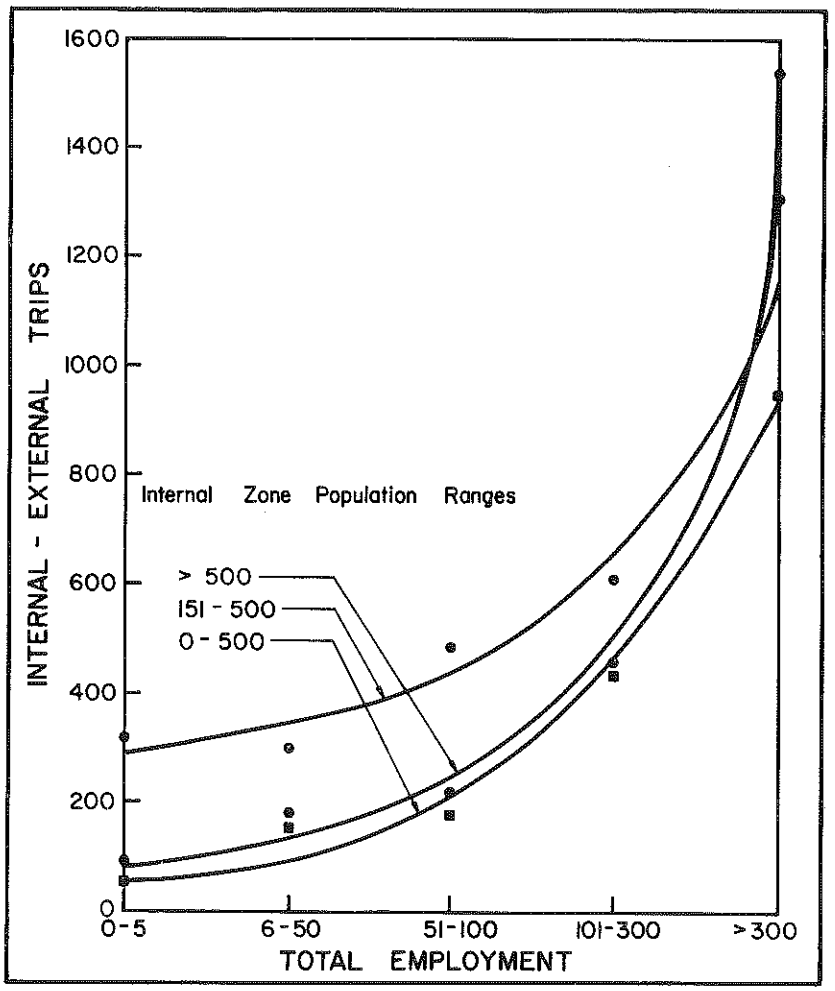

Figure 2. Relationship between Internal-External Trip Attractions and Total Employment for Various Population Ranges.

TABLE 11. STATISTICAL COMPARISON FOR EACH STUDY AREA AND EACH GROUP OF STUDY AREAS (INTERNAL-EXTERNAL REGRESSION EQUATIONS)

GROUP NUMBER	STUDY NUMBER AND NAME	STUDY YEAR POPULATION	NUMBER OF INTERNAL-EXTERNAL ZONES	R^2	STANDARD ERROR	MEAN OF DEPENDENT VARIABLE	COEFFICIENT OF VARIATION
Group I	5 Franklin	7,898	28	0.91	195	370	53
	6 Cynthiana	6,700	20	0.98	138	563	25
	9 Hazard	6,145	15	0.97	243	906	27
	17 Mt. Sterling	7,695	19	0.90	293	771	38
	18 Nicholasville	7,464	24	0.95	234	646	36
	21 Berea	9,210	24	0.81	120	331	36
	Combined Group I		130	0.81	353	564	63
Group II	1 Murray	14,713	20	0.95	240	970	25
	2 Glasgow	12,979	32	0.96	190	473	40
	7 Somerset	14,031	20	0.87	383	1,188	32
	12 Elizabethtown	12,300	45	0.94	195	488	40
	15 Danville	12,755	30	0.86	472	706	67
	16 Corbin	11,430	31	0.95	135	426	32
	22 Mayfield	13,436	25	0.90	289	1,016	28
	Combined Group II		203	0.79	404	690	59
Group III	4 Madisonville	18,224	48	0.96	147	411	36
	14 Winchester	16,205	30	0.95	179	627	29
	Combined Group III		78	0.94	171	494	35
Group IV	11 Henderson	24,965	77	0.70	153	289	53
	13 Hopkinsville	26,647	74	0.84	93	224	42
	20 Richmond	23,477	31	0.87	356	793	45
	Combined Group IV		182	0.78	229	348	66
Group V	3 Paducah	50,000	95	0.58	133	212	63
	8 Bowling Green	36,553	74	0.79	153	309	50
	Combined Group V		169	0.71	143	255	56

Table 12 presents data on the predictive abilities of internal-external regression models and internal-external cross-classification models for each of the study areas based on the group equations. Table 13 shows the same type of data for the study areas grouped according to population. Included in the tables are the number of zones used, actual trips, predicted trips, and root-mean-square errors for each of the 20 study areas. Root-mean-square errors were used as a means of comparing the predicted values calculated from the regression equations and the actual data obtained from origin-destination surveys. The root-mean-square error is comparable to the standard deviation, and it is related to a confidence interval or probability statement concerning the predicted values in a similar manner. In other words, two-thirds of the time the predicted values will deviate from the observed values by an amount no greater than the root-mean-square error.

It is obvious that considerably better predictions were achieved with the model developed from regression analysis as compared to the model developed by the cross-classification analysis. As shown in Table 12, the root-mean-square errors were significantly less for the regression model in all but one (Berea) of the 20 studies where combined equations were used to generate predictions. Results presented in Table 13 also indicate that greater accuracy was achieved with the regression model when the study areas were grouped by populaton. The large root-mean-square errors associated with some of the predictions can be explained in some cases because of the unusually large or unique producers and attractors of trips. As an example, the Murray area *(7)* was examined from the standpoint of eliminating unique zones to see how the error of prediction was affected. Presented in Table 14 are results of calculations showing how the accuracy of the prediction would be increased (reduced root-mean-square error) by discarding some zones. Three zones having employment three times greater than the average were discarded. The change in the root-mean-square error was from 346 to 249 for the regression model and from 693 to 238 for the cross-classification model. This indicated that the decision to discard some of the zones was very critical to the outcome of the prediction model. If some zones were discarded in the development of the general prediction model, then it would be necessary to estimate the internal-external trip attractions by some other means. The most valid estimates are based on data from past studies involving similar trip producers and attractors.

EXTERNAL-EXTERNAL TRIP MODELS: PERCENTAGE THROUGH TRIPS

As was shown previously in Table 7, the regression equation developed to predict the percentage of external-external trips was a function of AADT at the external station, percent trucks, and population. The statistical accuracy of this equation was reasonable; the standard error was 15.53, the multiple correlation coefficient (r^2) was 0.53, and the coefficient of variation was 49.

Table 7 gives the final cross-classification model used to predict the percentage of external-external trips at an external station. This model was also a function of AADT at the external station and percent trucks in the AADT at the external station, but the matrix did not include population. Functional classification was another means of segregating the data for the cross-classification analsyis.

Summarized in Table 15 is a comparison of the predictive abilities of external-external trip models. Included in the table are the number of external stations used, actual trips, predicted trips, and the root-mean-square errors for each of the 20 areas. The accuracy of the two models was approximately equal. However, the number of entries per cell in the cross-classification matrix was so small that the reliability of the results must be questioned.

EXTERNAL-EXTERNAL TRIP DISTRIBUTION MODELS

As a result of exhaustive regression analyses, equations for each of the four functional classifications were developed as was shown in Table 10. Each of the equations was a function of AADT at the destination station, percent trucks at the destination station, percentage through trips at the destination station, and the ratio of the AADT at the destination station to the combined AADT at all external stations.

Statistical results representing the accuracy of the models are presented in Table 16. While some statistical measures appear to produce inaccurate predictions, it is generally assumed that reasonably high standard errors exist with these prediction models. Results from these four distribution models compare favorably with results obtained by others *(2, 3)*. Overall, the models appear to be adequately reliable for planning purposes; this is true especially when the ease of application and the accuracy of the models are considered.

TABLE 12. INTERNAL-EXTERNAL TRIP PREDICTIONS FOR EACH STUDY AREA (COMPARISON OF REGRESSION ANALYSIS AND CROSS-CLASSIFICATION OF DATA)

STUDY NUMBER	STUDY AREA	INTERNAL-EXTERNAL ZONES USED IN MODELS	ACTUAL INTERNAL-EXTERNAL (AVERAGE TRIPS PER ZONE)	CROSS-CLASSIFICATION PREDICTION (AVERAGE TRIPS PER ZONE)	CROSS-CLASSIFICATION ROOT-MEAN-SQUARE ERROR	REGRESSION PREDICTION (AVERAGE TRIPS PER ZONE)	REGRESSION ROOT-MEAN-SQUARE ERROR
1	Murray	20	970	652	693	910	347
2	Glasgow	32	472	481	640	536	330
3	Paducah	95	213	450	329	212	136
4	Madisonville	48	411	476	626	445	156
5	Franklin	28	370	311	459	418	203
6	Cynthiana	20	563	507	678	588	228
7	Somerset	20	1,187	704	882	900	459
8	Bowling Green	74	309	585	435	285	171
9	Hazard	15	849	533	809	990	280
10	Campbellsville				DATA NOT AVAILABLE		
11	Henderson	77	289	418	281	298	177
12	Elizabethtown	45	488	395	554	534	254
13	Hopkinsville	74	224	421	437	298	147
14	Winchester	30	627	533	551	580	186
15	Danville	30	706	543	959	950	686
16	Corbin	31	406	371	292	414	188
17	Mt. Sterling	19	771	449	684	641	298
18	Nicholasville	24	645	271	777	397	555
19	Frankfort				DATA NOT AVAILABLE		
20	Richmond	31	793	589	673	597	413
21	Berea	24	331	369	274	532	316
22	Mayfield	25	1,016	677	564	840	367

TABLE 13. INTERNAL-EXTERNAL TRIP PREDICTION FOR EACH GROUP OF STUDY AREAS (COMPARISON OF REGRESSION ANALYSIS AND CROSS-CLASSIFICATION OF DATA)

GROUP NUMBER AND STUDY NUMBER	INTERNAL-EXTERNAL ZONES USED IN MODEL	ACTUAL INTERNAL-EXTERNAL AVERAGE TRIPS PER ZONE	CROSS-CLASSIFICATION PREDICTION (AVERAGE TRIPS PER ZONE)	CROSS-CLASSIFICATION ROOT-MEAN-SQUARE ERROR	REGRESSION PREDICTION (AVERAGE TRIPS PER ZONE)	REGRESSION ROOT-MEAN-SQUARE ERROR
Group I 5, 6, 9, 17, 18, 21	130	564	488	621	563	339
Group II 1, 2, 7, 12, 15, 16, 22	203	687	520	670	689	386
Group III 4, 14	78	494	498	598	498	168
Group IV 11, 13, 20	182	348	458	439	349	226
Group V 3, 8	169	255	509	380	244	153

TABLE 14. ROOT-MEAN-SQUARE ERRORS FOR INTERNAL-EXTERNAL TRIP MODELS (MURRAY URBAN AREA)

INTERNAL ZONE NUMBER	ACTUAL TRIPS (Y_a)	CROSS-CLASSIFICATION PREDICTION (Y_{cp})	DIFFERENCE $(Y_a - Y_{cp})^2$	REGRESSION ANALYSIS PREDICTION (Y_{rp})	DIFFERENCE $(Y_a - Y_{rp})^2$
1	2,860	1,542	1,737,124	3,390	280,900
2	1,529	1,542	169	766	582,169
3	593	464	16,641	565	284
4	452	485	1,089	413	1,521
5	420	610	36,100	552	17,424
6	316	301	225	344	784
7	598	945	120,409	1,032	188,356
8	1,104	1,309	42,025	1,187	6,889
9	779	610	28,561	913	17,956
10	503	485	324	455	2,304
11	444	301	20,449	344	10,000
12	3,589	1,309	5,198,400	4,043	206,116
13	947	464	233,289	535	169,744
14	2,251	945	1,705,636	1,433	669,124
15	139	154	225	243	10,816
16	585	185	160,000	240	119,025
17	476	301	30,625	310	27,556
18	189	185	16	222	1,089
19	600	301	89,401	439	25,921
20	1,035	610	180,625	777	66,564
Root-Mean-Square Error (All Zones Included)			693		346
Root-Mean-Square Error (Omitting Zones 1, 12, 14)			238		249

where Y_a = Actual number of trips
Y_{cp} = Cross-classification prediction
Y_{rp} = Regression analysis prediction

TABLE 15. EXTERNAL-EXTERNAL TRIP PREDICTIONS FOR EACH STUDY AREA (COMPARISON OF REGRESSION ANALYSIS AND CROSS-CLASSIFICATION OF DATA)

STUDY AREA NUMBER	STUDY AREA	EXTERNAL STATIONS	ACTUAL % THROUGH TRIPS AVERAGE PER STATION	CROSS-CLASSIFICATION PREDICTION (AVERAGE % TRIPS PER STATION)	CROSS-CLASSIFICATION ROOT MEAN-SQUARE ERROR	REGRESSION PREDICTION (AVERAGE % TRIPS PER STATION)	REGRESSION ROOT MEAN-SQUARE ERROR
1	Murray	9	18.5	30.0	12.5	33.1	16.1
2	Glasgow	8	33.5	36.1	15.1	35.4	14.0
3	Paducah	15	18.1	29.2	16.5	22.8	9.3
4	Madisonville	8	30.2	29.7	10.3	33.4	8.8
5	Franklin	6	25.3	23.5	8.5	33.3	11.6
6	Cynthiana	6	30.5	31.2	15.1	34.0	11.9
7	Somerset	9	43.1	27.2	19.2	20.3	26.4
8	Bowling Green	11	23.3	31.0	18.2	19.0	14.4
9	Hazard	4	17.7	37.0	25.8	41.5	24.8
10	Campbellsville		Data not available				
11	Henderson	10	47.2	34.9	19.4	27.4	25.8
12	Elizabethtown	12	49.3	35.6	24.0	37.6	26.3
13	Hopkinsville	12	25.9	34.3	18.0	26.9	15.1
14	Winchester	11	34.0	26.9	17.5	22.4	24.4
15	Danville	8	28.1	34.9	11.5	31.6	7.7
16	Corbin	7	44.1	42.1	15.3	31.6	28.0
17	Mt. Sterling	7	42.3	29.4	18.0	39.6	13.9
18	Nicholasville	7	41.8	34.4	12.7	36.0	9.9
19	Frankfort		Data not available				
20	Richmond	7	28.0	30.8	13.4	23.1	8.7
21	Berea	8	20.0	22.8	6.1	29.5	14.6
22	Mayfield	12	31.7	30.2	17.4	30.3	15.7
All Areas Combined		177	31.7	31.6	16.7	29.4	17.8

TABLE 16. STATISTICAL RESULTS FOR EXTERNAL-EXTERNAL TRIP DISTRIBUTION MODELS

FUNCTIONAL CLASSIFICATION	TOTAL OBSERVATIONS: FUNCTIONAL CLASS AT ORIGIN	MEAN OF DEPENDENT VARIABLE	R^2	STANDARD ERROR	COEFFICIENT OF VARIATION
Primary Arterial	478	11.60	0.54	12.85	111
Minor Arterial	733	11.61	0.43	11.13	97
Collector	79	11.74	0.35	12.64	108
Local	42	7.03	0.63	7.93	113

Note: Regression equations developed for each functional classification are presented in Table 10.

Further analyses of results were made by comparing the actual distribution of external-external trips with the predicted values. From the equations developed for external-external trip distribuitons, the results are in terms of percentage from one station to another. Three studies were selected for this comparison (Murray, Henderson, and Richmond). The results, in the form of trip tables, are presented in Tables 17 through 19. To facilitate the comparison between actual and predicted values, the percentage distribution of trips was translated into numbers of trips. These results are also presented in Tables 17 through 19. Root-mean-square errors calculated from actual and predicted percentage distribution of trips for each of the 17 areas are summarized in Table 20.

By applying the model representing the proper functional classification at each external station, an estimated percentage of external-external trips from a particular origin station to each destination station is generated. In most cases, the resulting sum of estimated percentages from one station to all other stations does not total 100 percent. To adjust the percentages, simply apply a proportional factor so that the resulting sum is 100 percent. When the estimated percent of trip ends is less than zero, the distribution to these stations should be set equal to zero before the percentages are factored. When this process is completed, a triangular trip matrix is developed to represent the total distribution of trips within an urban area. Since two estimates of trips are calculated for each pair of stations, it was necessary to average the two values to develop the triangular trip table. Using the Murray area as an example, a triangular trip table was prepared (Table 21). Two estimates of trips were used to calculate an average value. In this example, the percentages of through trips estimated by the models were translated into number of trips.

SUMMARY AND CONCLUSIONS

Three prediction models were developed: a model to predict the number of internal-external trips; a model to predict the percentage of external-external trips; and a model to distribute external-external trips. Both regression analysis and cross-classificaton techniques were tested in the development of the first two models, but only regression analysis was used to predict the distribution of through trips. Segregation of data into groups suitable for analysis did create some problems, but a method of trial-and-error evaluation enabled selection of the best combinationn of variables. Summarized in Table 22 are the independent variables required as input into the two internal-external models, the two external-external (through) models, and the through-trip distribution models. These independent variables were selected from data which were readily available, easy to forecast, and easy to monitor.

Population was the most significant variable which affected the outcome of the internal-external trip regression model. As previously noted in Table 4, there were five population groups. These were found to be the most distinctive means of separating the study areas for analysis. Many of the small urban areas in Kentucky were found to have travel patterns very similar to other towns of comparable population. Although not verified here, other studies have shown that geographical distribution has considerable influence on travel patterns, as does the proximity of the town to interstate, parkway, or other major routes. Socio-economic characteristics of small urban areas also play a significant role in determining the travel patterns.

TABLE 17. ACTUAL AND PREDICTED DISTRIBUTION OF EXTERNAL-EXTERNAL TRIPS (MURRAY AREA TRANSPORTATION STUDY)

PERCENTAGE OF TRIPS

STATION NUMBER	STATION NUMBER								
	22	23	24	25	26	27	28	29	30
22		0.0	11.8	19.3	52.9	52.6	21.4	32.7	13.2
		11.3	11.3	11.3	14.2	12.1	11.3	11.3	14.2
23	0.0		0.6	6.6	4.1	0.0	0.0	0.0	2.8
	1.7		8.0	8.0	1.7	5.5	8.0	8.0	1.7
24	6.3	3.4		15.2	13.4	11.4	37.0	0.0	13.7
	13.3	15.0		15.0	13.3	13.3	15.0	15.0	13.3
25	10.4	36.0	15.3		3.5	9.9	21.4	26.2	29.6
	9.9	11.1	11.1		9.9	10.3	11.1	11.1	9.9
26	59.9	46.2	28.3	7.3		18.5	10.9	13.1	37.0
	16.8	12.9	12.9	13.0		14.0	12.9	12.9	16.8
27	6.3	0.0	2.5	2.2	2.0		1.9	19.6	0.2
	4.7	4.4	4.4	4.4	4.7		4.4	4.4	4.7
28	7.7	0.0	24.8	14.2	3.5	5.7		0.0	4.6
	6.4	9.1	9.1	9.1	6.4	8.0		9.1	6.4
29	0.8	0.0	0.0	1.3	0.3	4.3	0.0		0.0
	0.0	6.6	6.6	6.6	0.0	4.7	6.6		0.0
30	8.9	18.8	17.2	37.0	22.0	1.4	8.5	0.0	
	13.0	14.0	14.0	14.0	13.0	12.5	14.0	14.0	

Root-Mean-Square Error = 15.7

NUMBER OF TRIPS

22		0	74	122	702	74	90	10	104
		13	71	72	189	17	48	3	113
23	0		4	42	54	0	0	0	22
	20		50	50	22	8	34	2	13
24	74	4		96	178	16	156	0	108
	156	17		95	176	19	63	5	105
25	122	42	96		46	14	90	8	234
	116	13	70		131	14	47	3	78
26	702	54	178	46		26	46	4	292
	197	15	81	82		20	55	4	133
27	74	0	16	14	26		8	6	2
	55	0	28	28	62		19	1	37
28	90	0	156	90	46	8		0	36
	75	11	58	58	84	11		3	50
29	10	0	0	8	4	6	0		0
	0	8	41	42	0	7	28		0
30	104	22	108	234	292	2	36	0	
	152	16	88	88	172	18	59	4	

Note: Within each block, the actual values are on top and the predicted values are on the bottom.

TABLE 18. ACTUAL AND PREDICTED DISTRIBUTION OF EXTERNAL-EXTERNAL TRIPS (HENDERSON AREA TRANSPORTATION STUDY)

PERCENTAGE OF TRIPS

STATION NUMBER	STATION NUMBER									
	83	84	85	86	87	88	89	90	91	92
83		75.3 64.0	69.5 64.0	66.9 87.2	28.7 64.0	87.0 87.2	81.4 64.0	80.4 64.0	74.8 87.2	74.3 64.0
84	15.8 14.8		1.8 8.5	0.2 14.8	7.2 8.5	1.3 14.8	4.8 8.5	6.7 8.5	11.7 14.8	3.5 8.5
85	2.8 3.7	0.3 7.4		1.0 3.7	10.8 7.4	0.7 3.7	0.8 7.4	1.3 7.4	1.2 3.7	4.7 7.4
86	5.0 13.9	0.1 4.4	1.8 4.4		0.0 4.4	3.8 13.9	1.0 4.4	1.0 4.4	3.9 13.9	1.6 4.4
87	0.1 1.4	0.2 5.3	1.3 5.3	0.0 1.4		0.1 1.4	0.3 5.3	0.4 5.3	0.2 1.4	2.3 5.3
88	26.3 23.2	1.9 5.5	5.4 5.5	15.3 23.2	3.6 5.5		5.4 5.5	2.2 5.5	2.2 23.2	1.2 5.5
89	22.8 17.0	6.5 11.2	5.4 11.2	3.7 17.0	17.9 11.1	5.0 17.0		3.7 11.2	4.9 17.0	6.3 11.2
90	0.0 9.1	3.2 6.8	3.1 6.8	1.2 9.1	7.2 6.8	0.7 9.1	1.3 6.8		0.3 9.1	6.6 6.8
91	16.0 14.4	12.0 8.7	6.4 8.7	11.1 14.4	7.7 8.7	1.6 14.4	3.8 8.7	0.7 8.7		2.7 8.7
92	3.5 5.1	0.8 6.9	5.4 6.9	1.0 5.1	21.5 6.9	0.2 5.1	1.1 6.9	3.2 6.9	0.6 5.1	

NUMBER OF TRIPS

83		1698 1443	306 282	542 707	16 36	2830 2838	2460 1933	866 690	1728 2016	380 327
84	1698 1594		8 38	2 120	4 5	44 481	146 258	72 92	270 342	18 44
85	306 395	8 168		8 30	6 4	24 119	24 225	14 80	28 85	24 38
86	542 1502	2 99	8 19		0 2	124 454	30 133	10 47	90 322	8 23
87	16 146	4 119	6 23	0 11		2 44	10 159	4 57	4 31	12 27
88	2830 2503	44 125	24 24	124 188	2 3		162 167	24 60	52 537	6 28
89	2460 1827	146 252	24 49	30 137	10 6	162 552		40 120	114 392	32 57
90	866 978	72 154	14 30	10 74	4 4	24 295	40 207		8 210	34 35
91	1728 1551	270 195	28 38	90 117	4 5	52 468	114 262	8 93		14 44
92	380 548	18 155	24 30	8 41	12 4	6 165	32 208	34 74	14 118	

Note: Within each block, the actual values are on top and the predicted values on the bottom.

TABLE 19. ACTUAL AND PREDICTED DISTRIBUTION OF EXTERNAL-EXTERNAL TRIPS (RICHMOND AREA TRANSPORTATION STUDY)

PERCENTAGE OF TRIPS

STATION NUMBER	STATION NUMBER						
	36	37	38	39	40	41	42
36		17.8	12.3	21.7	29.3	49.7	27.2
		18.0	20.1	20.1	20.1	18.0	18.0
37	1.1		1.1	1.4	1.5	2.0	2.5
	6.2		2.4	2.4	2.4	6.2	6.2
38	8.6	12.6		28.9	34.1	20.9	9.9
	26.7	26.7		25.8	25.8	26.8	26.7
39	4.9	5.2	9.4		4.1	5.4	8.5
	8.1	8.1	5.1		5.1	8.1	8.1
40	25.4	20.9	42.6	15.9		18.8	32.9
	23.6	23.6	23.7	23.7		23.6	23.6
41	54.2	34.5	32.8	26.0	23.6		19.6
	23.3	23.3	25.4	25.4	25.4		23.3
42	6.3	9.4	3.3	8.7	8.8	4.1	
	7.2	7.2	6.1	6.1	6.1	7.2	

NUMBER OF TRIPS

36		34	262	150	776	1654	192
		34	427	139	533	599	127
37	34		24	10	40	66	18
	190		51	17	63	207	44
38	262	24		200	904	696	70
	816	51		178	682	889	189
39	150	10	200		110	180	60
	247	15	109		136	269	57
40	776	40	904	110		626	232
	719	45	504	164		784	166
41	1654	66	696	180	626		138
	712	45	539	176	673		164
42	192	18	70	60	232	138	
	219	14	129	42	161	239	

Note: Within each block, the actual values are on top and the predicted values on the bottom.

TABLE 20. ROOT-MEAN-SQUARE ERRORS FOR TRIP DISTRIBUTION MODELS (PERCENTAGES OF TRIPS)

STUDY AREA NUMBER	STUDY AREA	ROOT-MEAN-SQUARE ERROR
1	Murray	12.9
2	Glasgow	13.8
3	Paducah	9.5
4	Madisonville	14.6
5	Franklin	16.9
6	Cynthiana	9.8
7	Somerset	Data not available
8	Bowling Green	11.6
9	Hazard	24.9
10	Campbellsville	Data not available
11	Henderson	8.1
12	Elizabethtown	11.5
13	Hopkinsville	10.3
14	Winchester	11.7
15	Danville	12.4
16	Corbin	16.7
17	Mt. Sterling	Data not available
18	Nicholasville	Data not available
19	Frankfort	Data not available
20	Richmond	9.8
21	Berea	14.9
22	Mayfield	10.3

TABLE 21. TRIANGULAR TRIP TABLE WITH NUMBER OF TRIPS ESTIMATED USING THE THROUGH-TRIP DISTRIBUTION MODELS (MURRAY AREA TRANSPORTATION STUDY)

STATION NUMBER	22	23	24	25	26	27	28	29	30
22									
23	20 17	13							
24	156 91	71	17 34	50					
25	116 94	72	13 32	50	70 83	95			
26	197 193	189	15 19	22	81 129	176	82 107	131	
27	55 36	17	5 7	8	28 24	19	28 21	14	62 41	20			
28	75 62	48	11 23	34	58 61	63	58 53	47	84 70	55	11 15	19			
29	0 2	3	8 5	2	41 23	5	42 23	3	0 2	4	7 4	1	28 16	3		
30	152 133	113	16 15	13	88 97	105	88 83	78	172 153	133	18 28	37	59 32	4	4 2	0	

Note: Numbers presented in each square are the two estimates of percentage trip interchanges for every pair of stations and the average of these values.

TABLE 22. INDEPENDENT VARIABLES REQUIRED AS INPUT FOR THE MODELS

INTERNAL-EXTERNAL TRIP MODELS

REGRESSION EQUATION	CROSS-CLASSIFICATION
1. Population of Internal Zone	1. Population of Internal Zone
2. Commercial Employment by Zone	2. Total Employment by Zone
3. Public Employment by Zone	
4. Industrial Employment by Zone	

EXTERNAL-EXTERNAL TRIP MODELS
(PERCENTAGE THROUGH TRIPS)

REGRESSION EQUATION	CROSS-CLASSIFICATION
1. AADT at External Station	1. Functional Classification
2. Percent Trucks of AADT at External Station	2. AADT at External Station
3. Population of Study Area	3. Percent Trucks of AADT at External Station

(DISTRIBUTION OF EXTERNAL-EXTERNAL TRIPS)

REGRESSION EQUATION

1. AADT at Destination Station
2. Percent Trucks of AADT at Destination Station
3. Percent Through Trips of AADT at Destination Station
4. Ratio of Destination Station AADT to Combined AADT at All External Stations (Squared)

The objective of this study was to develop models which could simulate both internal-external and external-external trips. A brief summary of comments on the prediction models and their implementation follows:

1. For predictions of internal-external trips, the regression equations presented in Table 5 should be used. These equations are categorized into five groups according to population of the urban area, and predictions of internal-external trips by zone are functions of zonal population and employment. The cross-classificaton prediction presented in Table 6 may have useful application if considerable care is taken to identify unique producers and attractors of trips and if special procedures for handling these trips are developed.

2. For predictions of percentage external-external (through) trips, the regression equation presented in Table 7 should be used. This regression equation is representative of all cases for predicting percentage external-external trips. The model for cross-classification is also presented in Table 7, but its utility is questionable because of the small number of entries in each cell in the matrix.

3. It was necessary to develop an external-external trip distribution model to implement results from development of a percent-through-trip model. Results from the percent-through-trip model can be input directly into one of the four distribution models presented in Table 10. This will enable the user to determine the percentage of through trips at a particular external station and then to distribute these trips to the other external stations within the study area. The final results will be an external-external triangular trip table similar to the one shown in Table 21.

4. Overall, the models developed in this study appear to be appropriate for planning purposes; this is true especially when the ease of application and accuracy of the models is considered.

REFERENCES

1. North Carolina Department of Transportation; *Procedure for Synthesizing Internal Traffic Movements,* 1976.

2. Khasnabis, S.; and Poole, M. R.; *Synthesizing Travel Patterns for a Small Urban Area,* **Traffic Engineering,** August 1975.

3. Modlin, D. G., Jr.; *Synthesis of Through Trip Patterns in Small Urban Areas,* Department of Civil Engineering, North Carolina State University, 1971.

4. Grecco, W. L.; Wegmann, F. J.; Spencer, J. A.; and Chatterjee, A.; *Transportation Planning for Small Urban Areas,* **NCHRP Report 167,** Transportation Research Board, 1976.

5. Jones, A. D.; *A Simplified Procedure for Major Thoroughfare Planning in Small Urban Areas,* Joint Highway Resarch Project Report 18, Purdue University and Indiana State Highway Commission, July 1972.

6. U. S. Department of Transportation, Federal Highway Administration; Urban Planning Division, *Trip Generation Analysis,* August 1975.

7. Mel Conner and Associates, for the Kentucky Department of Highways; *Murray, Kentucky Urban Area Transportation Study,* September 1968.

APPENDIX A

DATA USED IN DEVELOPMENT OF INTERNAL-EXTERNAL MODELS

STUDY NUMBER	ZONE NUMBER	DWELLING UNITS	POPULATION	COMMERCIAL EMPLOYMENT	INDUSTRIAL EMPLOYMENT	PUBLIC EMPLOYMENT	TOTAL EMPLOYMENT	INTERNAL-EXTERNAL TRIP ATTRACTIONS
1	1	83	222	967	13	182	1162	2860
1	2	94	168	192	116		308	1529
1	3	108	288	146			146	593
1	4	294	709	67			67	452
1	5	224	505	120	31		151	420
1	6	234	647	45			45	316
1	7	8	16	332			332	598
1	8	396	1138	327			327	1104
1	9	476	1170	225			225	779
1	10	340	845	75			75	503
1	11	237	779	38			38	444
1	123416		10917			713	713	3589
1	13	58	163	133	30		163	947
1	14	0	0	265	732		997	2251
1	15	18	36	40	6		46	139
1	17	88	265	28			28	585
1	18	204	700	30			30	476
1	19	89	326	18			18	189
1	20	596	1700	22			22	600
1	21	453	1240	165	21		178	1035
2	1	107	289	1080	82	131	1293	4387
2	2	204	518	38	0	0	38	386
2	3	304	882	7	2	0	9	215
2	4	195	460	43	8	0	51	468
2	5	282	742	119	10	0	129	551
2	6	168	442	2	0	0	2	236
2	7	84	204	65	0	124	189	430
2	8	79	421	204	50	14	268	722
2	9	504	1467	229	205	134	568	2434
2	10	308	992	81	2	46	129	649
2	11	272	775	54		2	56	202
2	12	144	351	27	91		118	216
2	13	204	612	9	2	10	21	372
2	14	180	596	13			13	259
2	15	109	354	31	1005	48	1084	855
2	16	188	517	4	2		6	193
2	17	27	54	110	37		147	686
2	18	69	161	130	891	3	1024	904
2	19	16	80					9
2	20	185	651	3	8	2	13	158
2	21	34	119	8			8	41
2	22	65	196	24	4		28	74
2	23	56	205	19		336	355	108
2	24	52	103					33
2	25	19	66					7
2	26	29	58					4
2	27	143	416	31	23		54	29
2	28	109	338	9			9	6
2	29	40	160	6			6	52
2	30	76	236	42			42	211
2	31	98	333	6	74	5	85	211
2	32	61	182					17
3	4	36	97	272	0	26	298	484
3	5	21	32	27	104	95	226	104
3	6	178	327	116	42	0	158	310
3	7	57	67	97	0	8	105	194
3	8	28	56	224	85	4	313	721
3	9	145	359	100	0	365	465	514
3	10	162	443	54	8	0	62	230
3	11	76	162	228	0	123	351	262

STUDY NUMBER	ZONE NUMBER	DWELLING UNITS	POPULATION	COMMERCIAL EMPLOYMENT	INDUSTRIAL EMPLOYMENT	PUBLIC EMPLOYMENT	TOTAL EMPLOYMENT	INTERNAL-EXTERNAL TRIP ATTRACTIONS
3	12	69	242	112	0	96	208	802
3	13	0	0	138	116	218	472	611
3	14	0	0	187	425	15	627	478
3	15	189	522	124	19	0	143	572
3	16	166	447	69	0	22	91	131
3	17	306	877	30	19	0	49	81
3	18	75	216	12	111	0	123	85
3	19	116	378	152	101	0	253	342
3	20	131	327	77	0	27	104	96
3	21	257	814	48	75	0	123	108
3	22	0	0	7	0	0	7	32
3	23	26	77	74	0	0	74	86
3	24	113	309	92	0	0	92	129
3	25	422	1099	93	27	2	122	415
3	26	238	529	138	0	0	138	308
3	27	187	528	229	647	10	886	688
3	28	41	163	145	40	0	185	134
3	29	7	21	147	0	0	147	434
3	30	39	127	46	0	0	46	42
3	32	40	60	8	0	0	8	8
3	33	122	376	0	0	0	0	67
3	34	61	255	3	0	21	24	4
3	35	297	975	129	0	80	209	41
3	37	50	130	3	0	0	3	66
3	38	26	44	3	0	0	3	35
3	39	46	196	3	0	0	3	10
3	40	69	267	3	0	0	3	8
3	41	374	1144	63	0	0	63	165
3	42	93	340	45	0	0	45	52
3	43	29	136	1	0	0	1	41
3	44	382	1251	168	0	19	187	209
3	45	218	752	16	0	0	16	123
3	46	57	160	0	0	0	0	3
3	47	28	112	0	0	0	0	3
3	48	161	508	0	0	0	0	72
3	49	378	972	320	150	0	470	289
3	50	317	842	21	0	12	33	128
3	51	913	2038	79	0	0	79	242
3	52	434	1116	257	0	30	287	338
3	53	0	0	6	700	0	706	372
3	54	238	540	34	0	68	102	205
3	55	102	265	34	0	17	51	205
3	56	309	750	54	0	83	137	230
3	57	151	248	332	0	525	857	706
3	58	92	184	213	0	1	214	313
3	60	15	29	265	3	0	268	299
3	61	47	71	67	0	0	67	118
3	62	155	478	63	0	0	63	227
3	63	403	1012	108	108	0	108	258
3	64	414	1243	102	102	0	102	268
3	65	518	1566	30	30	26	56	457
3	67	196	711	41	41	0	41	136
3	68	90	358	83	83	0	83	77
3	69	53	171	134	134	7	141	549
3	70	484	1473	105	105	38	143	358
3	71	366	755	66	66	16	102	252
3	72	259	998	105	105	0	200	349
3	73	266	699	137	137	2	139	200
3	74	20	29	161	161	5	626	731
3	75	98	251	187	187	0	197	327

STUDY NUMBER	ZONE NUMBER	DWELLING UNITS	POPULATION	COMMERCIAL EMPLOYMENT	INDUSTRIAL EMPLOYMENT	PUBLIC EMPLOYMENT	TOTAL EMPLOYMENT	INTERNAL-EXTERNAL TRIP ATTRACTIONS
3	76	55	164	30	0	0	30	8
3	77	165	539	60	0	0	60	37
3	78	23	151	0	0	0	0	177
3	79	124	484	11	0	0	11	80
3	80	78	196	0	0	0	0	212
3	81	184	648	22	0	0	22	61
3	82	395	1175	37	0	0	37	134
3	83	622	1909	249	575	75	899	738
3	84	443	1253	41	21	0	62	261
3	85	197	441	107	0	2	109	100
3	86	132	385	128	56	5	189	133
3	87	403	1461	6	0	58	64	112
3	88	70	197	17	0	10	27	30
3	90	71	255	9	0	0	9	83
3	91	96	288	12			12	20
3	92	166	416	11			11	155
3	94	150	407	66	0	0	66	278
3	96	177	603	53	0	0	53	37
3	97	275	1030	50	0	153	203	59
3	98	262	698	96	0	106	202	18
3	99	177	541	81	0	0	81	35
3	100	148	509	18	0	35	53	87
3	101	148	570	22	0	0	22	46
3	102	172	586	17	0	0	17	31
3	103	49	208	0	0	0	0	21
3	104	119	324	6	0	0	6	208
3	105	54	173	0	0	0	0	35
4	1	12	36	1238	29			3151
4	2	16	48	111	20		1267	380
4	3	296	894	97	24	40	131	573
4	4	154	461	109	25		161	355
4	5	158	477	214	136		134	837
4	6	191	559	257	2		350	514
4	7	195	575	28		11	259	288
4	8	174	526	211	0	10	307	385
4	9	299	903	14	5	0	28	303
4	10	243	734	48	0	2	72	259
4	11	8	24	1	0	33	46	164
4	12	283	855	61	9	38	151	497
4	13	251	758	33	2	15	115	284
4	14	286	863	71	36	0	150	326
4	15	267	806	61	38	0	142	265
4	16	107	621	271	42	783	1254	3360
4	17	279	843	215	84	0	299	773
4	18	307	927	31	84	2	117	436
4	19	334	1008	4	0	16	29	448
4	20	5	15	15	0	17	44	75
4	21	177	535	253	27	0	490	1068
4	22	210	634	23	0	0	80	279
4	23	22	66	0	0	0	65	2
4	24	57	172	6	21	0	62	93
4	25	135	408	6	42	0	96	63
4	26	8	24	0	0	0	86	18
4	27	7	21	113	39	44	336	415
4	28	2	6	8	456	0	464	270
4	29	2	6	0	164	0	164	9
4	30	0	0	18	84	0	102	14
4	31	8	26	0	0	0	0	4
4	32	216	702	7	0	0	7	156
4	33	149	484	12	2	0	117	170

STUDY NUMBER	ZONE NUMBER	DWELLING UNITS	POPULATION	COMMERCIAL EMPLOYMENT	INDUSTRIAL EMPLOYMENT	PUBLIC EMPLOYMENT	TOTAL EMPLOYMENT	INTERNAL-EXTERNAL TRIP ATTRACTIONS
4	34	190	618	22	0	2	33	357
4	35	209	709	129	2	63	234	1319
4	36	13	42	0	0	0	0	9
4	37	69	224	3	145	6	154	47
4	39	6	20	0	0	0	0	9
4	40	14	46	0	0	0	0	23
4	41	54	176	13	0	0	13	45
4	42	26	84	0	0	0	0	6
4	43	63	190	96	23	85	204	377
4	44	24	78	2	0	0	2	41
4	45	29	94	10	241	57	308	629
4	46	24	78	0	0	0	0	5
4	47	38	124	0	0	0	0	16
4	48	138	448	29	11	0	40	202
4	49	85	276	30	0	0	30	405
5	1	47	94	427	188	173	788	3037
5	2	45	131	149	30	28	207	744
5	3	154	447	19	12	4	35	214
5	4	83	241	38	625	0	663	694
5	5	81	308	0	0	2	2	213
5	6	172	550	4	0	0	4	341
5	7	74	266	0	9	0	9	156
5	8	183	458	121	64	106	291	516
5	9	49	167	4	6	68	78	196
5	10	62	198	1	3	0	4	123
5	11	260	806	37	5	0	42	426
5	12	63	208	30	35	28	93	229
5	13	124	397	27	0	0	27	107
5	14	36	122	0	0	0	0	35
5	15	82	238	14	6	0	20	86
5	16	223	870	8	0	24	32	200
5	17	341	989	8	0	0	8	612
5	18	124	384	161	414	2	577	1077
5	19	62	205	7	0	0	7	48
5	20	51	194	0	0	0	0	5
5	21	11	37	0	0	0	0	8
5	22	19	57	23	0	0	23	34
5	23	54	216	2	0	0	2	89
5	24	15	60	38	3	0	41	364
5	25	22	70	0	0	0	0	91
5	26	10	34	5	0	0	5	62
5	27	26	88	8	0	0	8	634
5	28	2	8	0	0	8	8	12
6	1	109	326	500	53	297	874	4007
6	2	84	252	25	0	11	72	380
6	3	103	308	32	43	0	136	535
6	4	104	311	33	0	0	94	409
6	5	210	647	217	0	0	229	1007
6	6	93	279	84	4	0	112	496
6	7	36	108	102	131	0	294	241
6	8	53	159	10	100	0	352	74
6	9	248	743	29	0	0	90	336
6	10	225	674	37	0	0	49	526
6	11	128	383	0	0	0	12	214
6	12	99	296	18	0	0	42	212
6	13	3	9	26	57	0	107	42
6	14	242	725	5	0	0	17	458
6	15	2	6	30	0	0	66	175
6	16	79	237	0	81	0	93	123
6	17	2	6	0	0	0	61	10

STUDY NUMBER	ZONE NUMBER	DWELLING UNITS	POPULATION	COMMERCIAL EMPLOYMENT	INDUSTRIAL EMPLOYMENT	PUBLIC EMPLOYMENT	TOTAL EMPLOYMENT	INTERNAL-EXTERNAL TRIP ATTRACTIONS
6	18	50	150	13	638	0	832	1062
6	19	359	1075	2	0	0	2	578
6	21	1	3	0	412	0	412	382
7	1	20	66	975	83	66	1124	4050
7	2	247	815	263	9	37	309	942
7	3	237	782	63	0	103	166	697
7	4	219	723	62	0	110	172	782
7	5	429	1416	107	0	57	164	1487
7	6	381	1257	144	538	0	682	1405
7	7	8	26	245	0	0	245	2347
7	8	135	472	119	0	0	119	878
7	9	99	346	123	141	0	264	865
7	10	281	984	220	146	143	509	1689
7	11	137	480	78	0	29	107	553
7	12	23	80	18	9	0	27	234
7	13	334	1169	71	25	0	96	959
7	14	59	206	0	0	0	0	106
7	15	360	1260	91	103	204	398	1198
7	16	59	200	66	17	0	83	305
7	17	198	693	148	0	12	160	974
7	19	187	654	11	0	0	11	228
7	20	376	1316	223	92	256	571	2180
7	21	285	998	219	441	17	677	1876
8	1	84	246	586		268	836	851
8	2	88	260	380			380	445
8	5	189	557	670	97	81	848	827
8	4	189	557	219	18		237	701
8	6	176	523	559		74	633	364
8	7	159	471	283		95	378	350
8	8	173	503	103		625	728	159
8	9	60	173	1030			1030	1420
8	10	207	601	420		13	433	581
8	11	143	413	276		327	603	629
8	12	154	448	166	185	358	709	581
8	13	404	1173	297	117	15	429	673
8	14	333	970	66			66	229
8	15	346	999	400	27	15	442	576
8	16	342	988	81	20	74	175	124
8	18	506	1462	243		38	281	368
8	19	345	999	51	7	20	78	378
8	20	282	824	278	178		456	690
8	21	230	664	46	1486	10	1542	702
8	22	245	708	142	180		322	468
8	23	71	211	153	42		195	171
8	24	96	277	2			2	12
8	25	78	231	33	451	24	508	200
8	26	177	523	42			42	165
8	27	582	1681	32			32	371
8	28	67	194	22		140	162	321
8	29	200	578	10			10	68
8	30	55	159					28
8	31	50	144					12
8	32	16	46	131	67	56	254	423
8	33	236	682	9			9	53
8	34	025	073	46	06	00	52	083
8	35	017	049					7
8	37	10	32	36			36	483
8	38	199	569	236	23		259	458
8	39	35	102	11			11	80
8	40	66	190	2	0	0	2	100

STUDY NUMBER	ZONE NUMBER	DWELLING UNITS	POPULATION	COMMERCIAL EMPLOYMENT	INDUSTRIAL EMPLOYMENT	PUBLIC EMPLOYMENT	TOTAL EMPLOYMENT	INTERNAL-EXTERNAL TRIP ATTRACTIONS
8	41	102	294	62	4	0	66	260
8	42	28	83	8	500	0	508	413
8	43	131	379	11	0	0	11	43
8	44	79	228	23	0	0	23	325
8	45	99	289	2	0	3	5	77
8	46	184	535	207	0	10	217	293
8	47	306	878	9	0	0	9	208
8	48	347	997	129	65	3	197	368
8	49	41	112	8	0	12	20	27
8	50	283	812	4	0	0	4	190
8	51	102	292	1	0	0	1	30
8	52	1	3	26	0	24	50	34
8	54	50	139	0	0	0	0	10
8	55	76	214	50	0	0	50	204
8	56	82	228	0	0	0	0	57
8	57	34	98	0	0	0	0	25
8	58	53	148	0	0	0	0	12
8	59	193	552	59	0	0	59	121
8	60	633	1823	129	0	36	165	446
8	61	151	437	19	0	19	38	124
8	62	338	974	99	0	0	99	280
8	63	317	916	25	0	0	25	113
8	64	82	236	53	0	0	53	74
8	65	93	269	36	0	0	36	43
8	66	44	127	0	0	0	0	23
8	67	29	83	16	0	0	16	72
8	68	50	144	1	0	0	1	18
8	69	104	289	98	1577	121	1796	1211
8	70	476	1375	112	0	12	233	393
8	71	154	445	7	0	0	7	172
8	72	473	1366	203	3	0	206	409
8	73	44	127	128	1590	0	1718	1103
8	74	276	792	360	0	0	360	1322
8	75	139	401	45	27	41	113	93
8	76	16	46	4	0	0	4	66
8	77	46	133	114	0	0	114	69
8	78	98	284	0	0	0	0	19
9	1	84	260	732	220	493	1445	4341
9	2	268	831	114	0	105	219	884
9	3	264	818	78	14	0	92	509
9	4	195	604	396	0	33	429	2138
9	5	341	1057	203	151	83	437	1389
9	6	156	484	96	100	6	202	1227
9	7	6	19	18	0	72	90	412
9	8	23	71	0	0	0	0	18
9	9	64	198	6	0	3	9	181
9	10	81	251	0	0	0	0	102
9	11	236	732	220	0	13	233	1369
9	12	192	595	26	0	56	82	501
9	14	15	46	160	18	0	178	350
9	15	35	108	0	0	0	0	54
9	16	22	68	65	0	0	65	116
11	1	61	156	350	138	230	718	880
11	2	13	35	625	79	551	1255	1368
11	3	90	247	199	0	0	199	435
11	4	69	181	273	151	19	443	546
11	5	127	349	72	199	0	271	350
11	6	212	581	46	0	82	128	261
11	7	49	129	34	7	0	41	107
11	8	261	707	24	0	0	24	219

STUDY NUMBER	ZONE NUMBER	DWELLING UNITS	POPULATION	COMMERCIAL EMPLOYMENT	INDUSTRIAL EMPLOYMENT	PUBLIC EMPLOYMENT	TOTAL EMPLOYMENT	INTERNAL-EXTERNAL TRIP ATTRACTIONS
11	9	90	244	52	146	6	204	249
11	10	274	1090	101	0	8	109	240
11	11	389	1062	37	76	18	131	238
11	12	169	483	35	0	0	35	134
11	13	341	931	62	0	13	75	194
11	14	140	407	29	0	31	60	164
11	15	162	437	28	0	0	28	211
11	16	200	538	71	0	35	106	354
11	17	157	426	42	73	6	121	456
11	18	81	250	121	25	25	171	287
11	19	263	813	132	0	0	132	370
11	20	122	365	45	20	20	85	217
11	21	113	349	91	179	0	270	348
11	22	58	176	4	0	58	62	108
11	23	247	763	34	40	25	99	144
11	24	283	874	47	63	30	140	298
11	25	23	77	9	0	0	9	18
11	26	26	87	61	0	0	61	133
11	27	120	401	191	0	7	198	363
11	28	2	7	6	0	0	6	23
11	30	141	489	127	4	69	200	465
11	31	10	35	27	334	0	361	186
11	32	8	28	25	511	0	536	200
11	34	41	142	29	15	0	44	67
11	33	4	14	12	0	0	12	438
11	35	64	222	2	0	0	2	43
11	36	242	840	17	0	0	17	280
11	37	63	210	9	0	0	9	95
11	38	6	20	0	0	0	0	2
11	40	6	21	0	0	0	0	6
11	41	15	51	17	166	38	221	525
11	42	7	23	0	0	0	0	104
11	43	238	795	52	0	0	52	314
11	44	179	490	106	60	0	166	821
11	45	72	197	317	0	0	317	1335
11	46	2	7	63	114	59	236	377
11	47	67	224	4	0	0	4	77
11	49	9	30	0	0	0	0	13
11	50	109	367	1	0	0	1	85
11	51	22	74	0	0	0	0	3
11	52	7	23	4	0	92	96	422
11	53	2	7	0	0	0	0	9
11	54	62	209	2	0	0	2	43
11	55	12	40	23	0	0	23	12
11	56	50	162	0	0	0	0	89
11	57	89	258	42	0	89	131	413
11	58	132	383	283	200	42	525	944
11	59	277	803	21	17	5	43	319
11	60	5	17	58	744	57	859	368
11	61	3	10	148	0	0	148	343
11	62	0	0	12	83	0	95	43
11	63	256	742	67	109	0	176	369
11	64	178	516	113	0	0	113	426
11	65	1	3	17	0	385	402	712
11	66	156	452	24	0	21	45	222
11	67	204	681	57	0	0	57	333
11	69	259	856	79	0	0	79	367
11	70	51	172	102	0	0	102	143
11	71	314	1049	254	0	0	254	699
11	72	115	384	293	10	0	303	504

STUDY NUMBER	ZONE NUMBER	DWELLING UNITS	POPULATION	COMMERCIAL EMPLOYMENT	INDUSTRIAL EMPLOYMENT	PUBLIC EMPLOYMENT	TOTAL EMPLOYMENT	INTERNAL-EXTERNAL TRIP ATTRACTIONS
11	73	0	0	48	0	0	48	526
11	74	140	468	54	0	0	54	252
11	75	119	397	7	0	0	7	111
11	76	82	276	4	0	0	4	58
11	77	19	64	18	0	39	57	190
11	78	36	121	5	0	0	5	28
11	79	10	34	2	0	0	2	26
11	80	7	23	0	0	0	0	21
11	81	104	347	2	0	0	2	82
12	1	14	28	1234	0	217	1451	3918
12	2	126	315	393	419	65	877	1272
12	3	347	937	115	0	25	140	986
12	4	280	756	67	0	0	67	526
12	5	154	492	149	0	11	160	476
12	6	118	342	17	45	39	101	305
12	7	13	37	251	0	134	385	1489
12	8	263	868	104	2	0	106	652
12	9	116	313	0	0	0	0	290
12	10	213	575	104	0	0	104	885
12	11	128	346	91	0	25	116	460
12	12	218	589	11	0	232	243	637
12	13	390	1053	167	0	0	167	1725
12	14	265	768	4	0	0	4	375
12	15	71	205	35	0	0	35	139
12	16	141	381	9	0	0	9	327
12	17	0	0	10	0	20	30	45
12	20	31	89	7	37	0	44	37
12	21	8	23	102	0	0	102	223
12	22	26	75	79	210	0	289	572
12	23	18	52	42	0	26	68	205
12	24	6	17	0	0	0	0	11
12	25	20	58	0	0	0	0	8
12	26	40	116	4	0	0	4	60
12	27	20	58	30	1023	0	1053	422
12	28	84	243	0	482	0	482	540
12	29	18	52	0	0	30	30	8
12	30	52	150	0	0	0	0	82
12	32	55	159	28	33	0	61	63
12	33	247	667	30	0	68	98	414
12	34	54	156	60	0	0	60	181
12	35	241	651	258	0	359	617	2498
12	36	12	34	204	0	0	204	628
12	37	9	26	0	0	0	0	3
12	38	8	23	0	0	0	0	13
12	39	58	168	9	0	0	9	13
12	41	51	147	71	0	0	71	328
12	42	4	12	0	0	0	0	17
12	43	18	52	0	0	0	0	12
12	44	140	376	78	0	0	78	499
12	45	69	191	61	0	0	61	156
12	46	0	0	56	0	0	56	267
12	47	108	313	9	0	0	9	89
12	48	79	229	5	0	70	75	105
12	49	22	63	0	0	0	0	15
13	1	63	241	115	0	259	374	570
13	2	17	41	678	0	104	782	972
13	3	42	80	551	112	174	837	858
13	4	170	428	196	90	0	286	441
13	5	38	96	328	14	22	364	486
13	6	26	37	207	32	0	239	668

STUDY NUMBER	ZONE NUMBER	DWELLING UNITS	POPULATION	COMMERCIAL EMPLOYMENT	INDUSTRIAL EMPLOYMENT	PUBLIC EMPLOYMENT	TOTAL EMPLOYMENT	INTERNAL-EXTERNAL TRIP ATTRACTIONS
13	8	250	430	123	14	0	137	285
13	9	307	780	168	100	56	324	447
13	10	149	426	55	0	42	97	183
13	11	439	1387	22	0	20	42	193
13	12	176	549	25	39	36	100	204
13	13	16	40	61	0	0	61	127
13	14	458	1170	55	21	65	141	208
13	15	188	451	223	66	0	289	272
13	16	183	439	43	0	23	66	187
13	17	231	642	24	0	0	24	101
13	18	277	620	40	0	0	40	129
13	19	135	236	3	0	0	3	65
13	20	221	528	30	432	62	524	524
13	21	148	407	191	0	37	228	430
13	22	65	212	295	0	0	295	749
13	23	241	778	29	63	6	98	234
13	24	328	941	30	4	0	34	127
13	25	97	291	42	5	0	47	71
13	26	150	474	24	0	16	40	155
13	27	211	715	63	0	0	63	73
13	28	254	861	54	0	32	86	315
13	32	117	340	61	90	0	151	295
13	33	41	119	5	0	28	33	24
13	34	80	233	53	0	2	55	103
13	35	61	183	63	167	0	230	230
13	36	194	681	29	30	5	64	219
13	37	165	579	139	0	0	139	255
13	38	332	1036	40	0	0	40	286
13	39	117	365	156	0	31	187	511
13	40	184	602	3	0	21	24	111
13	41	265	795	16	0	0	16	318
13	42	121	333	17	0	0	17	101
13	43	166	541	27	0	81	108	147
13	44	307	881	197	0	0	197	710
13	45	142	408	223	0	0	223	413
13	46	106	318	139	0	0	139	225
13	48	139	417	139	0	47	186	322
13	49	90	270	30	0	0	30	98
13	50	5	15	3	100	0	103	45
13	51	98	294	32	0	2	34	172
13	52	77	231	5	0	300	305	462
13	53	102	346	0	0	0	0	17
13	54	11	37	0	0	0	0	17
13	55	13	44	0	0	0	0	7
13	56	23	78	25	0	0	25	90
13	57	13	44	8	0	0	8	30
13	59	70	206	22	0	0	22	41
13	61	20	59	0	0	0	0	6
13	62	70	206	3	0	0	3	58
13	63	17	50	0	0	0	0	19
13	64	133	391	90	0	0	90	99
13	65	6	18	0	0	0	0	21
13	66	8	24	30	0	0	30	174
13	67	9	26	0	0	0	0	3
13	68	6	18	0	0	0	0	11
13	69	6	18	0	0	0	0	14
13	70	9	27	0	0	0	0	8
13	71	4	12	0	0	0	0	5
13	72	170	510	0	0	34	34	123
13	74	360	1174	11	0	0	11	325

STUDY NUMBER	ZONE NUMBER	DWELLING UNITS	POPULATION	COMMERCIAL EMPLOYMENT	INDUSTRIAL EMPLOYMENT	PUBLIC EMPLOYMENT	TOTAL EMPLOYMENT	INTERNAL-EXTERNAL TRIP ATTRACTIONS
13	75	3	9	0	0	0	0	3
13	76	53	159	3	0	0	3	12
13	77	81	264	17	0	0	17	147
13	80	10	34	0	661	0	661	518
13	81	4	14	6	0	0	6	6
13	82	2	6	0	0	0	0	5
13	83	1	3	167	748	0	915	579
13	84	76	228	5	63	0	68	94
14	1	147	475	898	365	167	1430	3939
14	2	113	365	140	3	19	162	796
14	3	262	846	14	0	0	14	595
14	4	257	830	160	2	54	216	851
14	5	234	757	72	600	12	684	884
14	6	154	496	102	9	46	157	974
14	7	261	843	21	0	0	21	271
14	8	125	405	11	0	8	19	112
14	9	409	1320	7	0	31	38	629
14	10	306	983	57	31	0	88	719
14	11	164	522	93	27	82	202	642
14	12	50	156	2	0	0	2	81
14	13	24	74	0	0	0	0	18
14	14	366	1173	17	13	0	30	646
14	15	209	675	57	668	0	725	781
14	16	333	1041	179	15	0	194	582
14	17	101	326	64	664	32	760	513
14	18	146	462	125	5	0	130	363
14	19	604	1952	235	7	221	463	2192
14	20	288	908	18	0	0	18	446
14	21	169	546	254	2	48	304	1039
14	22	18	55	184	4	0	188	252
14	23	20	61	0	0	0	0	12
14	24	137	422	16	0	0	16	391
14	25	10	30	18	0	0	18	79
14	26	12	37	0	0	0	0	6
14	27	2	6	0	0	0	0	2
14	28	5	15					3
14	29	129	397	8	0	0	8	271
14	32	3	9	54	625	0	679	713
15	1	92	268	1435	5	416	1856	6498
15	2	134	390	26	0	0	26	229
15	3	244	710	261	0	12	273	1184
15	4	178	518	17	0	56	73	660
15	5	296	861	19	0	0	19	283
15	6	268	780	8	0	15	23	318
15	7	232	675	126	46	30	202	895
15	8	113	651	10	0	0	10	99
15	9	8	438	217	257	191	665	655
15	10	122	370	30	0	0	30	205
15	11	148	431	157	6	13	176	777
15	12	181	880	114	0	31	145	720
15	13	8	23	86	554	29	669	192
15	14	163	474	104	19	49	172	746
15	15	208	605	45	0	12	57	343
15	16	210	611	14	0	62	76	372
15	17	121	352	2	0	0	2	192
15	18	3	9	0	0	0	0	14
15	19	4	39	18	0	43	16	312
15	20	216	629	629	20	0	43	285
15	21	8	23	23	672	0	706	838
15	22	244	710	710	0	0	128	756

STUDY NUMBER	ZONE NUMBER	DWELLING UNITS	POPULATION	COMMERCIAL EMPLOYMENT	INDUSTRIAL EMPLOYMENT	PUBLIC EMPLOYMENT	TOTAL EMPLOYMENT	INTERNAL-EXTERNAL TRIP ATTRACTIONS
15	23	311	905	905	393	0	481	1205
15	24				15	0	29	36
15	25	8	23	23	54	0	77	674
15	27	176	512	512	0	3	172	1157
15	28	3	9	9	0	0	0	13
15	30				1017	0	1017	712
15	32	26	76	76				22
15	33	263	765	765	0	23	319	786
16	1	93	276	527	41	126	694	2183
16	2	107	321	367	91	33	491	1770
16	3	265	795	0	0	0	0	226
16	4	252	756	0	0	27	27	725
16	5	193	578	50	0	0	50	391
16	6	147	441	0	0	0	0	65
16	7	238	714	138	0	39	177	983
16	8	258	774	52	77	55	184	436
16	9	0	0	0	400	0	400	179
16	10	242	726	163	0	0	163	766
16	11	281	843	273	0	21	294	1411
16	12	213	639	62	18	0	80	659
16	13	74	222	122	0	0	122	767
16	14	43	129	1	0	0	11	95
16	15	60	180	0	0	0	0	73
16	16	77	213	4	0	0	0	98
16	17	106	318	0	0	0	0	94
16	18	93	279	0	0	33	33	48
16	19	130	390	3	0	0	3	51
16	20	145	435	20	15	0	35	276
16	21	160	480	0	0	0	0	22
16	22	31	93	0	609	0	609	476
16	23	91	273	0	0	0	0	84
16	24	34	102	0	0	0	0	2
16	25	10	30	0	0	0	0	1
16	26	7	21	0	0	0		25
16	27	52	156	77	23	0	100	630
16	28	82	246	0	0	0	0	79
16	29	106	318	2	0	0	2	121
16	30	55	165	34	0	0	34	146
16	31	177	513	11	0	0	1	322
17	1	137	411	672	9	56	737	3675
17	2	146	438	1	0	1	2	235
17	3	111	333	170	124	0	294	1417
17	4	183	549	63	4	0	67	1241
17	5	303	909	57	0	157	214	1284
17	6	262	786	17	0	38	55	735
17	7	145	435	7	0	0	7	516
17	8	87	261	45	0	1	46	491
17	9	3	9	0	0	29	29	200
17	10	7	21	49	421	21	491	291
17	11	174	522	16	11	3	30	205
17	12	239	717	23	18	0	41	715
17	13	165	495	21	0	0	21	512
17	14	23	69	43	0	0	43	1178
17	15	87	261	16	1292	0	1308	962
17	16	288	864	5	144	0	149	681
17	19	28	84	0	0	0	0	23
17	20	110	330	14	0	0	14	251
17	21	14	42	0	0	0	0	38
18	1	61	186	345	0	75	420	4309
18	2	90	275	28	0	1	29	563

STUDY NUMBER	ZONE NUMBER	DWELLING UNITS	POPULATION	COMMERCIAL EMPLOYMENT	INDUSTRIAL EMPLOYMENT	PUBLIC EMPLOYMENT	TOTAL EMPLOYMENT	INTERNAL-EXTERNAL TRIP ATTRACTIONS
18	3	207	606	29	0	2	31	901
18	4	318	886	90	0	0	90	1683
18	5	178	489	26	0	0	26	660
18	6	179	528	47	6	11	64	737
18	7	676	2116	97	0	0	97	2044
18	8	335	1063	13	0	86	99	1783
18	9	84	257	44	0	0	44	539
18	10	21	64	0	207	0	207	281
18	11	3	10	0	0	98	98	50
18	12	3	10	0	0	0	0	33
18	13	70	243	3	0	0	3	127
18	14	25	87	140	0	0	140	956
18	15	14	43	30	0	0	30	341
18	16	22	68	4	0	0	4	92
18	17	15	48	0	0	0	0	28
18	18	18	49	0	0	0	0	25
18	19	26	113	12	7	0	19	59
18	20	30	94	6	0	0	6	95
18	21	21	66	4	0	0	4	102
18	22	34	107	1	11	0	12	64
18	24	8	21	0	0	0	0	15
18	25	11	35	2	0	0	2	5
20	1	120	271	569	79	149	797	3148
20	2	111	236	696	4	128	828	1211
20	3	422	1029	102	15	71	188	612
20	4	507	1274	157		25	182	1027
20	5	311	711	60		5	65	469
20	6	162	439	16		58	74	218
20	7	187	496	213			213	816
20	8	354	1154	176			176	892
20	9	461	1537	138	453	26	617	1554
20	10	1	3					7
20	11	57	182	19		111	130	267
20	13	162	455	12		32	44	115
20	14	492	1347	18		28	46	551
20	15	241	684					430
20	16	313	909	445			445	1404
20	17	360	756	4		2367	2371	4321
20	18			104	250		354	579
20	19	218	667	328		136	464	1226
20	20	331	1027	261	3		264	1436
20	21	67	214	43			43	51
20	22	144	458	5			5	123
20	23	4	12					11
20	24	8	25			3	3	98
20	26	150	479	8			8	82
20	27	246	727	64			64	1162
20	29			66			66	351
20	30	110	348	146			146	489
20	32	78	175	12		100	112	24
20	33	1	3			236	236	582
20	34	189	584	312			312	964
20	35	27	86	14			14	365
21	1	35	102	205	0	82	287	789
21	2	165	479	31	0	0	31	208
21	3	197	571	45	0	0	45	196
21	5	173	502	80	0	0	80	485
21	6	0	0	3	0	80	83	60
21	7	4	12	28		150	178	232
21	8	6	590	32		442	474	304

STUDY NUMBER	ZONE NUMBER	DWELLING UNITS	POPULATION	COMMERCIAL EMPLOYMENT	INDUSTRIAL EMPLOYMENT	PUBLIC EMPLOYMENT	TOTAL EMPLOYMENT	INTERNAL-EXTERNAL TRIP ATTRACTIONS
21	9	21	633	299		57	356	906
21	10	51	148	5			5	33
21	11	26	75	15			15	60
21	12	163	473	68			68	549
21	14	105	305	33			33	362
21	16	111	322	58			58	249
21	17	69	200	45			45	261
21	18	219	635	33	48		81	303
21	19	229	664	12	286		298	460
21	20	242	702	26			26	334
21	21	115	334	4			4	181
21	22	118	342	144	124		268	569
21	23	218	632	94			94	851
21	24	142	412	10			10	205
21	25	77	223	4			4	120
21	26	41	119	3	234	2	239	173
21	27	40	116					45
22	1	42	73	370		121	491	1772
22	2	43	88	446	4	53	503	1659
22	3	390	821	381	6	76	463	1894
22	4	596	1609	291	476		767	1811
22	5	290	567	273	644	293	1210	2496
22	6	372	837	266	877		1143	2204
22	7	6	18					34
22	8	83	354	151	2	20	173	727
22	9	164	499	107		77	184	468
22	10	186	532	35		25	60	507
22	11	380	1070	186	24	120	330	1374
22	12	608	1556	111	14	35	160	1173
22	13	368	937	71		42	113	931
22	14	25	90	10	1766		1776	2167
22	15	127	347	77	22		99	503
22	16	30	92	7			7	30
22	17	41	120	14			14	92
22	18	95	305	13	33		46	230
22	19	65	189	26			26	70
22	20	356	972	37		25	62	683
22	21	656	1825	234		10	244	1573
22	22	67	184	272	1	60	333	2369
22	23	6	17	19	469		488	520
22	24	34	95	1	83		84	74
22	25	84	239	13			13	49

APPENDIX B

DATA USED IN DEVELOPMENT OF EXTERNAL-EXTERNAL MODELS

STUDY NUMBER	COMMERCIAL EMPLOYMENT	INDUSTRIAL EMPLOYMENT	PUBLIC EMPLOYMENT	TOTAL EMPLOYMENT	POPULATION	STATION NUMBER	FUNCTIONAL CLASSIFICATION	AWDT	% TRUCKS OF AWDT	% THRU TRUCKS (1)	% THRU TRIPS (1)	% THRU TRUCKS (2)	% THRU TRIPS (2) DUMMY VARIABLES FUNCTIONAL CLASSIFICATION
1	3235	949	895	5079	14713	22	1	3550	15	11	33	4	201000
1	3235	949	895	5079	14713	23	2	1668	6		7		130100
1	3235	949	895	5079	14713	24	2	4195	9	2	15	1	190100
1	3235	949	895	5079	14713	25	2	3165	11	3	20	2	230100
1	3235	949	895	5079	14713	26	1	3901	15	8	34	8	341000
1	3235	949	895	5079	14713	27	3	782	26	8	18	16	330010
1	3235	949	895	5079	14713	28	2	2479	10	4	17	5	200100
1	3235	949	895	5079	14713	29	2	1018	9		3		30100
1	3235	949	895	5079	14713	30	1	3950	8	4	20	2	161000
2	2394	2496	855	5745	12979	33	2	3098	11	10	67	5	480100
2	2394	2496	855	5745	12979	34	2	3540	12	5	34	6	380100
2	2394	2496	855	5745	12979	35	2	3253	14	4	30	6	370100
2	2394	2496	855	5745	12979	36	1	1712	5	14	9	1	141000
2	2394	2496	855	5745	12979	37	1	5249	17	7	41	7	441000
2	2394	2496	855	5745	12979	38	2	3421	12	6	38	5	360100
2	2394	2496	855	5745	12979	39	1	2695	18	5	33	7	371000
2	2394	2496	855	5745	12979	40	2	1143	9	2	16	1	150100
3	11075	3908	277	614759	50000	106	2	3431	28	10	29	10	270100
3	11075	3908	277	614759	50000	107	2	6276	19	7	35	4	290100
3	11075	3908	277	614759	50000	108	2	4619	21	5	20	6	260100
3	11075	3908	277	614759	50000	109	1	1927	24	7	20	12	341000
3	11075	3908	277	614759	50000	110	3	871	24	4	8	3	80010
3	11075	3908	277	614759	50000	111	2	593	29	1	6	2	120100
3	11075	3908	277	614759	50000	112	1	628	21	1	4	2	41000
3	11075	3908	277	614759	50000	113	4	5029	21	7	28	7	270001
3	11075	3908	277	614759	50000	114	4	989	16	1	4	2	70001
3	11075	3908	277	614759	50000	115	4	2877	20	5	25	5	250001
3	11075	3908	277	614759	50000	116	2	4923	18	5	26	6	300100
3	11075	3908	277	614759	50000	117	2	1266	21	3	11	3	80100
3	11075	3908	277	614759	50000	118	2	1658	20	3	12	3	150100
3	11075	3908	277	614759	50000	119	1	535	28	2	8	3	91000
3	11075	3908	277	614759	50000	120	2	6427	19	8	36	6	300100
4	3850	1855	1224	6929	18224	51	2	8372	18	17	67	16	640100
4	3850	1855	1224	6929	18224	52	2	5171	9	3	25	3	250100
4	3850	1855	1224	6929	18224	53	1	9051	21	16	65	18	641000
4	3850	1855	1224	6929	18224	54	2	6117	4	1	10	1	110100
4	3850	1855	1224	6929	18224	55	2	1536	9	3	17	3	150100
4	3850	1855	1224	6929	18224	56	3	424	14	3	19	6	280010
4	3850	1855	1224	6929	18224	57	2	426	3		12		120100
4	3850	1855	1224	6929	18224	58	1	3232	10	4	27	4	331000
5	1142	2089	443	3674	7898	30	2	3603	14	7	40	8	370100
5	1142	2089	443	3674	7898	32	2	3123	7	1	15	3	170100
5	1142	2089	443	3674	7898	33	3	4198	10	7	37	5	370010
5	1142	2089	443	3674	7898	35	2	1647	10	2	14	3	210100
5	1142	2089	443	3674	7898	36	2	982	9	4	33	3	270100
5	1142	2089	443	3674	7898	37	2	935	9	4	13	5	140100
6	1163	1519	308	2990	6700	22	1	6983	12	5	35	5	351000
6	1163	1519	308	2990	6700	23	2	894	5	1	16	1	180100
6	1163	1519	308	2990	6700	24	2	1979	9	4	21	4	240100
6	1163	1519	308	2990	6700	25	1	2989	8	9	53	5	431000
6	1163	1519	308	2990	6700	26	2	2768	11	5	32	6	370100
6	1163	1519	308	2990	6700	27	2	1522	7	4	26	3	310100
7	2669	828	557	4054	14031	22	1	8016	8			16	761000
7	2669	828	557	4054	14031	23	2	1068	1			1	170100
7	2669	828	557	4054	14031	24	2	1854	1			3	260100
7	2669	828	557	4054	14031	25	1	3576	5			10	531000
7	2669	828	557	4054	14031	26	2	1623	3			7	400100
7	2669	828	557	4054	14031	27	2	822	1			3	360100
7	2669	828	557	4054	14031	28	2	1271	1			2	150100
7	2669	828	557	4054	14031	29	1	10317	7			14	641000

STUDY NUMBER	COMMERCIAL EMPLOYMENT	INDUSTRIAL EMPLOYMENT	PUBLIC EMPLOYMENT	TOTAL EMPLOYMENT	POPULATION	STATION NUMBER	FUNCTIONAL CLASSIFICATION	AWDT	% TRUCKS OF AWDT	% THRU TRUCKS (1)	% THRU TRIPS (1)	% THRU TRUCKS (2)	% THRU TRIPS (2)	DUMMY VARIABLES FUNCTIONAL CLASSIFICATION
7	2669	828	557	4054	14031	30	2	4964	5			10		610100
8	8875	2990	351515380		36533	79	2	5605	12	2	11	1		100100
8	8875	2990	351515380		36533	80	1	14433	29	28	71	27		711000
8	8875	2990	351515380		36533	81	2	1165	8	1	7	2		60100
8	8875	2990	351515380		36533	82	2	2107	5		5			70100
8	8875	2990	351515380		36533	83	1	3700	7	3	13	3		131000
8	8875	2990	351515380		36533	84	1	10826	39	37	90	38		901000
8	8875	2990	351515380		36533	85	2	3701	8	1	9	1		90100
8	8875	2990	351515380		36533	86	1	4615	11	4	17	6		191000
8	8875	2990	351515380		36533	87	2	2698	10	3	18	4		180100
8	8875	2990	351515380		36533	88	2	792	7		10			150100
8	8875	2990	351515380		36533	89	2	2971	3		5			60100
9	2114	503	864	3481	6145	17	2	5635	5	1	10	1		130100
9	2114	503	864	3481	6145	18	1	3989	18	6	33	5		271000
9	2114	503	864	3481	6145	19	3	805	8		11			140010
9	2114	503	864	3481	6145	20	1	6232	13	3	17	4		181000
11	5368	3563	206010991		24965	83	1	20317	13	10	53	10		551000
11	5368	3563	206010991		24965	84	2	3955	12	7	57	8		520100
11	5368	3563	206010991		24965	85	2	2201	6	2	20	2		240100
11	5368	3563	206010991		24965	86	1	1209	12	9	67	9		751000
11	5368	3563	206010991		24965	87	2	507	13	5	11	8		190100
11	5368	3563	206010991		24965	88	1	3614	29	14	90	27		911000
11	5368	3563	206010991		24965	89	2	5699	16	14	53	11		480100
11	5368	3563	206010991		24965	90	2	2449	7	4	44	4		460100
11	5368	3563	206010991		24965	91	1	4360	16	9	53	11		501000
11	5368	3563	206010991		24965	92	2	2131	11	3	24	4		240100
12	3898	2260	1697	7855	12300	50	1	12842	8	4	31	5		341000
12	3898	2260	1697	7855	12300	51	2	1297	4	1	8	1		130100
12	3898	2260	1697	7855	12300	52	1	12981	23	26	98	23		461000
12	3898	2260	1697	7855	12300	53	2	2096	18	7	31	9		360100
12	3898	2260	1697	7855	12300	54	1	2748	19	17	81	18		921000
12	3898	2260	1697	7855	12300	55	2	845	11	1	14	1		240100
12	3898	2260	1697	7855	12300	56	3	7098	10	6	41	4		540010
12	3898	2260	1697	7855	12300	57	2	2796	13	6	29	8		320100
12	3898	2260	1697	7855	12300	58	1	11193	31	30	101	31		911000
12	3898	2260	1697	7855	12300	59	1	2700	20	17	95	19		941000
12	3898	2260	1697	7855	12300	60	2	4804	7	5	36	4		370100
12	3898	2260	1697	7855	12300	61	3	1393	5	5	33	2		160010
13	4734	1333	1603	7640	26647	85	2	3748	25	14	37	17		400100
13	4734	1333	1603	7640	26647	86	1	3300	22	26	88	18		811000
13	4734	1333	1603	7640	26647	87	2	2274	8	1	8	1		100100
13	4734	1333	1603	7640	26647	88	2	1094	5	1	4	2		70100
13	4734	1333	1603	7640	26647	89	1	3096	11	4	23	5		271000
13	4734	1333	1603	7640	26647	90	1	3797	26	23	43	23		461000
13	4734	1333	1603	7640	26647	91	1	7400	18	11	78	10		371000
13	4734	1333	1603	7640	26647	92	2	1814	7	1	5	1		50100
13	4734	1333	1603	7640	26647	93	2	1969	7		4			50100
13	4734	1333	1603	7640	26647	94	1	3500	13	6	32	7		321000
13	4734	1333	1603	7640	26647	95	2	2191	8	1	14	1		200100
13	4734	1333	1603	7640	26647	96	2	1505	9	1	11	1		140100
14	2806	3040	720	6566	16205	33	2	4996	4	1	19	1		260100
14	2806	3040	720	6566	16205	34	2	2538	4	2	30	2		310100
14	2806	3040	720	6566	16205	35	3	933	2	1	16			180010
14	2806	3040	720	6566	16205	36	2	1015	6	1	10			110100
14	2806	3040	720	6566	16205	37	3	3343	12	3	33	4		360010
14	2806	3040	720	6566	16205	38	2	883	4	2	13	2		110100
14	2806	3040	720	6566	16205	39	2	3961	6	2	27	2		270100
14	2806	3040	720	6566	16205	40	1	13710	10	9	85	8		811000
14	2806	3040	720	6566	16205	41	2	1696	8	4	33	4		320100
14	2806	3040	720	6566	16205	42	1	13196	10	9	88	9		881000

STUDY NUMBER	COMMERCIAL EMPLOYMENT	INDUSTRIAL EMPLOYMENT	PUBLIC EMPLOYMENT	TOTAL EMPLOYMENT	POPULATION	STATION NUMBER	FUNCTIONAL CLASSIFICATION	AWDT	% TRUCKS OF AWDT	% THRU TRUCKS (1)	% THRU TRIPS (1)	% THRU TRUCKS (2)	% THRU TRIPS (2)	DUMMY VARIABLES FUNCTIONAL CLASSIFICATION
14	2806	3040	720	6566	16205	43	2	1252	3	1	20	1		270100
15	3464	3083	985	7532	12755	34	1	5452	13	9	48	8		391000
15	3464	3083	985	7532	12755	35	2	2570	5	1	30	2		330100
15	3464	3083	985	7532	12755	36	2	4039	6	1	16	2		250100
15	3464	3083	985	7532	12755	37	2	2048	7	4	25	4		230100
15	3464	3083	985	7532	12755	38	2	4515	12	9	36	10		390100
15	3464	3083	985	7532	12755	39	1	7068	7	3	26	3		261000
15	3464	3083	985	7532	12755	40	1	1874	6	1	16	1		161000
15	3464	3083	985	7532	12755	41	1	2650	10	4	28	4		251000
16	1916	1274	334	3524	11430	32	1	12951	14	15	87	13		841000
16	1916	1274	334	3524	11430	33	2	1565	4	1	12	1		140100
16	1916	1274	334	3524	11430	34	1	2257	7	4	36	2		321000
16	1916	1274	334	3524	11430	35	1	10574	16	14	89	14		871000
16	1916	1274	334	3524	11430	36	2	2985	5	2	16	2		220100
16	1916	1274	334	3524	11430	37	1	5031	18	12	48	16		531000
16	1916	1274	334	3524	11430	38	2	2991	5	3	21	4		270100
17	1146	2454	369	3969	7695	22	1	7073	9			3		451000
17	1146	2454	369	3969	7695	23	2	2368	10			4		540100
17	1146	2454	369	3969	7695	24	3	976	2			0		200010
17	1146	2454	369	3969	7695	25	2	766	8			0		350100
17	1146	2454	369	3969	7695	26	2	4243	14			9		520100
17	1146	2454	369	3969	7695	27	2	3266	37			17		500100
17	1146	2454	369	3969	7695	28	2	2484	8			3		400100
18	921	231	273	1425	7464	26	1	13909	22			22		481000
18	921	231	273	1425	7464	27	2	1796	6			6		250100
18	921	231	273	1425	7464	28	2	3171	5			5		440100
18	921	231	273	1425	7464	29	1	7297	22			22		751000
18	921	231	273	1425	7464	30	2	1696	6			6		370100
18	921	231	273	1425	7464	31	2	1681	8			8		300100
18	921	231	273	1425	7464	32	3	1601	2			2		340010
20	4880	1390	3520	9791	23477	36	2	7631	6	3	40	2		310100
20	4880	1390	3520	9791	23477	37	2	1124	7	2	17	2		120100
20	4880	1390	3520	9791	23477	38	1	10608	6	2	20	2		221000
20	4880	1390	3520	9791	23477	39	1	2769	5	2	25	3		281000
20	4880	1390	3520	9791	23477	40	1	9457	5	2	28	3		321000
20	4880	1390	3520	9791	23477	41	2	9499	6	3	35	2		380100
20	4880	1390	3520	9791	23477	42	2	2276	6	3	31	2		250100
21	1477	1616	813	3906	9210	28	1	3117	6			1		271000
21	1477	1616	813	3906	9210	29	2	1304	3			1		260100
21	1477	1616	813	3906	9210	30	2	2548	4			2		280100
21	1477	1616	813	3906	9210	31	1	9694	5			1		191000
21	1477	1616	813	3906	9210	32	2	719	15			11		100100
21	1477	1616	813	3906	9210	33	2	359	6			2		100100
21	1477	1616	813	3906	9210	34	2	5041	8			2		270100
21	1477	1616	813	3906	9210	35	2	2412	5			1		130100
22	3411	4421	975	8789	13436	26	1	5732	10	6	40	6		351000
22	3411	4421	975	8789	13436	27	1	1820	21	15	66	14		641000
22	3411	4421	975	8789	13436	28	1	6976	7	2	17	3		221000
22	3411	4421	975	8789	13436	29	2	1086	4	1	7	1		120100
22	3411	4421	975	8789	13436	30	1	3928	6	4	39	2		341000
22	3411	4421	975	8789	13436	31	1	1402	5	1	15	1		161000
22	3411	4421	975	8789	13436	32	2	3232	6	2	13	1		130100
22	3411	4421	975	8789	13436	33	2	738	5		7			110100
22	3411	4421	975	8789	13436	34	2	4322	11	8	33	8		300100
22	3411	4421	975	8789	13436	35	1	1542	20	16	80	17		811000
22	3411	4421	975	8789	13436	36	2	2580	7	4	28	4		270100
22	3411	4421	975	8789	13436	37	1	3556	8	5	35	5		401000

APPENDIX C

DEFINITIONS AND EQUATIONS REPRESENTING STATISTICAL MEASURES

DEFINITIONS AND EQUATIONS REPRESENTING STATISTICAL MEASURES

1. Squared Correlation Coefficient -- r^2

   A measure of the amount of total variance in the dependent variable explained by the independent variable in the equation over that which could be explained by the mean of the dependent variable alone.

   $$r^2 = \sum_1^n (Y_p - Y)^2 / \sum_1^n (Y_a - Y)^2$$

   where Y_a = actual values representing the dependent variables,
   Y_p = predicted values using models,
   Y^p = mean of actual values, and
   n = number of observations.

2. Standard Error of Estimate -- SE

   The standard error of estimate is a measure of the dispersion of the observed data points about the regression line. If the difference between the actual value and the predicted value follows a normal distribution, approximately two-thrids of the sample values will be within one standard error of estimate of the regression line.

   $$\text{Standard Error of Estimate (SE)} = \sqrt{\sum_1^n (Y_a - Y_p)^2 / [n - (P + 1)]}$$

   where P = number of parameters which have to be estimated,
   Y_a = actual values representating the dependent variable,
   Y_p = predicted values using models, and
   n^p = number of observations.

3. Coefficient of Variation -- CV

   The coefficient of variation is a statistic used to indicate the relative magnitude of the standard error of estimate.

   CV = (Standard Error of Estimate / Mean of Dependent Variable) x 100

4. Root-Mean-Square Error

   A measure of the accuracy of prediction when comparing actual and predicted values. The root-mean-square error is related to a confidence interval or probability level such that two-thirds of the time the predicted values will deviate from the observed values by an amount no greater than the root-mean-square error.

   $$\text{Root-Mean-Square Error} = \sqrt{\sum_1^n (Y_a - Y_p)^2 / n}$$

   where Y_a = actual values representating the dependent variable,
   Y_p = predicted values using models, and
   n^p = number of observations.