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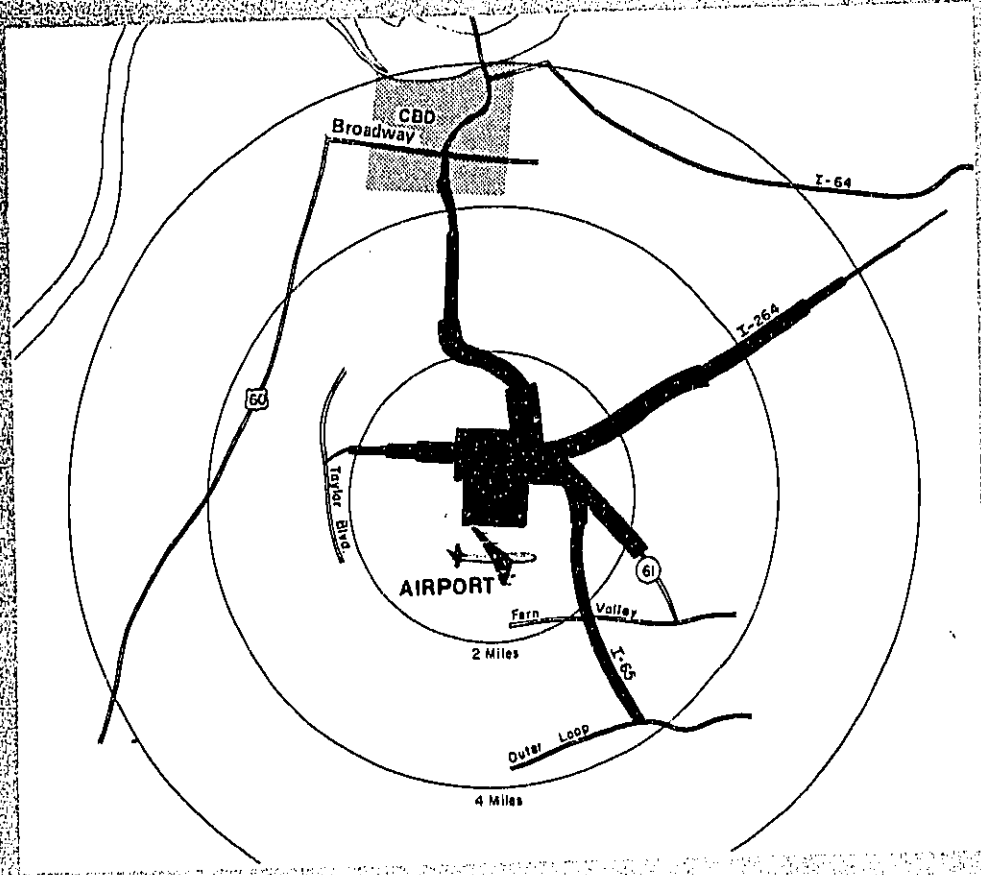
AIRPORT ACCESS STUDY

IMPACT OF AIRPORT-ORIENTED VEHICLE TRIPS ON HIGHWAY FACILITIES



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U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
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REPORT IN BRIEF

This study was initiated by the Federal Highway Administration's Urban Planning Division for the primary purpose of developing a method to assess the impact of airport-oriented vehicular trips on highway facilities. This was accomplished using existing urban transportation study data files and computer programs available from the Federal Highway Administration.

The data used in this study were obtained from four selected urbanized areas. The areas selected were: Birmingham, Alabama - Boston, Massachusetts - Louisville, Kentucky and Minneapolis-St. Paul, Minnesota. From each selected area, two standard transportation planning files were obtained; that is,

1. A "link-data" file describing the characteristics of the highway network (link distance, speed, volume, capacity, etc.)
2. A "trip-record" file describing the characteristics of all trips made within the study area (trip origin, destination, mode, etc.)

The procedure employed to generate the data presented in this report was as follows for each selected area -

The "link-data" file was used to build a computerized model of the highway network. The resulting "network description" was then used as input to an existing computer program to build minimum time paths from each node in the network to every other node. These minimum time paths or "trees" were then "skimmed" to obtain the traveltime between each pair of traffic analysis zones. The "trip record" file was processed to produce a matrix of zone-to-zone vehicle volumes. The resulting "trip table" was further processed to produce a summary of total vehicle trip-ends by traffic analysis zone.

The total vehicle trip table was used in conjunction with the network and tree files to "load" total vehicle trips onto the highway network. The resulting "loaded network" was further processed to produce average daily, directional link volume and vehicle-mile information relative to total vehicle trips made within the study area. In addition, the total vechicle trip table and the skimmed tree files were used to generate a total vehicle trip length frequency distribution.
The total vehicle, network and tree files were again used to load the highway network; however, this time only vehicle trips having an origin at the airport zone (this is the zone in which the airport was located) were loaded onto the highway network. The resulting loaded network was again further processed to produce average - daily directional link volume and vehicle trips having an origin at the airport. The term airport will refer to the zone in which the airport is located for the remainder of this report. Also, trip length frequency distribution information for vehicle trips having an origin at the airport was generated.
The data generated as a result of the above process were then analyzed and subsequently summarized by five major categories for presentation.

The five categories chosen were TRIP, VEHICLE-MILE, TRIP LENGTH, LINK and GEOGRAPHIC ORIENTATION. More detail relative to each of the above categories follows.

TRIP - data are presented in this report comparing total vehicle trips to airport - oriented vehicle trips. Prior to making these comparisons, vehicle trips having an origin at the airport were doubled to account

for vehicle trips having a destination at the airport. The values presented in the trip category thus reflect a comparison of total and airport - oriented (to and from) vehicle trips.

VEHICLE-MILE - As for the trip information, the vehicle-mile information generated as a result of loading trips from the airport was doubled to account for vehicle-miles of travel to the airport.

TRIP LENGTH - the trip length information presented herein represents a comparison of a total vehicle trip length distribution (areawide) to a trip length distribution reflecting vehicles having an origin at the airport. The assumption underlying this comparison is that the trip length distribution of vehicles having a destination at the airport mirrors those having an origin at the airport and does not therefore affect the relationship.

LINK - the two loaded networks (total vehicle and vehicles having an origin at the airport) were compared, link-by-link, on a directional basis. All links carrying one percent or more vehicles having an origin at the airport were posted on a highway network map. Twenty concentric one-mile rings having the airport as their centerpoint were drawn and pertinent information was extracted and tabulated by mileage ring. Other information was tabulated by volume group.

It is important that the reader understand that these data do not reflect vehicle trips to the airport.

GEOGRAPHIC ORIENTATION - the illustrations included herein showing the dispersion of airport trips reflect trips both to and from the airport. In other words, trips from the airport were doubled prior to construction of the illustrations.

A great deal of information relative to the characteristics of airport - oriented vehicle trips was produced as a result of this study. Much of these data are tabulated and presented in the results and appendix sections of this report. The highlights of these data are presented in the following summary titled - Characteristics of Airport - Oriented Vehicular Travel.

CHARACTERISTICS OF AIRPORT-ORIENTED
VEHICULAR TRAVEL

ITEM	STUDY AREA			
	Birmingham Alabama	Boston Massachusetts	Louisville Kentucky	Minn.-St. Paul Minnesota
A. General Information				
1. Study Year (year of data)	1965	1963	1964	1958
2. Population within study area	587,000	3,540,550	751,888	1,376,865
3. Square miles " " "	500	2300	485	890
4. Number of traffic zones	410	728	744	536
B. Airport Information				
1. Airport studied	Birmingham Municipal	Logan International	Standiford Field	Wold Chamberlain
2. Airport Classification 1/	Medium-Hub	Large-Hub	Medium-Hub	Large-Hub
3. Enplanements (1965)	342,000	2,805,000	654,000	1,606,000
4. Projected Enplanements (1980)	1,418,000	14,832,000	3,382,000	8,530,000
C. Trip Information				
1. Total Vehicle Trips	1,229,640	5,483,965	1,005,188	2,406,770
2. Vehicle Trips to Airport	6,806	20,838	6,110	15,466
3. Percent Airport(2/1x100)	0.56	0.38	0.61	0.64
D. Vehicle-Mile Information				
1. Total Vehicle-miles	5,908,883	30,814,746	5,718,720	4,881,407
2. Airport Vehicle-miles	47,942	277,198	48,352	30,954
3. Percent Airport (2/1x100)	0.81	0.90	0.85	0.63

CHARACTERISTICS OF AIRPORT-ORIENTED
VEHICULAR TRAVEL (continued)

ITEM	STUDY AREA			
	Birmingham Alabama	Boston Massachusetts	Louisville Kentucky	Minn.-St. Paul Minnesota
E. Average Trip Length (min.)				
1. Total Vehicles	12.3	11.7	11.3	14.0
2. Vehicle Trips from Airport	16.2	27.8	13.4	23.8
3. Average Trip Length Ratio (2/1)	1.3	2.4	1.2	1.7
F. Link Information				
1. Total number of links in network	4,525	10,004	6,426	7,755
2. Maximum link volume observed in (Vehicles from airport)	1730	7476	2153	7579
3. 15th highest link volume observed (Vehicles from airport)	469	2714	648	1883
4. Distance from airport (miles) - 15th highest link	3.50	3.00	4.30	1.45
5. Number of links carrying one-percent or more vehicles from airport	178	497	224	587
6. Percent of total links carrying one percent or more vehicles from airport	3.9	5.0	3.5	7.6
7. Number of links where % vehicles from airport 1.0 and vol. from airport 100	96	309	65	287
8. Number of links where % vehicles from airport 1.0 and vol. from airport 250	54	203	39	115

1/ Communities which generated one-percent or more of the Nation's scheduled air carrier domestic enplaned passengers during the twelve months ending June 30, 1967 are classified by FAA as large-hub. Communities which generated 0.25 to 0.99 percent are classified as medium-hub.

Several conclusions can be drawn from the work accomplished in this study. The first and perhaps most important is that data files and computer programs common to every urban transportation study can be used to generate information to measure (in gross terms) the impact of airport-oriented vehicular travel on highway facilities.

Another conclusion which seems quite obvious from the data presented herein is that airport-oriented travel is insignificant when evaluated on an average-daily, regional basis. This conclusion is based upon the fact that airport-oriented travel accounts for only 0.55 percent of total vehicle trips and 0.80 percent of total vehicle-miles of travel (average of four study areas).

Yet another conclusion that can be reached is that airport-oriented travel does not perform as other type trips from a trip length frequency distribution standpoint (a skewed distribution with one major peak at the low end of the curve) but rather displays many peaks throughout its entire range. Since this multiple peaking has the effect of increasing the average trip length (Total/Air = 1.4 on the average), large increases in airport travel will increase vehicle-miles of travel at a faster rate than other types of travel.

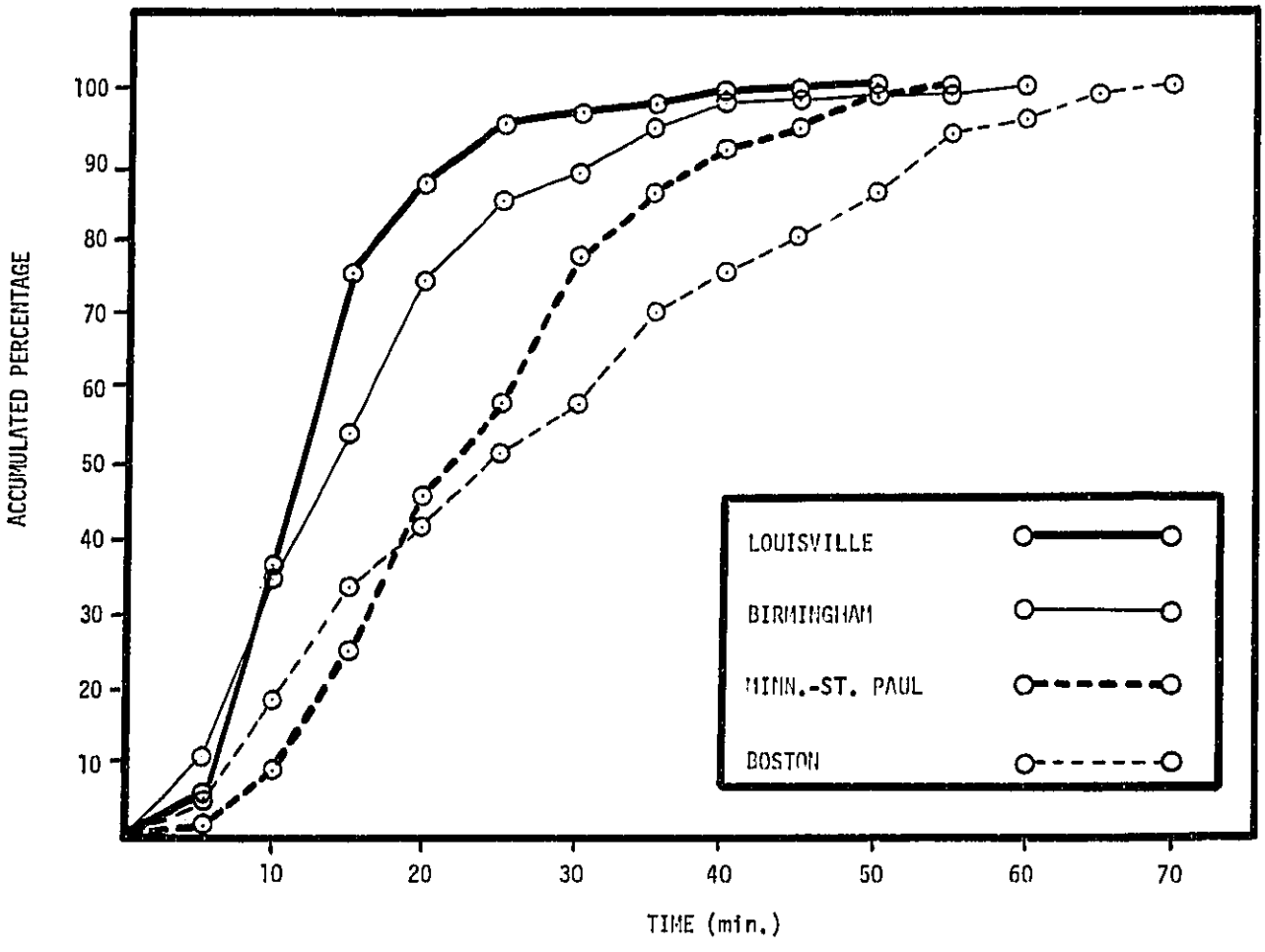
In reference to the average trip length, it can be concluded that the average airport trip is about 20 minutes long (average of four areas = 20.3); however, the number of trips made within 20 minutes varies considerably by study area. In Louisville, 88 percent of all trips to and from the airport are less than or equal to 20 minutes whereas in Boston only 41 percent of

all airport trips are less than or equal to 20 minutes. These accumulated percentages are displayed by five minute interval on the following page.

It can also be concluded that about 5.0 percent of the highway links in an urban area carry one percent or more vehicles from the airport; however, only about 1.3 percent of these links carry what is considered to be a significant number of vehicles (250 or more) and, these links are generally in close proximity to the airport. This is based on the fact that the average distance from the airport for the 15th highest link observed in the four areas was only 3.06 miles.

ACCUMULATED PERCENTAGE AIRPORT TRIPS

BY FIVE MINUTE TIME INTERVAL



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INTRODUCTION

The air transportation industry has experienced tremendous growth during recent years and, all recognized indicators point to a continued strong growth during the current decade. As an example, consider the Port Columbus Airport in Columbus, Ohio (A medium-hub airport). Projections call for an increase in commercial air passenger traffic of 100 percent by 1975, of 240 percent by 1980 and up to 520 percent by 1985. Other projections call for large increases in industrial development adjacent to the airport and in non-airport oriented urban travel utilizing airport access facilities.

The projected growth cited above for a typical airport warrants the attention of all regional transportation planners since growth of this magnitude will greatly increase demand for airport access and terminal facilities - particularly for highway and parking facilities. This last statement is based on the fact that the great majority of present airport trips are made by auto (87 percent in Columbus) and that a substantial change in travel mode seems unlikely since the trip origins of airport oriented travel are widely dispersed. For example, only eight percent of all Port Columbus Airport trips originate in the Columbus Regional Center.

During recent years, regional transportation planners have begun to pay increasing attention to the airport complex. There are several reasons for this among which are: 1) the growth experienced at the airport and the expansion programs under way in many areas to accommodate this growth 2) the fact that many areas have only recently reached the point in the

overall planning process to allow for special generator studies, and 3) the establishment of Departments of Transportation at both the Federal and State levels allowing for even greater analysis of the interaction between all modes of transportation.

With this increased attention has come the realization that airport access planning is a complicated problem requiring sophisticated analysis procedures. In some instances, conventional urban planning tools and existing data may not be adequate to perform the type of analysis required. In such cases, new techniques and additional data may be required; however, it appears that a great deal of information can be generated and analysis performed utilizing existing data files and established planning techniques.

PURPOSE OF STUDY

The study documented in this report had three main purposes; i.e.,

1. To develop a method of measuring the impact of average-daily, airport-oriented vehicular traffic on highway facilities using only readily available data files common to every comprehensive urban transportation study.

2. To demonstrate the feasibility of the approach developed by applying it to four urbanized areas.

3. To document the results obtained to show the area-wide impact of average-daily, airport-oriented vehicular traffic on highway facilities in the selected areas.

SCOPE OF STUDY

The Urban Planning Division recognizes that this study is somewhat limited in scope. The Division was cognizant of these limitations at the time the study was conceived but felt then as now that the scope was adequate for the purpose intended. Included in recognized limitations are:

1. The study considers only highway access facilities. It is recognized that public transit can play an important role in providing access to airports and must be considered in any comprehensive airport access study. Parking facilities at the airport should also be considered. This study should therefore be recognized as one undertaken to establish planning procedures that can be easily modified and expanded to accommodate all forms of transportation serving the airport complex.
2. The scope of this work is limited to an analysis of total, average-daily, vehicular traffic. It does not consider the peaking characteristics of trips to and from airports. It does consider the aggregate of vehicular trips for all (i.e., purposes, passengers, workers, sightseers, etc.)
3. The scope of this study is limited to the use of existing computer programs and available data from four urbanized areas ranging in population from 587,000 to 3.5 million. The data used span the years 1958 to 1965 and, consequently, are not extremely current.

DATA USED IN STUDY

The data used in this study was obtained from four urbanized areas quite diverse both in terms of socio-economic characteristics and geographic location. Selected statistics for the four areas are listed in Table 1.

TABLE 1

SUMMARY OF STUDY AREA CHARACTERISTICS

Selected Statistics	Birmingham Alabama	Boston Massachusetts	Louisville Kentucky	Minn.-St. Paul Minnesota
Study Year	1965	1963	1964	1958
Population (Study Area)	587,000	3,540,550	751,888	1,376,865
Study Area (Sq. Mile)	500	2300	485	890
No. of Traffic Zones	410	728	744	536
Airport Studied	Birmingham Municipal	Logan International	Standiford Field	Wold Chamberlain
Airport Classification	Medium-Hub	Large-Hub	Medium-Hub	Large-Hub
Daily Enplanements (1965)	342,000	2,805,000	654,000	1,606,000
Projected Enplanements (1980)	1,418,000	14,832,000	3,382,000	8,539,000

From each of the four selected areas, two planning files were obtained; i.e.:

1. A set of link-data records describing the highway network existing at the time of the base-year survey.

2. A set of trip records describing the characteristics of all trips made within the study area.

All subsequent information presented in this report was developed from these files.

METHOD OF APPROACH

Each of the four urbanized areas previously mentioned were contacted and requested to submit highway network and trip record data suitable for computer processing. Although there were slight variations in the form of the data supplied, all basically consisted of a set of highway network link-data records and a set of trip records.

Upon receipt of these data, the link-data records were processed through several available computer programs in the Urban Planning Battery to produce a highway network description, a set of minimum time paths and a matrix of zone-to-zone travel times.

In addition, the trip record file was used in conjunction with the trip table builder computer program to produce a total vehicle, average-daily, non-directional trip table. This table was subsequently "split" to produce a directional trip table.

Other processing was undertaken to produce a summary of trip-ends by analysis zone and to develop trip length frequency distribution summaries for all trips and for only those trips having their origin at the airport. The former data were produced by merely processing the trip matrix file and the latter through processing of the zone-to-zone trip and time matricies.

The network, minimum path and trip files were next used as input to an assignment program to generate reports of vehicle volumes by highway link or, loaded network reports. This process was repeated twice, i.e., once for all trips and once for only those trips emanating from the airport. The two loaded networks generated as a result of the assignment operation were then used as input to a slightly modified comparison program to produce a link-by-

link comparison of vehicle volumes (total versus trips from the airport) and the percentage of total volume on each link that has an origin at the airport.

Each link carrying one percent or more vehicles having an origin at the airport was then manually posted on a highway map of the area. Twenty concentric one-mile rings were drawn using the airport as the center point and pertinent information was extracted. These data and all other data generated were then consolidated for analysis, tabulation and graphic display. A generalized flow chart of the entire process is shown in Figure 1.

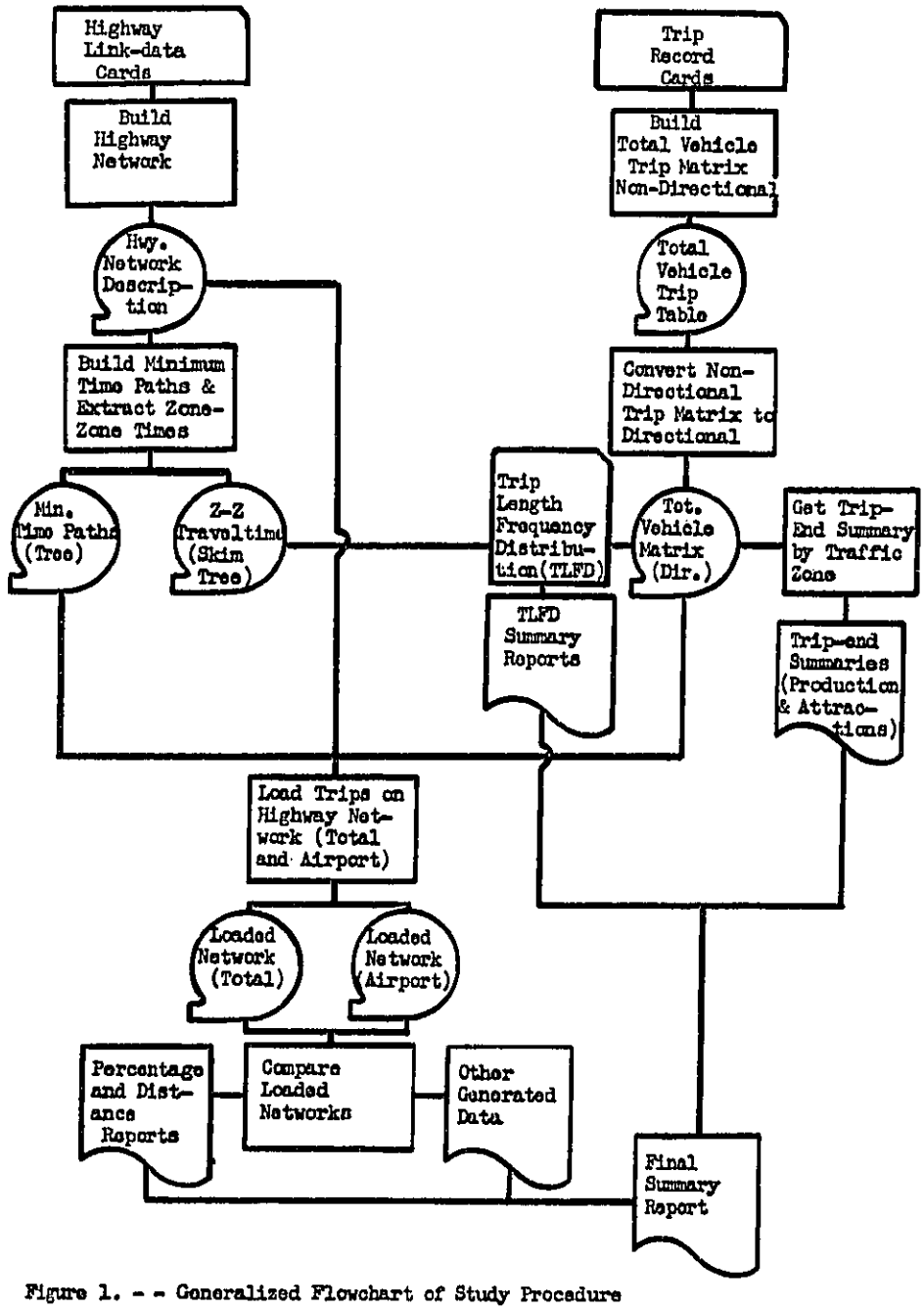


Figure 1. - - Generalized Flowchart of Study Procedure

RESULTS

The processing of the two data files used in this study (trips and network) yielded a great deal of information on the characteristics of airport-oriented travel. This information was classified as one of five types; i.e., TRIP, VEHICLE-MILE, TRIP LENGTH, LINK AND GEOGRAPHIC ORIENTATION. The results obtained are summarized below by study area and information type. In reviewing these data, several items should be kept in mind.

The figures cited under the categories of TRIP and VEHICLE - MILES information reflect trips to and from the airport.

The trip length information reflects a comparison of total vehicle trips and vehicle trips having an origin at the airport.

The LINK ANALYSIS information represents a comparison of directional volumes. The information is presented in this manner since it was derived from a comparison of total vehicle link volumes and link volumes obtained by loading trips emanating from the airport (a directional volume).

The GEOGRAPHIC ORIENTATION sketches should be used to obtain an overall view of the dispersement of airport-oriented travel. Although every effort was made to sketch the airport-oriented volumes as precisely as possible, this was at times difficult due to the procrdure involved (printout to link map to road map to sketch map.) The volumes indicated by the flow bands represent trips to and from the airport.

BIRMINGHAM, ALABAMA

TRIP INFORMATION -- The trip data used in the Birmingham analysis were collected in a 1965 Origin-Destination Survey of the Region. These data show that 1,229,640 vehicle trips were made within the study area on an average day. Of this total, 3,403 vehicles have a trip origin at the airport. Doubling this figure to account for vehicles having a destination at the airport indicates that 0.56 percent of total vehicle trips are airport-oriented.

VEHICLE-MILES -- The results of the assignment phase produced information on vehicle-miles of travel in the Birmingham study area. The assignment showed a total of 5,908,833 vehicle-miles of travel taking place within the area. Airport-oriented travel accounted for 47,942 or 0.81 percent of the total. A summary of total and airport vehicle-miles by freeway and other highway facilities (local, collector, arterial, etc.) is shown in Table 2.

TABLE 2

TOTAL AND AIRPORT VEHICLE-MILES
BY FACILITY TYPE

BIRMINGHAM, ALABAMA

FACILITY TYPE	VEHICLE-MILES TOTAL	AIRPORT
Freeway	———	———
Other	5,908,883	47,942
TOTAL	5,908,883	47,942

TRIP LENGTH -- The trip length frequency distributions for both total and airport trips were developed by one-minute intervals and are displayed in Figure 2.[1/] As can be seen, there is significant difference in the two distributions. Total trips peak at four minutes and decrease from that point to zero at about 78 minutes. Airport trips, on the other hand, show multiple peaks throughout their 69 minute range.

The average trip length was also found to be quite different for the two trip types; i.e., 12.3 minutes for total trips and 16.2 minutes for airport trips. The average trip length ratio (airport/total) was found to be 1.3.

Detailed investigation of the trip length frequency distribution summary showed that 74 percent of all Birmingham Airport trips are completed in 20 minutes or less. An accumulated percentage of airport trips by five minute interval is shown in Table 3.

TABLE 3

ACCUMULATED PERCENTAGE OF AIRPORT TRIPS BY FIVE MINUTE INTERVAL

(BIRMINGHAM, ALABAMA)

Time Interval (Min.)	Accumulated Percentage Airport Trips
0-5	11
0-10	35
0-15	54
0-20	74
0-25	85
0-30	89
0-35	95
0-40	98
0-45	98
0-50	98
0-55	99
0-60	99
0-65	100

1/ Although the airport trip length frequency distribution was developed using only trips having an origin at the airport, it is viewed as representative of total airport trips in all subsequent discussion.

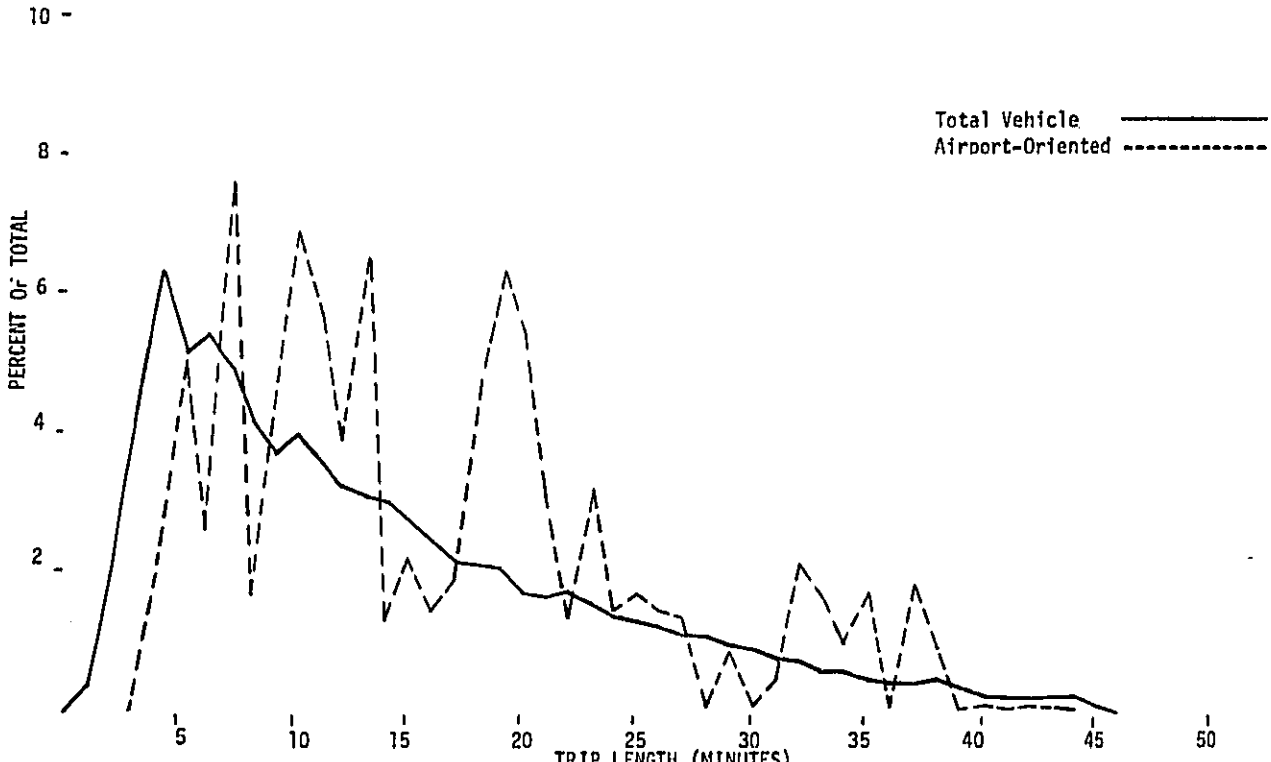


Figure 2. -- Trip Length Frequency Distributions (Total and Airport)
BIRMINGHAM, ALABAMA

LINK ANALYSIS - - A link-by-link comparison of assigned airport to assigned total trips indicates that 178 links carry at least one percent airport traffic.[2/] These 178 links are summarized by distance from the airport and by volume group in Tables A-1 and A-2 located in the appendix.

Inspection of Table A-1 shows that the greatest number of links carrying one percent or more airport traffic are located between four and five miles from the airport. Furthermore, 84 percent of all links carrying at least one percent airport traffic are within 6 miles of the airport.

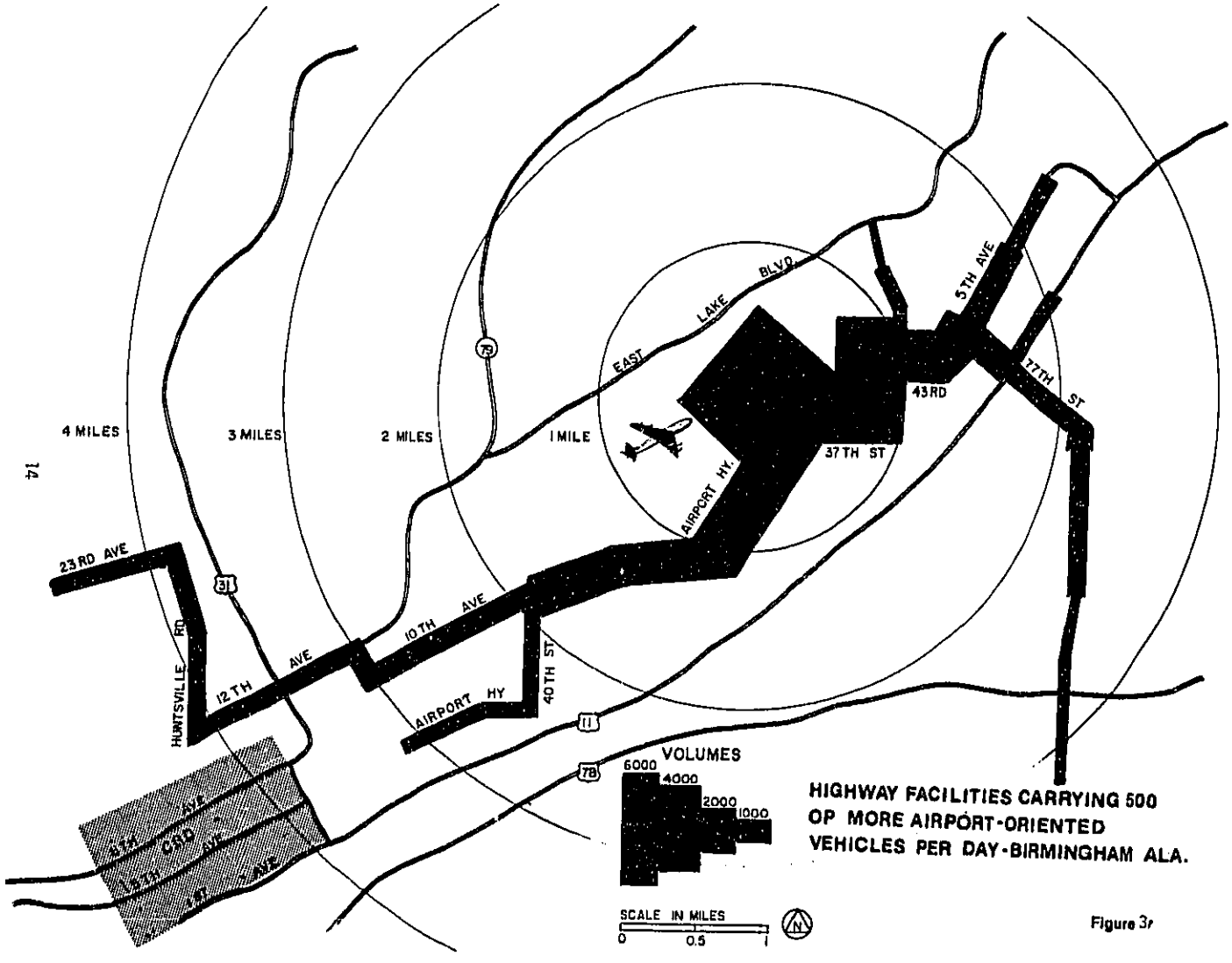
Table A-2 shows that the great majority of the 178 links carrying at least one percent airport traffic are concentrated in low volume, low airport percentage cells. Additional analysis showed that only 96 of the 178 links carry at least 100 airport trips and that only 54 carry at least 250 airport trips. A summary of the top fifteen airport access links in the entire study area is shown in Table A-3. This table shows the Airport Link Volume, Total Link Volume, Percent Airport and Distance From Airport for each link.

GEOGRAPHIC ORIENTATION

To develop some insight into the degree of dispersement of airport-oriented vehicular traffic, all links carrying 500 or more airport-oriented vehicles (non-directional) were plotted. A sketch of the results is shown in Figure 3.

As can be seen, the traffic is quite dispersed with major movements to the Northeast and South as well as to the Southwest towards the Central Business District.

2/ In all subsequent "link analysis" discussion, it is to be understood that airport traffic is synonomous with vehicle trips having an origin at the airport.



HIGHWAY FACILITIES CARRYING 500 OR MORE AIRPORT-ORIENTED VEHICLES PER DAY-BIRMINGHAM ALA.

Figure 3

BOSTON, MASSACHUSETTS

TRIP INFORMATION - - The Boston, Massachusetts data were collected in 1963. These data indicate that 5,483,965 vehicle trips were made within the region on an average day in 1963. Airport-oriented trips were found to account for 20,838 or 0.38 percent of this total vehicle trip universe.

VEHICLE-MILES - - As in other large urban areas, a tremendous number of vehicle-miles are generated each day within the Boston region. Results of the traffic assignment showed that 30,814,746 vehicle-miles of travel occurred within the Boston study area on an average day in 1963. Airport-oriented travel accounted for 277,198 or 0.90 percent of this total. A summary of vehicle-miles by facility type is shown below in Table 4.

TABLE 4

TOTAL AND AIRPORT VEHICLE-MILES
BY FACILITY TYPE

BOSTON, MASSACHUSETTS

FACILITY TYPE	VEHICLE-MILES	
	TOTAL	AIRPORT
Freeway	11,339,276	153,238
Other	19,475,470	123,960
TOTAL	30,814,746	277,198

TRIP LENGTH - - A plot of the total vehicle and airport trip length frequency distributions is shown in Figure 4. The average trip lengths were found to be 11.7 minutes for total trips and 27.8 minutes for airport trips for a trip length ratio of 2.4 (27.8/11.7). This ratio was found to the highest of the four areas studied.

Inspection of the Boston trip length frequency plots shows a pattern similar to Birmingham; i.e., the total trip plot contains one major peak at the low end of the distribution while the airport plot contains several major peaks at 10, 12, 32 and 54 minutes.

As indicated by the average airport trip length (27.8 minutes), people in Boston spend more time getting to and from the airport than do people in any of the other three areas investigated. This is apparent from the summary of accumulated percentage of airport trips by time interval shown below. It will be remembered that 74 percent of all airport trips in Birmingham were made in 20 minutes or less.

TABLE 5

ACCUMULATED PERCENTAGE OF AIRPORT TRIPS
BY FIVE MINUTE INTERVAL

(Boston, Massachusetts)

Time Interval (Min.)	Accumulated Percentage Airport Trips
0-5	5
0-10	19
0-15	33
0-20	41
0-25	51
0-30	58
0-35	70
0-40	76
0-45	80
0-50	86
0-55	93
0-60	95
0-65	99
0-70	100

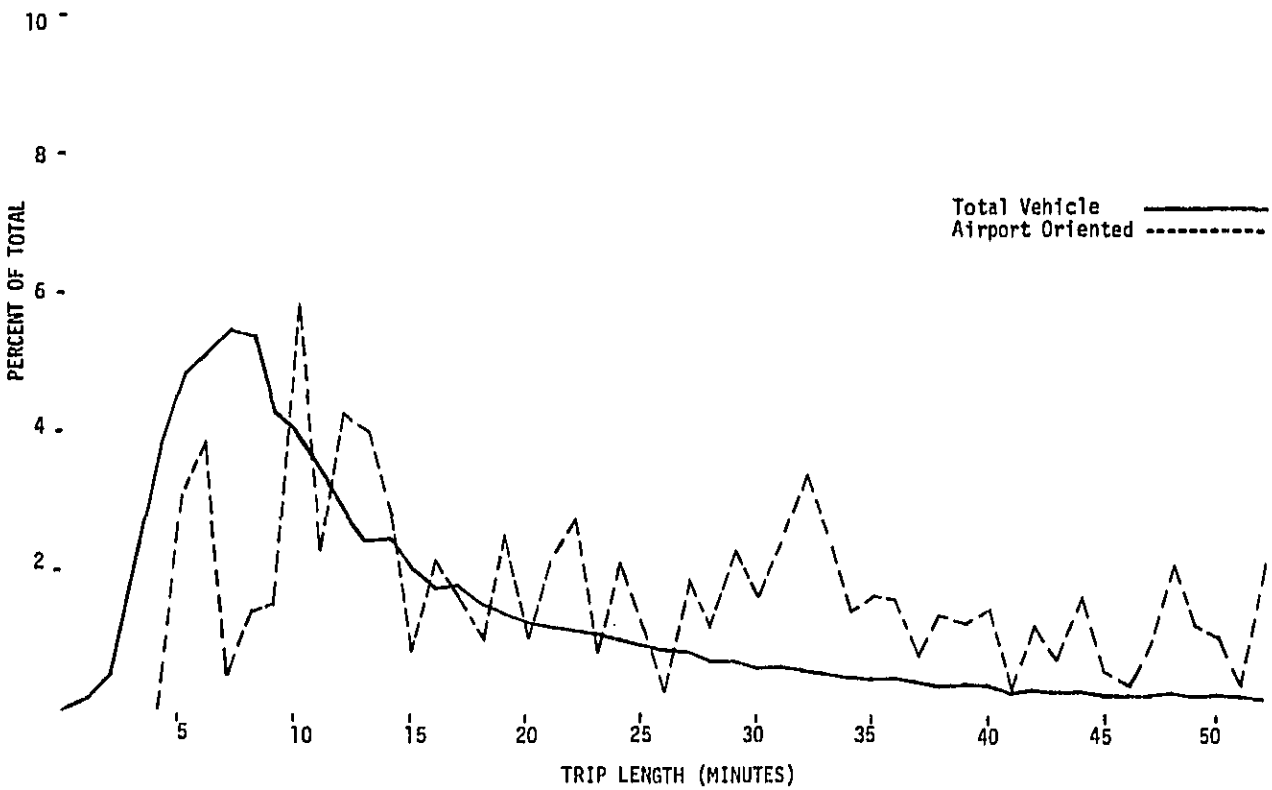


Figure 4. - - Trip Length Frequency Distribution (Total and Airport)
BOSTON, MASSACHUSETTS

LINK ANALYSIS - - A comparison of total and airport volumes on a link-by-link basis showed that 497 links carry at least one percent airport traffic. This represents about five percent of the total number of links in the network. The distribution of these links by distance from the airport and volume group is shown in Tables A-4 and A-5.

Inspection of Table A-4 shows that 296 of the total 497 links (about 60 percent) carrying one percent or more airport traffic are within 10 miles of the airport. Furthermore, about 35 percent of these links are within 5 miles of the airport.

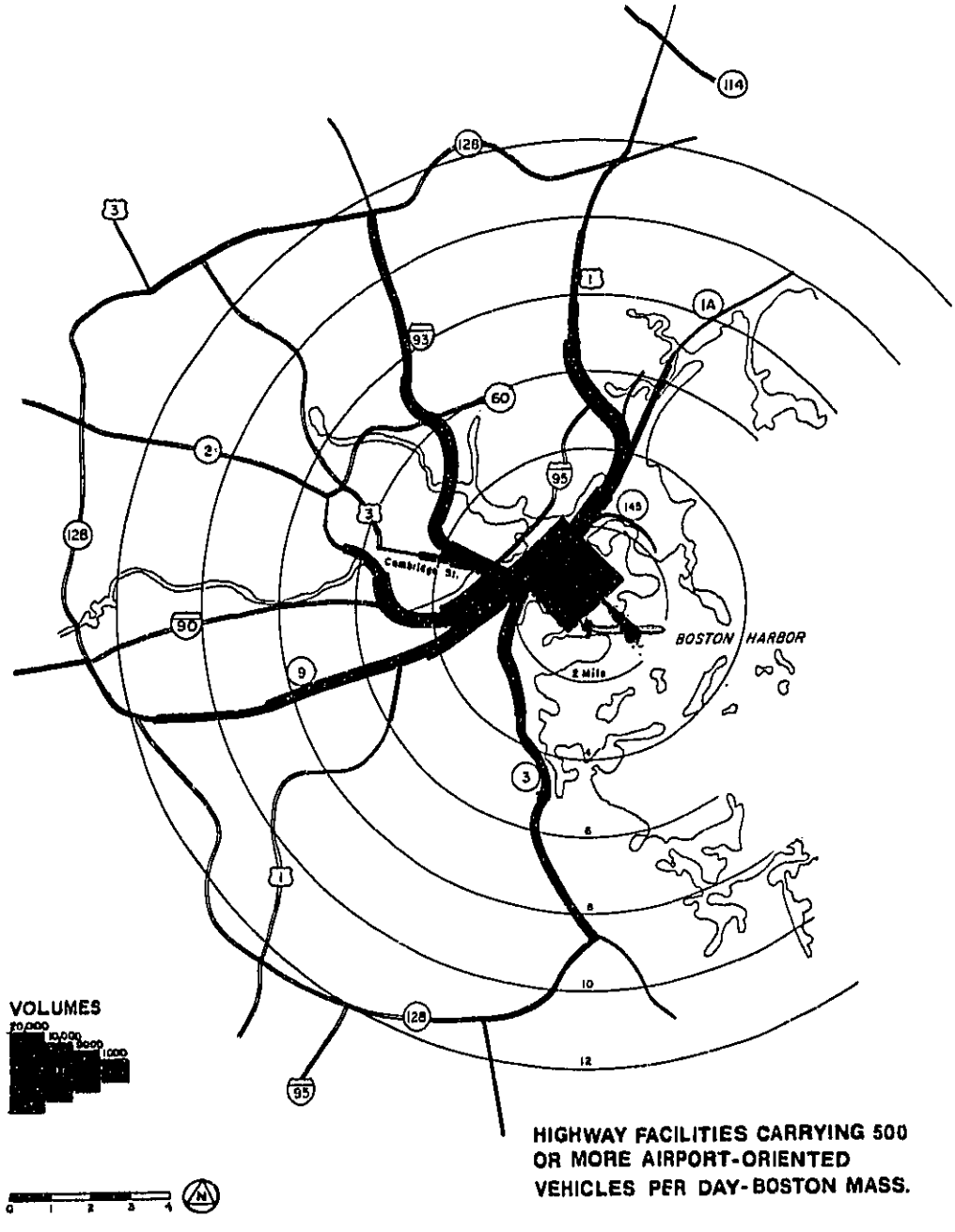
Table A-5 shows that most of the links carrying one percent or more airport traffic are concentrated in low percentage cells. Only 52 of the links (about 10 percent) carry five percent or more airport traffic.

Additional analysis of these data showed that many of the links carrying one percent or more airport traffic were in very low volume groups. This is illustrated by the fact that only 309 of the 497 links carry 100 or more airport trips and only 203 carry 250 or more airport trips.

As for Birmingham, those fifteen links carrying the greatest number of airport trips have been tabulated and are displayed in Table A-6. It will be noted that the airport volume on the fifteenth highest link in Boston is 2,714. This volume is about 1,000 vehicles greater than the highest airport link volume observed in Birmingham (1,730).

GEOGRAPHIC ORIENTATION

Figure 5 shows the orientation and magnitude of vehicle trips to and from Logan International Airport. As can be seen, these trips are widely



HIGHWAY FACILITIES CARRYING 500 OR MORE AIRPORT-ORIENTED VEHICLES PER DAY-BOSTON MASS.

Figure 5

dispersed. Significant volumes can be observed to the North almost to the New Hampshire Line, to the South as far as Brockton and to the West to Route 128.

It will be noted from inspection of volume band widths that of the nearly 11,000 vehicles approaching the Boston CBD, a significant number are destined to other parts of the area.

LOUISVILLE, KENTUCKY

TRIP INFORMATION - - The data used in the Louisville, Kentucky analysis were collected in 1964. These data show that 1,005,188 total vehicle and 6110 airport-oriented trips are made each day in the Louisville region. In other words, 0.61 percent of all vehicle trips are airport-oriented.

VEHICLE-MILES - - Total vehicle-miles generated each day within the Louisville region were found to be 5,718,720. Airport-oriented vehicle-miles were found to be 48,352 or 0.85 percent of the total vehicle-mile universe. A summary of total and airport vehicle-miles by facility type is shown below in Table 6.

TABLE 6

TOTAL AND AIRPORT VEHICLE-MILES
BY FACILITY TYPE

(LOUISVILLE, KENTUCKY)

FACILITY TYPE	VEHICLE-MILES	
	TOTAL	AIRPORT
Freeway	1,693,713	29,540
Other	4,025,007	18,812
TOTAL	5,718,720	48,352

TRIP LENGTH - - The average total vehicle trip length in Louisville was found to be 11.3 minutes. The average airport-oriented vehicle trip length was found to be 13.4 minutes yielding a trip length ratio of 1.2 (13.8/11.3). This trip length ratio was found to be the smallest of the four computed in this study.

Figure 6 shows the trip length frequency distributions for both total and airport-oriented trips. Of particular interest here is the tremendous peaking that occurs between seven and fourteen minutes. Included within this time interval are 64 percent of all airport-oriented trips. In other words, 64 percent of all vehicles entering or leaving the Louisville Airport travel no more than 14 minutes.

Of the four areas studied, the best airport access in terms of minutes traveled is provided by Louisville. As shown below, 88 percent of all trips to and from the airport are performed in 20 minutes or less.

TABLE 7

ACCUMULATED PERCENTAGE OF AIRPORT TRIPS BY FIVE MINUTE INTERVAL

(LOUISVILLE, KENTUCKY)

Time Interval (Min.)	Accumulated Percentage Airport Trips
0-5	6
0-10	37
0-15	76
0-20	88
0-25	95
0-30	96
0-35	97
0-40	99
0-45	99
0-50	100

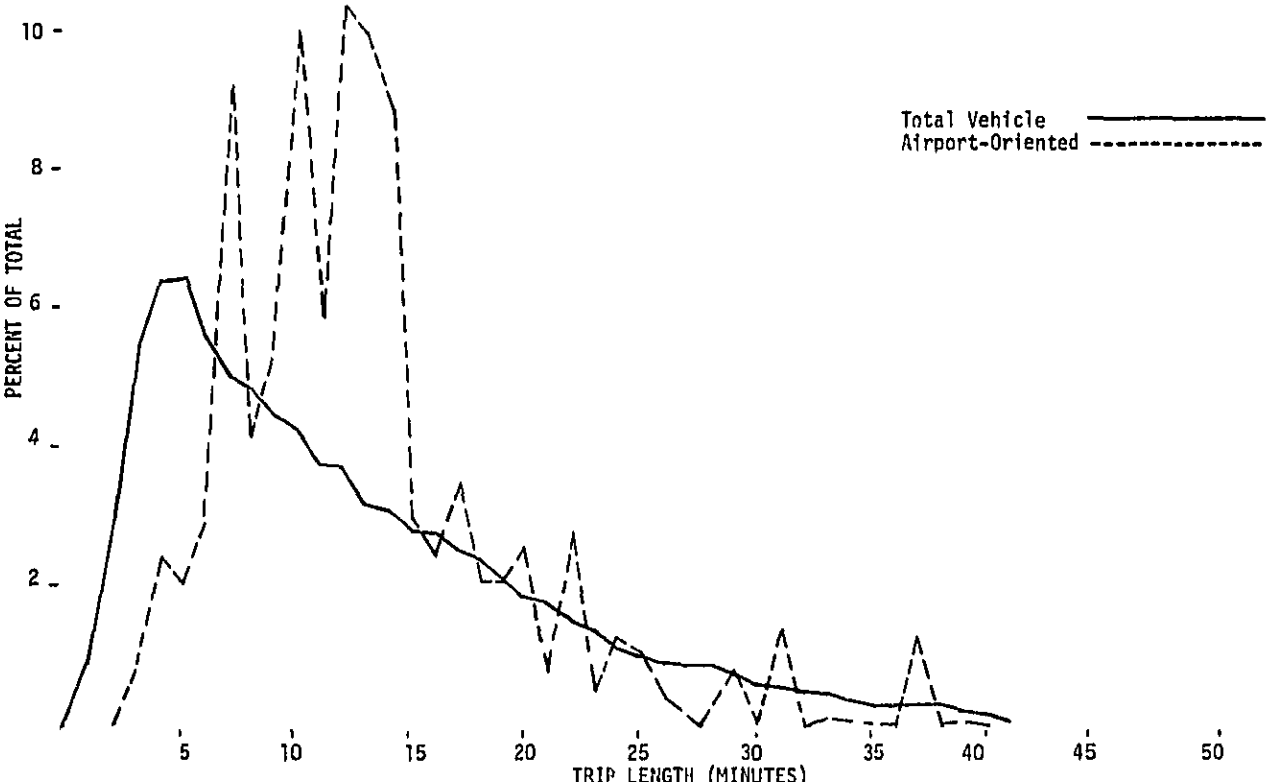


Figure 6 -- Trip Length Frequency Distributions (Total and Airport)
LOUISVILLE, KENTUCKY

LINK ANALYSIS - - The link-by-link comparison showed that there were 224 links in the Louisville network that carried one percent or more airport-oriented traffic. This represents about 3.5 percent of the total links in the network. The distribution of these links by distance from the airport and volume group is shown in Tables A-7 and A-8.

Reference to Table A-7 shows that there are only two links further than 9.99 miles from the airport that carry more than three percent airport traffic.

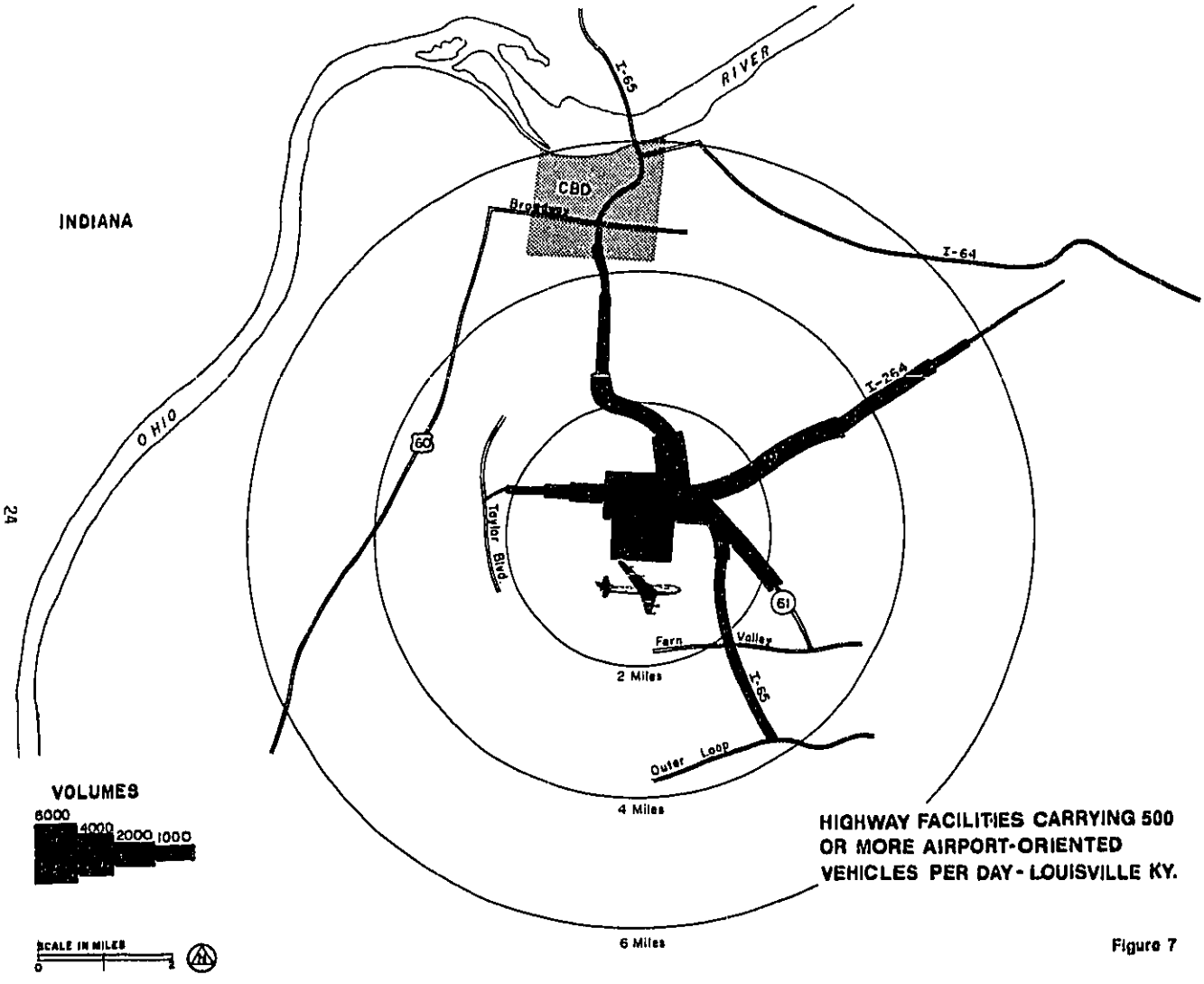
Table A-8 shows that the great majority of all 224 links previously mentioned are concentrated in low percentage cells; i.e., about 90 percent of all links carry less than three percent airport traffic. Furthermore, most of these links contain an insignificant number of airport-oriented vehicles. For example, only 65 links have an airport volume of 100 vehicles or more and only 39 have an airport volume of 250 vehicles or more.

Table A-9 summarizes the top 15 airport links in the Louisville region. As in Birmingham, the highest ranking of these 15 links carries less traffic than the fifteenth highest link in Boston.

GEOGRAPHIC ORIENTATION

Figure 7 shows those highway facilities in Louisville, Kentucky that carried 500 or more airport-oriented vehicles in 1963. As can be seen, the trips disperse to the North, South, East and West.

It will be noted that very few of the facilities lie outside of the two-mile ring. It will also be noted that the vehicular volume at the two-mile ring on I-264 East is of about the same magnitude as that observed at



HIGHWAY FACILITIES CARRYING 500 OR MORE AIRPORT-ORIENTED VEHICLES PER DAY - LOUISVILLE KY.

Figure 7

the two-mile ring on I-65 North. This latter movement could be classified as CBD oriented.

MINNEAPOLIS - ST. PAUL, MINNESOTA

TRIP INFORMATION - - The trip information for Minneapolis - St. Paul was collected in 1958 and is the least current of the four sets used in this study. These data show that on the average day in 1958, there were 2,406,770 vehicle trips made in the Minneapolis - St. Paul region. Of these total trips, 15,466 or 0.64 had either an origin or destination at the airport.

VEHICLE-MILES - - The results of an assignment of total vehicle trips showed a total of 4,881,407 vehicle-miles of travel in the region. The results of an assignment of airport-oriented trips showed a total of 30,954 vehicle-miles of travel indicating that the airport generates 0.63 percent of all vehicle-miles of travel logged in the region. These vehicle-miles could not be summarized by facility type as for the other three areas because of the network coding procedure employed.

TRIP LENGTH - - The total vehicle average trip length was found to be 14.0 minutes. The airport-oriented average trip length was found to be 23.8 minutes for an average trip length ratio of 1.7.

Plots of the total and airport-oriented trip length frequency distributions are shown in Figure 8. Inspection of these plots shows a pattern similar to the other three areas investigated; i.e., a standard total vehicle distribution and a multi-peaked airport-oriented distribution.

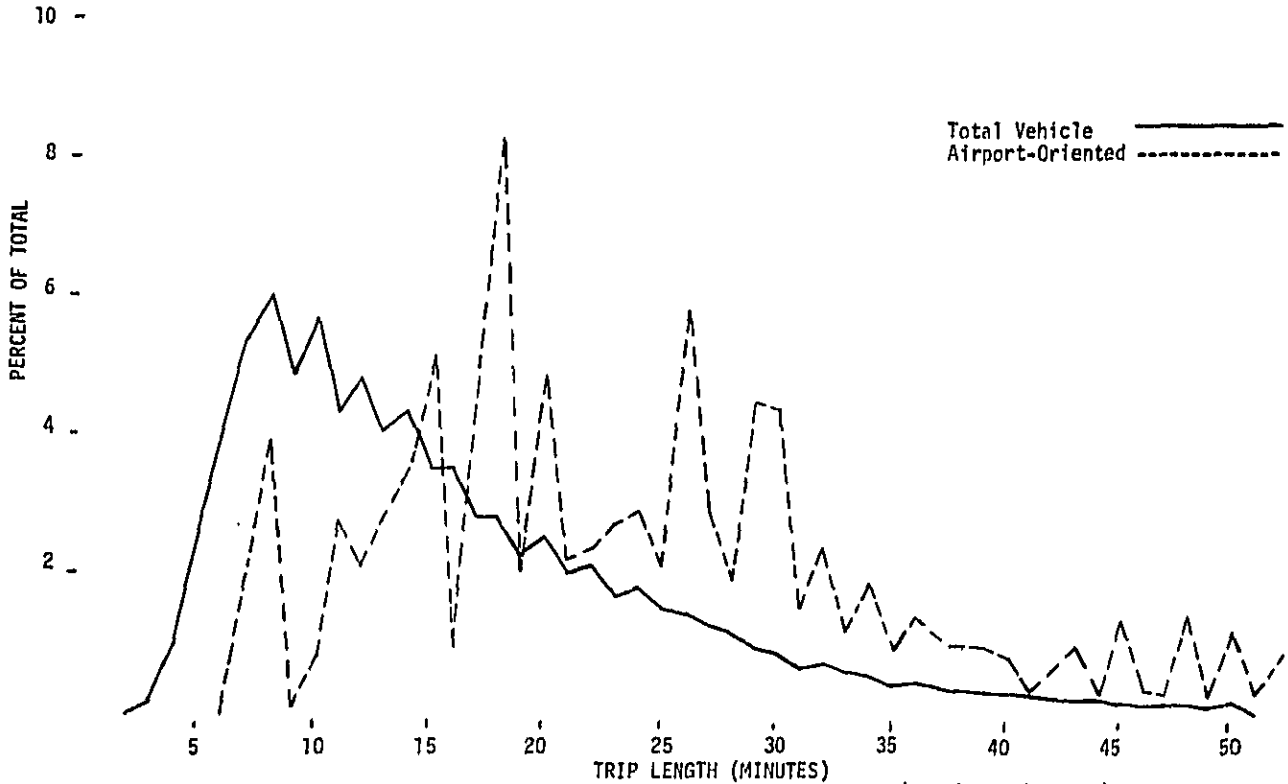


Figure 8. - - Trip Length Frequency Distributions (Total and Airport)
MINNEAPOLIS-ST. PAUL, MINNESOTA

As for the three preceding study areas, an accumulated percentage of airport trips by five minute interval has been tabulated and is shown below in Table 8.

TABLE 8

ACCUMULATED PERCENTAGE OF AIRPORT TRIPS BY FIVE MINUTE INTERVAL

(MINNEAPOLIS - ST. PAUL, MINNESOTA)

Time Interval (Min.)	Accumulated Percentage Airport Trips
0-5	2
0-10	9
0-15	25
0-20	46
0-25	58
0-30	78
0-35	86
0-40	91
0-45	94
0-50	98
0-55	100

LINK ANALYSIS - - A link-by-link comparison of airport and total traffic showed there were 587 links in the Minneapolis - St. Paul region carrying one percent or more airport trips. This represents 7.6 percent of the total number of links in the network (9992) and is the largest number of links found in the four areas investigated.

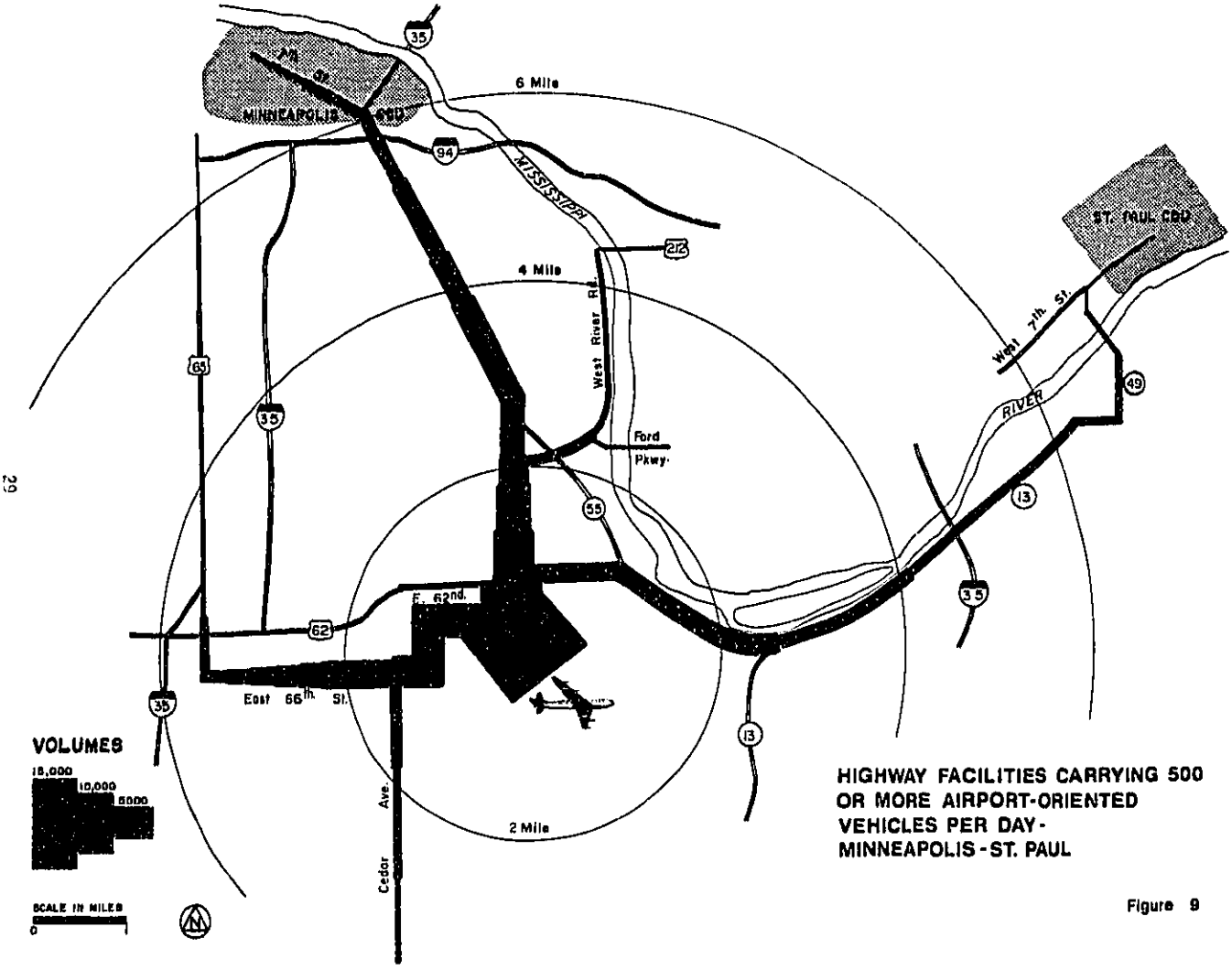
Tables A-10 and A-11 show the distribution of the 587 links by distance from the airport and volume group. It will be noted that 199 (34 percent) of the 587 links carry between 1.00 and 1.99 percent airport traffic. Table A-12 shows that 486 or 83 percent of the 587 links carrying one percent or more airport traffic lie within five miles of the airport.

Additional analysis of these data showed that of the 587 links carrying one percent or more airport traffic only 287 carried an airport volume of 100 or more airport vehicles. Furthermore, only 115 links carried by a volume of 250 or more airport vehicles.

Table A-12 summarizes pertinent data for those fifteen links carrying the greatest number of airport vehicles in the Minneapolis - St. Paul region. Of interest here are the very high percentages obtained for these links.

GEOGRAPHIC ORIENTATION

As for the three preceding areas, a sketch showing those highway facilities carrying 50 or more airport - oriented vehicle trips per day was constructed. Reference to the sketch (Figure 9) shows, as for the other areas investigated, a dispersion of trips with major movements to the North, South, East and West. The influence of the Central Business District of Minneapolis and St. Paul is evident.



HIGHWAY FACILITIES CARRYING 500 OR MORE AIRPORT-ORIENTED VEHICLES PER DAY - MINNEAPOLIS - ST. PAUL

Figure 9

APPENDIX

TABLE A-1

NUMBER OF LINKS BY DISTANCE FROM AIRPORT AND PERCENT AIRPORT TRAFFIC

(BIRMINGHAM, ALABAMA)

DISTANCE FROM AIRPORT (MILES)	PERCENT AIRPORT TRAFFIC							
	1.00-1.99	2.00-2.99	3.00-3.99	4.00-4.99	5.00-9.99	10.00-14.99	15.00+	Total
0-0.99	0	2	1	1	2	0	3	9
1.00-1.99	6	2	2	4	6	4	0	24
2.00-2.99	14	5	2	1	2	2	0	26
3.00-3.99	10	6	2	2	0	0	1	21
4.00-4.99	30	8	2	0	1	0	1	42
5.00-5.99	14	8	3	0	2	0	0	27
6.00-6.99	8	0	0	0	1	0	0	9
7.00-7.99	4	1	0	0	1	0	0	6
8.00-8.99	2	0	2	0	0	0	0	4
9.00-9.99	3	0	0	0	0	0	0	3
10.00 +	7	0	0	0	0	0	0	7
TOTAL	98	32	14	8	15	6	5	178

TABLE A-2

NUMBER OF LINKS BY VOLUME GROUP AND PERCENT AIRPORT TRAFFIC

(BIRMINGHAM, ALABAMA)

VOLUME GROUP	PERCENT AIRPORT TRAFFIC							
	1.00-1.99	2.00-2.99	3.00-3.99	4.00-4.99	5.00-9.00	10.00-14.99	15.00+	Total
0-999	5	7	2	0	3	0	2	19
1000-1999	10	7	1	2	0	0	0	20
2000-2999	11	3	0	0	0	0	0	14
3000-3999	13	5	0	0	1	2	0	21
4000-4999	4	0	0	0	1	1	0	6
5000-9999	18	1	8	6	3	1	3	40
10000-14999	17	5	1	0	3	2	0	28
15000 +	20	4	2	0	4	0	0	30
TOTAL	98	32	14	8	15	6	5	178

TABLE A-3

FIFTEEN LINKS CARRYING GREATEST NUMBER OF AIRPORT TRIPS

(BIRMINGHAM, ALABAMA)

RANK	AIRPORT VOLUME	TOTAL VOLUME	PERCENT AIRPORT	DISTANCE FROM AIRPORT (MILES)
1	1730	9614	17.99	0.90
2	1531	9332	16.40	0.20
3	1469	9343	15.72	0.40
4	1465	10658	13.74	0.60
5	1446	10495	13.89	1.00
6	1346	14007	9.60	1.20
7	1279	14418	8.87	1.40
8	1209	15931	7.58	1.60
9	1209	15447	7.82	1.30
10	1209	15931	7.58	1.70
11	1138	17784	6.39	2.30
12	684	11004	6.21	1.60
13	595	5805	10.24	2.00
14	490	4264	11.49	2.90
15	490	15047	3.11	3.50

TABLE A-4

NUMBER OF LINKS BY DISTANCE FROM AIRPORT AND PERCENT AIRPORT TRAFFIC

(BOSTON, MASSACHUSETTS)

DISTANCE FROM AIRPORT (MILES)	PERCENT AIRPORT TRAFFIC							
	1.00-1.99	2.00-2.99	3.00-3.99	4.00-4.99	5.00-5.99	10.00-14.99	15.00 +	TOTAL
0- .99	0	0	0	0	3	3	4	10
1.00-1.99	11	4	7	5	12	5	8	52
2.00-2.99	16	17	5	1	4	4	1	48
3.00-3.99	12	8	9	2	4	4	1	40
4.00-4.99	12	6	5	11	2	1	0	37
5.00-5.99	9	11	0	1	2	0	0	23
6.00-6.99	13	4	3	2	0	0	0	22
7.00-7.99	15	0	3	2	0	0	0	28
8.00-8.99	15	6	4	0	0	0	0	25
9.00-9.99	6	3	2	0	0	0	0	11
10.00 +	152	32	14	2	0	0	1	201
TOTAL	261	99	52	26	27	17	15	497

TABLE A-5

NUMBER OF LINKS BY VOLUME GROUP AND PERCENT AIRPORT TRAFFIC

(BOSTON, MASSACHUSETTS)

VOLUME GROUP	PERCENT AIRPORT TRAFFIC							
	1.00-1.99	2.00-2.99	3.00-3.99	4.00-4.99	5.00-9.99	10.00-14.99	15.00 +	Total
0-999	14	4	3	2	1	0	2	26
1000-1999	27	21	12	4	2	0	0	66
2000-2999	27	1	2	1	1	0	0	32
3000-3999	23	4	2	2	1	0	0	32
4000-4999	14	3	2	0	0	1	0	20
5000-9999	53	15	8	3	8	7	6	100
10000-14999	25	4	3	3	4	4	1	44
15000 +	78	47	20	11	10	5	6	177
TOTAL	261	99	52	26	27	17	15	497

TABLE A-6

FIFTEEN LINKS CARRYING GREATEST NUMBER OF AIRPORT TRIPS

(BOSTON, MASSACHUSETTS)

RANK	AIRPORT VOLUME	TOTAL VOLUME	PERCENT AIRPORT	DISTANCE FROM AIRPORT (MILES)
1	7476	28441	26.28	0.30
2	5470	34542	15.83	1.50
3	5470	28960	18.88	1.10
4	5470	28960	18.88	1.50
5	5470	28960	18.88	1.50
6	5470	28960	18.88	0.70
7	2873	14406	19.74	1.60
8	2873	42166	6.81	1.80
9	2873	42279	6.79	1.70
10	2714	46412	5.84	2.60
11	2743	48414	5.66	2.50
12	2743	30432	9.01	2.30
13	2743	38865	7.05	2.10
14	2743	25000	10.97	1.90
15	2714	54888	4.94	3.00

TABLE A-7

NUMBER OF LINKS BY DISTANCE FROM AIRPORT AND PERCENT AIRPORT TRAFFIC

(LOUISVILLE, KENTUCKY)

DISTANCE FROM AIRPORT (MILES)	PERCENT AIRPORT TRAFFIC							
	1.00-1.99	2.00-2.99	3.00-3.99	4.00-4.99	5.00-9.99	10.00-14.99	15.00 +	TOTAL
0-0.99	7	3	1	0	2	0	0	14
1.00-1.99	16	5	0	0	0	0	0	21
2.00-2.99	10	4	2	0	0	0	0	16
3.00-3.99	31	3	0	0	0	0	0	34
4.00-4.99	36	10	0	0	0	0	0	46
5.00-5.99	25	5	1	1	0	0	0	32
6.00-6.99	6	4	3	0	0	0	0	13
7.00-7.99	6	2	0	1	3	0	0	11
8.00-8.99	3	0	0	0	1	0	0	4
9.00-9.99	8	0	1	0	0	0	0	9
10.00 +	17	5	1	1	0	0	0	24
TOTAL	165	41	9	3	6	0	0	224

TABLE A-8

NUMBER OF LINKS BY VOLUME GROUP AND PERCENT AIRPORT TRAFFIC

(LOUISVILLE, KENTUCKY)

VOLUME GROUP	PERCENT AIRPORT TRAFFIC							
	1.00-1.99	2.00-2.99	3.00-3.99	4.00-4.99	5.00-9.99	10.00-14.99	15.00 +	TOTAL
0-999	19	4	4	2	2	0	0	31
1000-1999	25	12	3	1	2	0	0	43
2000-2999	18	4	0	0	0	0	0	22
3000-3999	14	3	0	0	0	0	0	17
4000-4999	20	0	0	0	0	0	0	20
5000-9999	32	5	0	0	0	0	0	37
10000-14999	14	1	0	0	0	0	0	15
15000 +	23	12	2	0	2	0	0	39
TOTAL	165	41	9	3	6	0	0	224

TABLE A-9

FIFTEEN LINKS CARRYING GREATEST NUMBER OF AIRPORT TRIPS

(Louisville, KENTUCKY)

RANK	AIRPORT VOLUME	TOTAL VOLUME	PERCENT AIRPORT	DISTANCE FROM AIRPORT (MILES)
1	2153	24103	8.93	0.40
2	1709	27718	6.27	0.40
3	860	28792	2.98	2.20
4	860	28792	2.98	2.60
5	860	27868	3.08	2.85
6	849	30910	2.74	0.60
7	831	29518	2.81	1.10
8	831	29831	2.78	1.70
9	830	24441	3.39	0.70
10	808	38404	2.10	3.50
11	808	40599	1.99	3.60
12	808	40599	1.99	3.75
13	768	39566	1.94	2.00
14	698	33260	2.09	4.30
15	648	23816	2.72	1.50

TABLE A-10

NUMBER OF LINKS BY DISTANCE FROM AIRPORT AND PERCENT AIRPORT TRAFFIC

(MINNEAPOLIS - ST. PAUL, MINNESOTA)

DISTANCE FROM AIRPORT (MILES)	PERCENT AIRPORT TRAFFIC							
	1.00-1.99	2.00-2.99	3.00-3.99	4.00-4.99	5.00-9.99	10.00-14.99	15.00 +	TOTAL
0-0.99	4	3	0	3	10	6	12	38
1.00-1.99	23	14	17	15	28	15	11	123
2.00-2.99	35	15	18	17	41	7	4	137
3.00-3.99	50	13	11	11	27	2	1	115
4.00-4.99	44	5	17	6	1	0	0	73
5.00-5.99	11	5	2	4	5	0	0	27
6.00-6.99	7	3	2	0	1	0	0	13
7.00-7.99	6	4	0	3	4	0	0	17
8.00-8.99	6	6	0	0	4	0	0	16
9.00-9.99	12	5	0	0	4	0	0	21
10.00 +	1	3	1	2	0	0	0	7
TOTAL	199	76	68	61	125	30	28	587

TABLE A-11

NUMBER OF LINKS BY VOLUME GROUP AND PERCENT AIRPORT TRAFFIC

(MINNEAPOLIS - ST. PAUL, MINNESOTA)

VOLUME GROUP	PERCENT AIRPORT TRAFFIC							
	1.00-1.99	2.00-2.99	3.00-3.99	4.00-4.99	5.00-9.99	10.00-14.99	15.00 +	TOTAL
0-999	10	15	7	7	15	3	6	63
1000-1999	38	10	7	5	27	6	3	96
2000-2999	26	5	10	8	22	6	0	77
3000-3999	27	10	5	5	14	5	3	69
4000-4999	18	10	5	5	14	0	3	55
5000-9999	40	21	13	18	23	6	8	129
10000-14999	29	5	14	5	7	3	5	68
15000 +	11	0	7	8	3	1	0	30
TOTAL	199	76	68	61	125	30	28	587

TABLE A-12

FIFTEEN LINKS CARRYING GREATEST NUMBER OF AIRPORT TRIPS

(MINNEAPOLIS - ST. PAUL, MINNESOTA)

RANK	AIRPORT VOLUME	TOTAL VOLUME	PERCENT AIRPORT	DISTANCE FROM AIRPORT (MILES)
1	7579	7579	100.00	0.10
2	5049	6514	77.50	0.35
3	3341	4704	71.82	0.45
4	3200	7005	45.68	0.75
5	2908	8119	35.81	0.95
6	2530	3254	63.98	0.75
7	2530	3325	76.09	0.35
8	2519	3898	64.67	0.95
9	2078	5853	35.50	1.05
10	1983	4959	39.98	1.25
11	1983	12269	16.16	1.30
12	1983	12173	16.29	1.45
13	1974	12495	15.79	1.60
14	1914	4806	39.82	1.05
15	1883	6336	29.71	1.40

59840