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STATEWIDE MULTI-MODAL TRANSPORTATION MODELING:

AN EVALUATION OF THE STANFORD RESEARCH INSTITUTE'S

INTERCITY DEMAND/MODAL SPLIT MODEL

By

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INTRODUCTION

The purpose of this research is to examine on a preliminary basis the performance of the Stanford Research Institute's Intercity Passenger Demand/Modal Split Model[1] prepared for the Michigan Department of Transportation in 1971 for use in Statewide multi-modal planning. At the onset of this research minimal investigation and testing of the model had been performed at the agency. The model will be tested for its prediction performance of common carrier modes by comparing generated results from the model with three separate sources of actual modal origin-destination data.

Section 1 of this paper discusses the need and evolution of statewide multi-modal planning and its application toward use as a policy tool. Attention is given to the contribution of the Northeast Corridor Research Project in upgrading the state-of-the-art in intercity transportation modeling.

Section 2 gives a detailed explanation and analysis of the Stanford Research Institute Model.

The statewide transportation modeling system used for this research and for planning purposes at the Michigan Department of Transportation is discussed in Section 3.

Section 4 has four main parts. In Part One is background information on modeling procedures used in analysis of each modal component of the SRl Model. Parts Two, Three, and Four analyze the results of tests performed on the model for rail, bus, and air modes, respectively.

A summary of the results of this research and conclusions are given in Section 5. The remainder of the chapter gives attention to future research needs in statewide intercity modeling.

I. THE EVOLUTION OF STATEWIDE MULTI-MODAL MODELING

The role of transportation as a major infrastructure component has evolved into a highly complex and delicate one. This observation reflects both the variety of policy instruments transportation involves (i.e., the existence of various modes) and the myriad of consequences transportation contributes to society. There is a growing need for statewide multi-modal planning. In broad terms statewide planning implies a concern for large facilities serving long-distance movement. Regional and urban planning is concerned with shorter distance movements and with the specific placement of terminals or route locations of roadways. The pressures for statewide transportation planning derive from the fact that a lack of a comprehensive and coordinated approach to transportation imposes real costs upon society. Statewide planning can be seen as a process to aid in investment decision-making. In a comprehensive fashion it should define transportation needs, clarify problems and issues and give assistance in predicting the impacts of alternative policies. In order to successfully use statewide multi-modal planning, it is important to have an idea of the range of conditions which the modal systems may have to serve. This point reflects the concern that there is significant uncertainty regarding the future and thus, there are a series of different public actions, which, if taken, would result in different impacts upon such variables as the socio-economic and natural environment. Statewide

modeling is a tool to test the effects of alternative policies. For example, what would be the effect if a state were to decide to promote vast fiscal and institutional support for mass transit and limit its support for highway development? Or, what changes in travel habits would occur given different levels of fuel supply cutbacks? In order to answer questions such as these, a statewide modeling approach is necessary and the data for this research must be comprehensive in nature, inclusive of all modes and must be statewide in scope.

The current practice of statewide planning is an outgrowth of highway planning at the urban level. Though statewide planning has been discussed over the last decade in professional circles, little attention has really been directed toward significantly upgrading the state-of-the-art.[2] In general, transportation planning has devoted much of its resources towards researching urban and regional concerns. The current status of statewide planning has been aptly reflected by the noted scholar, Peter Stopher, Director of the Transportation Center at Northwestern University:

> With the exception of work done in the 1960s for the Northeast Corridor (by Quandt and Baumol, and McLynn and Watkins) there has been very little work done in attempting to develop sophisticated procedures for travel forecasting between cities.[3]

Current efforts at statewide planning are the by-product of highway studies conducted in the last 40 years. It is useful to consider statewide planning in a continuum, as part of the historical evolution of planning. Phillip Hazen, in his unpublished thesis, <u>A Comparative Analysis of Statewide Transportation Studies</u>, delineates three distinct periods of transportation planning: 1916-1935, 1936-1955 and 1955-1975.[4] He sees the fourth period, 1975-1995, as an evolution of the previous three where emphasis turns to multi-modal planning and the need for coordination of the various modes at the state level.

1916-1935: The Federal-aid Road Act of 1916 first provided federal funds for building highways. The Federal-aid Highway Act of 1921 provided for the selection of the federal-aid road system connecting all important population centers.

1936-1955: This second period was marked by the concept of providing a better constructed highway built to handle the increasing volumes of automobile and truck traffic and to provide a secondary level of highways serving places of lesser importance. The Hayden-Cartwright Act of 1934 authorized expenditures, not to exceed one and one half percent of federal funds to each state for making surveys, plans and engineering investigations of projects for future construction. From this legislation there evolved a rather institutionalized series of highway planning surveys which provided information such as traffic volumes, vehicle speeds, truck weights and origin and destination information. Planning techniques in this period rarely considered analysis of interdependencies among various highway links, but rather emphasized planning to relieve the most pressing of currently observed problems. In most cases this involved investment in urban-oriented roads.

1956-1975: The third period has been characterized as the "interstate system era." With the Federal-aid Highway Act of 1956, this country engaged in massive investment in interstate highway development. In total, 41,000 miles of interstate highways were scheduled to be built. A key development in this period was the extensive utilization of origin-destination surveys of existing travel patterns. As travel patterns became more dispersed, emphasis turned from an almost complete urban orientation to a more balanced approach in consideration of rural or intercity travel. With this type of information, techniques which evaluate a state highway network as a system of interdependent links became implementable.

1975-1995: With the completion of the interstate system in the early 1980s, a new period in planning will evolve. In the past ten years or more growing emphasis has been placed on the importance of non-highway passenger modal planning. Most states have now created Transportation Departments from their previous Highway Departments. Added responsibilities have been assumed in planning for rail, bus and aviation needs. It becomes increasingly important that efficient investment decisions are made as budget constraints and energy supply limitations place additional problems on state agencies. Statewide planning's role, in testing alternative policies, is increasingly important.[5]

The stimulus for research in intercity multi-modal modeling came from the Northeast Corridor Project. Most recent research is, in fact, based on work performed during this study. In 1965 the High Speed Ground Transportation Act was passed and some $148 million was appropriated over the following six years for research in multi-modal planning. The first major demonstration project of the Act was the Northeast Corridor Project which encompassed the population corridor stretching between Boston and Washington, D.C. The project was generated by a sense that the modes providing for corridor movement in the Northeast were overcrowded, unable to expand their capacities adequately and subject to decision-making that was not sufficiently centralized to yield solutions. It was felt by some that the greatest lack of balance and coordination of investment strategy was found in urban areas and regions in the Northeast. In order to overcome these perceived imbalances, the approach of the project was to start with some desired level of transportation service, consider ways to provide it most effectively by whatever mode, and then simulate the play of demand against resource availability to reach the most effective system as a whole. Explicit from the beginning was the idea that the project would pose alternative transportation system patterns for the corridor from among which decision makers could choose. Nine widely different alternatives were developed. Different mixes of short-haul air and high speed ground modes in combination with conventional means of passenger transport were produced. The need for simulation of various alternatives in the corridor resulted in considerable funding of research money into computer modeling of the various modes.[6] Two major models produced from this research are the Quandt and Baumol Abstract Model and the McLynn Cross-Elasticity Model. The SR1 model is a derivative of these models. The models are descendents of the basic gravity model which hypothesizes trip demand between a pair of cities as proportional to their population size and inversely related to some impedance factor, such as distance between them.

The Quandt-Baumol model assumes that demand is characterized by the values of service variables exhibited by the various modes. Examples of service variables are travel time, travel cost, and departure frequency. The model presupposes that individuals are characterized by modal neutrality. A person thus chooses among modes on the basis of their characteristics rather than on the basis of what they are called. Modal competition is introduced into the demand equation by causing the predicted demand for the given mode of travel to depend on the price of the cheapest mode and the time of the fastest competing mode as well as the service characteristics of the given mode. The number of passengers T_{ijk} who travel between city i and city j by way of mode k is estimated as follows:[7]

$$T_{ijk} = P_i^{\alpha_1} P_j^{\alpha_2} \left(\frac{P_i Y_i + P_j Y_j}{P_i + P_j} \right)^{\alpha_3} f_1(H) f_2(C) f_3(D)$$

where:

$$f_1(H) = (H_{ij}^b)^{\beta_0} (H_{ijk})^{\beta_1}$$

$$f_2(C) = (C_{ij}^b)^{\gamma_0} (C_{ijk})^{\gamma_1}$$

$$f_3(D) = (D_{ij}^b)^{\delta_0} (D_{ijk})^{\delta_1}$$

T_{ijk} = demand between city i and city j via mode k
P = city population
Y = city income (per capita)
H = travel time
C = travel cost
D = departure frequency

Superscript b indicates best for that city pair, therefore (H_{ij}^b) is the travel time of the mode serving cities i and j which has the shortest travel time.

$\alpha_1, \alpha_2, \alpha_3, \beta_0, \beta_1, \gamma_0, \gamma_1, \delta_0, \delta_1$ are parameters to be estimated.

One of the virtues of the model is its ability to predict demand for new types of modes insofar as the new mode can be described by a new set of values for the service variables. Another advantage is the relative simplicity of construction. The major criticism of the model is that it often fails causality tests; i.e., it is not based on behavioral characteristics of passengers but is extracting temporal or structural correlation in the data base.

The McLynn Cross-Elasticity Model is also a gravity model utilizing an abstract model construction. The major addition made to the abstract model is the cross-elasticity concept, denoted by the following ratio.

$$W_k = \frac{C_k \prod_i X_{ik}^{\alpha_{ik}}}{\sum_{j=1}^{m} c_j \prod_i X_{ij}^{\alpha_{ij}}}$$

where:

W_k = for example, is the cost variable in the modal split
C, α = calibration coeffieicnts
X = transportation cost variable
i = index identifying a mode
j = index identifying a modal attribute

McLynn's formula is based on the idea that the rate of change in modal share with respect to each variable can be measured by the elasticity of modal share. Elasticity of modal share is defined as the percentage change in modal share resulting from a percentage change in a given modal attribute. Cross-elasticity then, is the change in a mode's share resulting from a change in another mode's attributes. The cross-elasticity concept can be applied to all considered variables. In the Northeast Corridor Project research, time and frequency elasticities, besides that for cost, per mode, were calculated.[8]

As with all models, the Quandt-Baumol and McLynn models are an approximation of reality. The real life demand/modal split process involves a large number of complex and changing patterns of subjective relationships. In contrast, the models employ very simple relationships shown empirically to be most significant.

II. THE STANFORD RESEARCH INSTITUTE'S INTERCITY DEMAND/MODAL SPLIT MODEL

In 1970 the Michigan Department of Transportation contracted with the Stanford Research Institute to produce a series of computer programs to conduct transportation modeling. One of the models was to be an intercity passenger model that would perform demand and modal split for four modes: automobile, rail, bus and air. In June, 1971 a report was prepared by John W. Billheimer documenting the model, The Michigan Intercity Passenger Demand Model.[9]

The model is a descendant of the gravity model which can be stated as:

$$D = \frac{K(\text{Origin Population} \times \text{Destination Population})^{\alpha}}{\text{distance}^{\beta}}$$

Where:

K, α and β = calibration coefficients

SR1 investigated a number of current intercity models before choosing the McLynn model as the basic type of model to be used for Michigan analysis. Due to the diversity of populated areas in the state, ranging from the heavily industrialized Detroit area to isolated rural hamlets, some modifications were made to the model.

The SR1 model uses the number of families in each state zone whose income exceeds $10,000 as a trip generation characteristic. The impedence function is a composite of the time, cost and frequency of service experienced on each interzonal mode of travel. These three measures reflect a sum of the access, line-haul and egress portions of a trip. Based on the zone-to-zone data, the model calculates percentages of trips using each mode and uses these percentages in combination with automobile trip tables and income data to generate trips by mode for each zone pair.

The model is defined by the following relationships:[10]

$$W_m = \begin{cases} a_m t_m^{\alpha(1)} c_m^{\alpha(2)} \left[1 - \exp(-k f_m)\right]^{\alpha(3)} & (m \neq \text{auto}) \\ t_m^{\alpha(4)} c_m (1.7)^{\alpha(5)} & (m = \text{auto}) \end{cases} \qquad (1)$$

$$W = \sum_m W_m \qquad (2)$$

$$D = \begin{cases} \beta(0)(F_i F_j)^{\beta(1)} W^{\beta(2)} & F_i F_j > G \\ \beta'(0)(F_i F_j)^{\beta'(1)} W^{\beta(2)} & F_i F_j \leq G \end{cases} \qquad (3)$$

$$D_m = D W_m / W \qquad (4)$$

Where:

W_m = a modal travel conductance
W = total travel conductance
D = total predicted travel demand
D_m = daily one-directional modal demand
a_m = common carrier conductance multiplier
t_m = total $(i \rightarrow j)$; i.e., origin-destination pair travel time for the n-th mode (hours)
c_m = total $(i \rightarrow j)$ out of pocket per capita cost (dollars)
f_m = frequency of $(i \rightarrow j)$ service (trips per day)
F = number of families with annual incomes exceeding \$10,000 (families x 10^5) in the origin or destination zone.
G = specified value used to segment pairs having larger population products from those having smaller products
α = weightings for the impedance measures to account for the traveler's perceived importance of each measure

The β coefficients are zone specific constants. They are included to compensate for factors that are not explicitly included in the model.

K = modal level of service conductance multiplier

The following bounds were imposed on the model parameters in advance of the calibration process:

$$0 \leq \beta'(0) \leq \beta(0)$$

$$0 \leq \beta'(1) \leq \beta(1) \leq 1.1$$

$$0 \leq \beta(2) \leq 1$$

$$-5 \leq \alpha(j) \leq 0 \qquad j = 1, 2, 4, 5$$

$$\alpha(3) = .3247$$

$$K = 0.12$$

$$0 \leq a_M \leq 5$$

The bounds were found to be necessary to maintain the model's consistency of behavior. If $\beta(1)$, for example, was allowed to exceed 1.1, population increases would have a disproportionate effect on predicted demand. Likewise, should $\beta(2)$ exceed unity, a small change in time or cost by one mode could cause excessive increases in travel over competing modes. The α exponents are held to be negative so that small changes in time or cost will not have a disproportionate effect on demand. α^3 and K values are simply those set by McLynn in his studies. An upper boundary was placed on the common carrier conductance multiplier because it was felt that larger values would create unrealistic imbalances between common carrier traffic and automobile traffic.

The model was tested by SRl and calibrated by 1967 data from 20 city pairs, eight of which were intrastate pairs. The calibration places resulted in the identification of the following parameter values:[11]

$$a_M = \begin{cases} 1.5 & M = \text{air} \\ 0.75 & M = \text{bus, rail} \end{cases}$$

$$\alpha(1) = \alpha(2) = -1.5$$

$$\alpha(3) = 0.3247, \; k = 0.12$$

$$\alpha(4) = \alpha(5) = -1.8$$

$$\beta(0) = 25{,}000, \; \beta'(0) = 2{,}500$$

$$\beta(1) = 1.0, \; \beta'(1) = 0.1$$

$$\beta(2) = 0.9$$

$$\sigma = 0.075$$

As can be seen, the parameters whose changes have the greatest potential impact on demand are the time and cost components $\alpha^{(1)}$, $\alpha^{(2)}$, $\alpha^{(4)}$ and $\alpha^{(5)}$ and the conductance exponent β^{2} . Service frequency $\alpha^{(3)}$ is the least effective of the input variables in terms of its ability to influence sizeable demand changes. Since an increase in time and price for a given mode implies that the mode has become relatively less attractive (if all other modes do not change), the size of the calibrated exponents $\alpha^{(1)}$ and $\alpha^{(2)}$ must be negative to ensure that increases in time and price for the mode decrease that mode's share. If $\alpha^{(3)}$ the measure of modal frequency is a transformation which increases with increased frequency, then an increase in frequency signals an improvement in a model's competitive position and the sign of the $\alpha^{(3)}$ must be positive.

because of its service characteristics. In the Northeast Corridor studies, induced demand made up approximately 85 percent of increases in volume resulting from improvements in service.[12]

The SR1 model is evaluated by Bennett, Ellis and Prokopy of Peat, Marwick, Mitchell and Company (PMM) in a paper performed for the United States Department of Transportation.[13] The authors selected seven intercity modal split models and tested their prediction powers against Northeast Corridor data as well as non-Northeast Corridor data. All of the models were either tested or derived from research done for the Northeast Corridor Project. The researchers concluded that all models tended to overestimate bus and rail traffic and underestimate air traffic. The models were found to overestimate low volume traffic on all modes and tended to compensate by underestimating automobile and air traffic at high volume levels. In comparing the SR1 model against Northeast Corridor data it was found that the model overestimated bus traffic and underestimated air and rail traffic, though the air estimates were very close to the observed. In non-Northeast Corridor data, the SR1 model again was found to overestimate in bus volumes, compare well in air traffic, and overestimate rail. Thus, from these findings, it seems clear that, in the PMM tests, the model consistently overestimated bus traffic, tended to predict air volume quite well, and had mixed results in the rail mode. Compared to the other models, according to ability to replicate observed volumes, in Northeast Corridor pairs, SR1 ranked sixth, second, and fifth, respectively as to bus, air and rail and fifth, first, and fifth, respectively according to non-Northeast Corridor pairs.

The elasticity concept of McLynn is reflected in the value of these parameters. For example, the cost parameter $\alpha^{(2)}$ is set at -1.5. Hence, a one percent increase in price would result in a 1.5 percent decrease in the number of trips demanded. This price elasticity assumption follows that changes in price have a slight disproportional change in the volume of demand. Likewise, the time elasticity parameter $\alpha^{(1)}$ also exceeds this change function. It is somewhat unusual that time and price elasticities are the same in that some studies have concluded time to be a more significant change variable than price.

SRl concluded that the model tends to underestimate long-distance trips (defined as over 600 miles) and overestimate traffic involving short distances. Another problem discovered was the relationship between induced versus diverted demand. The model tends to overstate induced demand at the expense of diverted demand. When improvements in a single mode cause an incremental increase in the number of travelers using that mode, the travelers can be assumed to come from one of two sources: (1) Other modes (diverted demand); (2) the pool of potential travelers who currently are not included in total intercity demand (induced demand). There are two potential types of induced demand, assuming that modal choice remain constant. The travelers could be induced to change their previous chosen destinations for various trip purposes and thus go to other destinations served by the corridor because of its attractive service characteristics. Secondly, travelers could maintain their destination choices but select a different routing to get there; thus abandoning their old routing and choosing the subject corridor

III. THE MICHIGAN DEPARTMENT OF TRANSPORTATION'S STATEWIDE MODELING SYSTEM

The transportation modeling system used for this research is the system devised and operated by the Statewide Transportation Planning Procedures Section of the Michigan Department of Transportation in Lansing, Michigan. Modeling in Michigan can either be performed on a 547 zone or a 2300 zone classification. The 547 zone system was chosen for this research. Michigan is divided into 508 of these zones. Zone boundaries coincide with political boundaries. Major cities are each one zone with the exception of Detroit which is three zones. Some of the smaller cities also are one zone. In rural areas, the size of a zone may vary from one to several townships. Besides the zones in Michigan there are 39 other zones which are divided into 32 for neighboring states and Canada and an outer ring of seven zones. The outstate zones are never smaller than a county and the seven outer zones may be several states. The zonal system is shown in Maps 1 and 2. Each zone has a "centroid" or center of population. This is a given point within the zone at which all travel is assumed to originate or terminate. This paper will consider only intrastate zones in that socio-economic data for outstate zones are not currently available.[14]

The basic element of the statewide highway network is a "link", a small segment of highway approximately 1-5 miles in length. Each link is uniquely identified by a pair of numbers called nodes, designating its end points. A node number is found at each intersection and often at county lines. Thus, a link is generally a segment of highway between two consecutive intersections. Other links, called "access" or "centroid" links are included which connect the centroids to the highway system. Links and centroid links are shown in Map 3.

The highway network is composed of three major data components: The Statewide Socio-economic Data File; the Statewide Transportation Network and the Statewide Public and Private Facility File. Each of these files provides information which is summarized into the 508 intrastate analysis zones.

The Socio-economic File contains 888 pieces of selected census information concerning the overall population characteristics within each zone. The data is from the 1970 Census of Population and Housing.

The Transportation Network File contains the physical description of each highway link such as average speed, distance and annual daily traffic volumes.

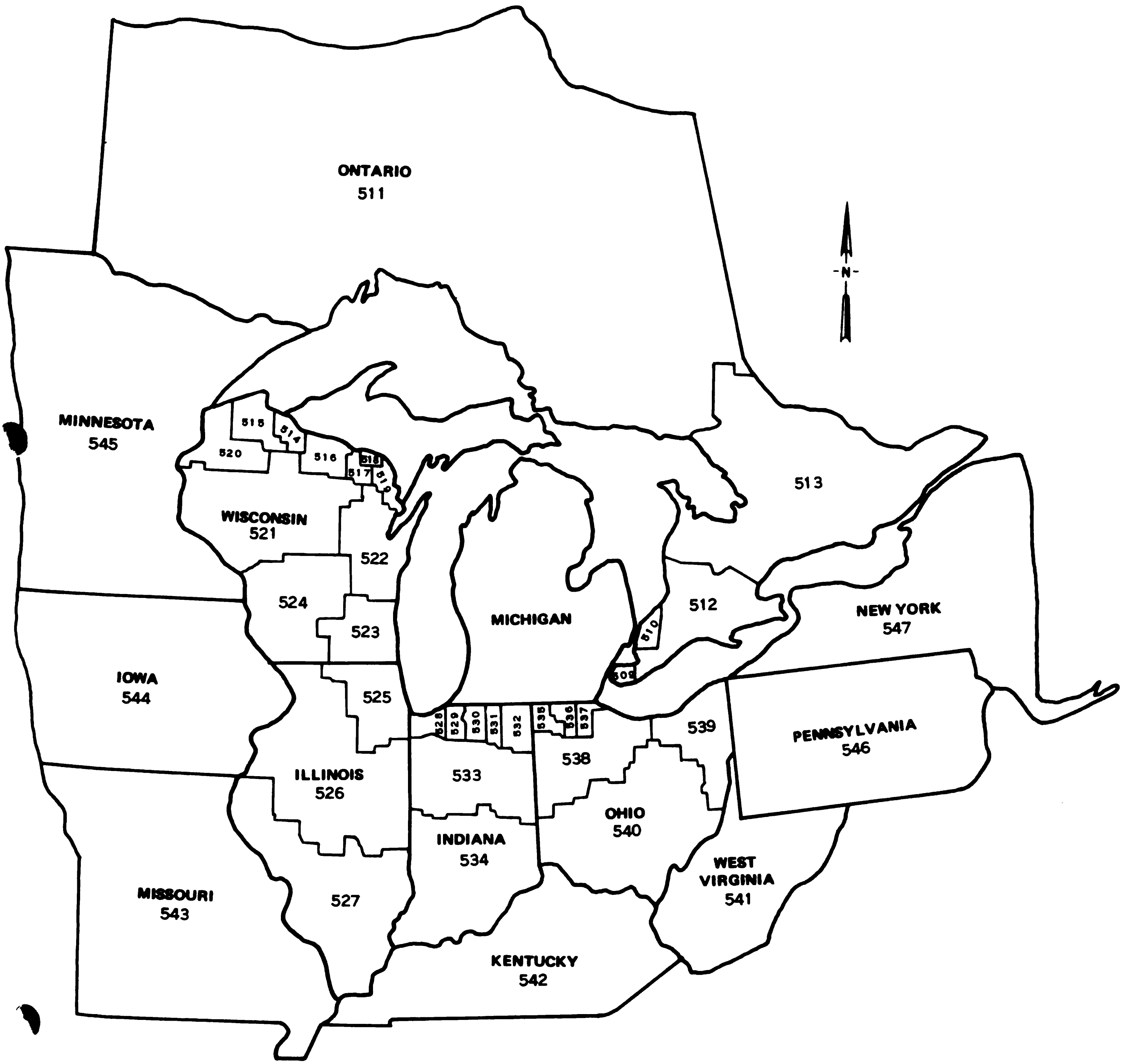
The Public and Private Facility File contains information pertinent to the man-made, physical aspects of the environment, such as the location of airports and major commercial centers.

Using these three files it is possible to accomplish a very useful process called proximity analysis which analyzes the relationship between facilities and various socio-economic characteristics. A computer program accumulates selected socio-economic data based on driving time bands from the zone of the selected facility under study. The driving times between each of the 508 zones is derived from "skimmed trees". Before discussion of

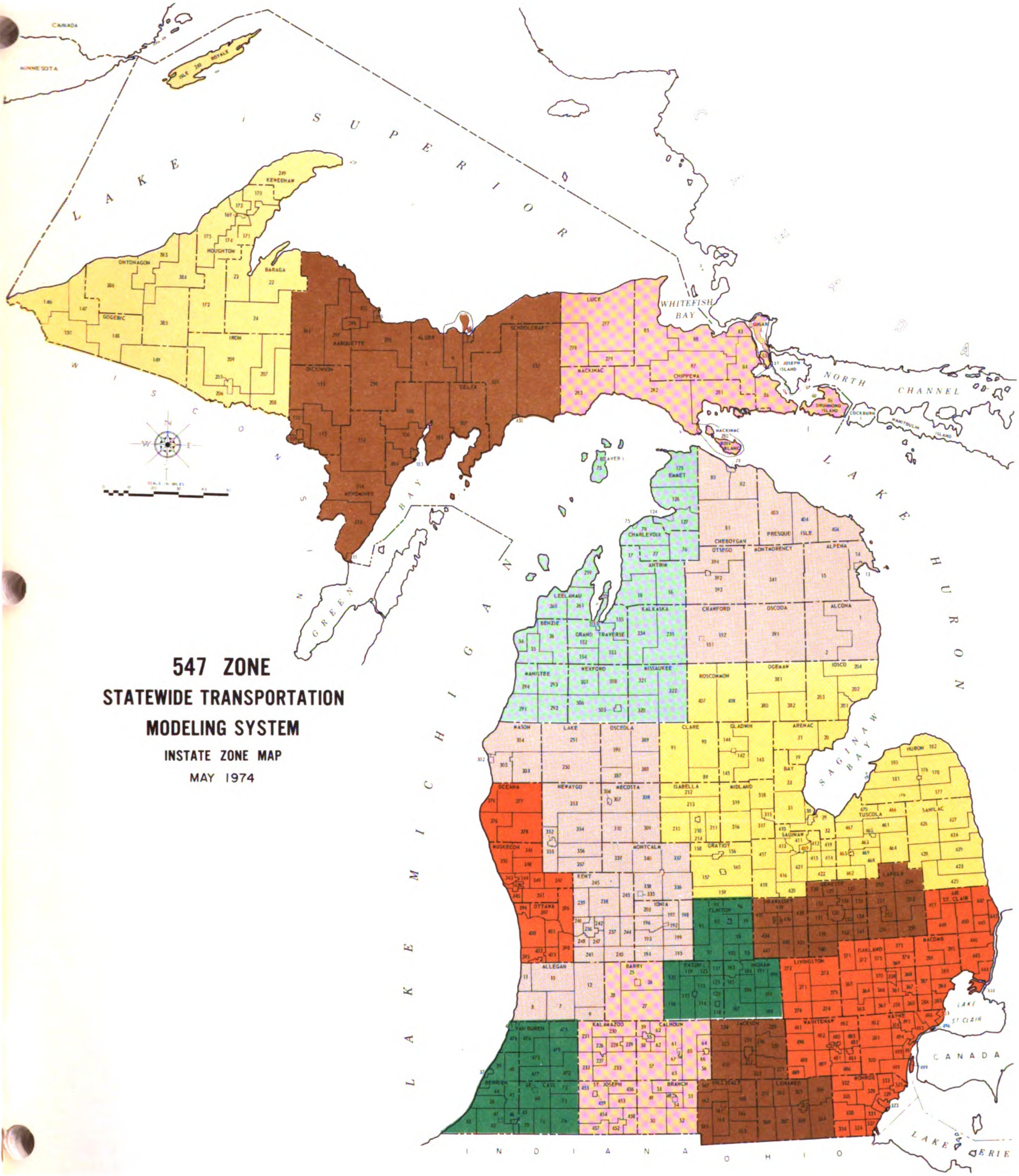
MAP 1

MICHIGAN'S TRANSPORTATION MODELING SYSTEM

547 ZONE
OUTSTATE ANALYSIS ZONES

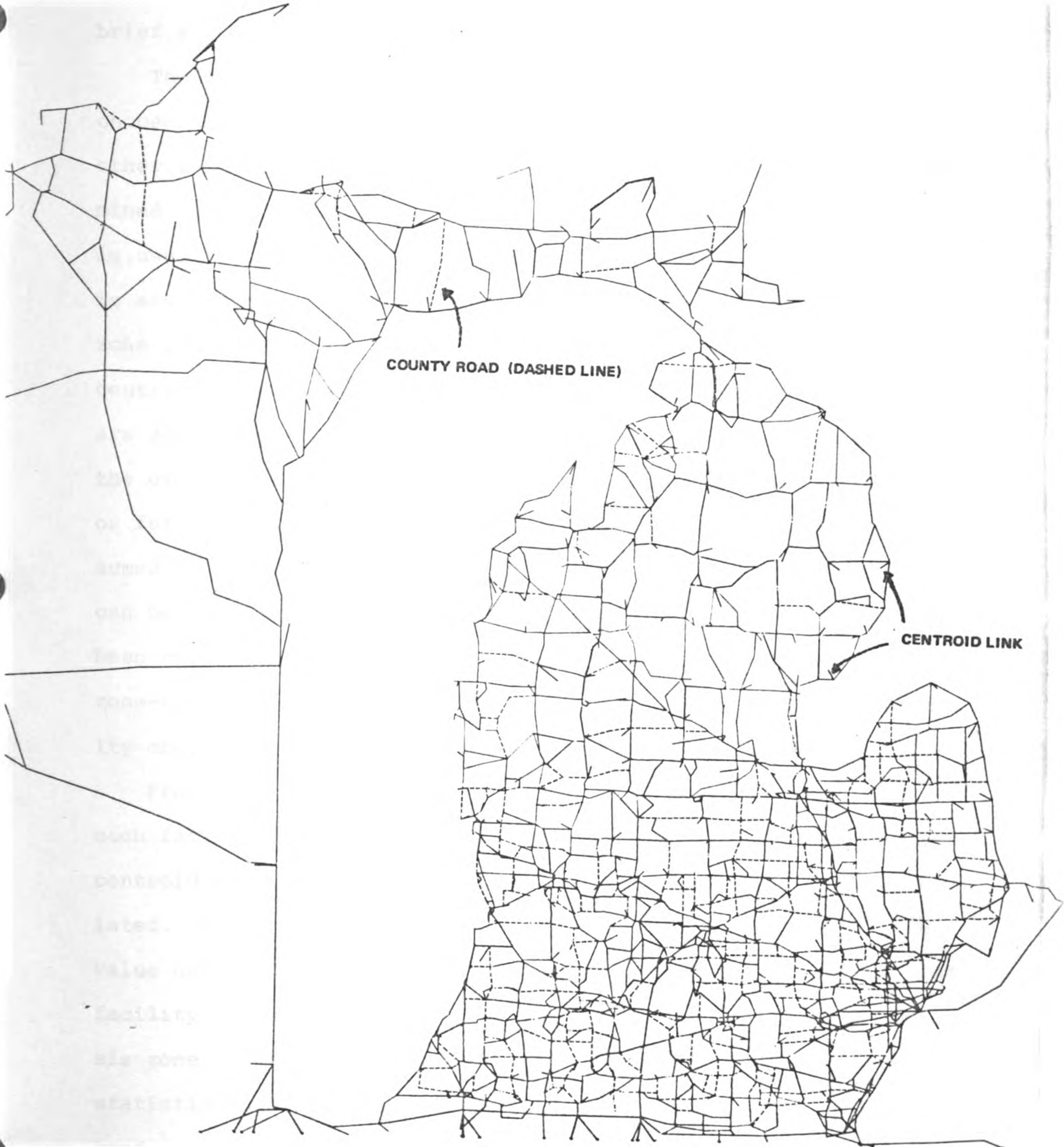


MAP 2


547 ZONE
STATEWIDE TRANSPORTATION
MODELING SYSTEM
INSTATE ZONE MAP
MAY 1974
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
SAGINAW BAY
GREEN BAY
WHITEFISH BAY
NORTH CHANNEL
CANADA
INDIANA
OHIO
LAKE ERIE
LAKE ST. CLAIR

MAP 3

MICHIGAN STATEWIDE HIGHWAY NETWORK PLOT (547 ZONE SYSTEM)



proximity analysis and its use in the research in this paper, a brief explanation of the skim tree process is presented.

The basis of the skim tree process is the analysis used to choose the "path of least resistance" from each zone to every other zone. In this research the average driving time, as determined by the distance and speed information coded in each link, is used to select the minimal paths. The time between two zones is assumed to be that time required to travel between the two zone centroids. The centroid of a zone is a given time from the centroid of another zone so that all persons residing in one zone are assumed to live within that traveling time of all persons in the other zone, although portions of the zone may be closer or further apart. Since the total population of a zone is assumed to reside at the centroid, no travel time within a zone can be calculated. Once the paths between all desired zones have been completed, the paths or trees are "skimmed" to select the zone-to-zone travel times. These times are then used in proximity analysis.

Proximity analysis searches in the selected time bands of each facility for zone centroids. The value assigned to the zone centroid within the desired time radius of the facility is accumulated. Since the facility is located at the zone centroid, the value assigned to that zone is included in the final sum for that facility. The output from this process summarizes for each analysis zone and for each time band: 1) The total socio-economic statistic occurring in the band, and 2) a list of zones in the band.

IV. MODELING PROCEDURES AND RESULTS

1. Documentation of Procedures and Analyses

The research performed was conducted on the Michigan Department of Transportation's Burroughs 7700 Computer. The automobile was assumed to be the dominant mode. The highway network and planning model used in this research was developed in 1966 by the Statewide Studies Unit of the Michigan Department of Transportation with assistance from the consultant firm of Arthur D. Little. The demand model is a gravity type model and has been recalibrated according to traffic volumes recorded continually by the Department's traffic monitoring system. The SR1 model compares the characteristics of the highway mode for a given pair against the service characteristics of a common carrier mode. The generated volume for that mode then results from diverted demand from the automobile mode and from induced demand.

Highway cost calculations used in all modeling processes are shown in Appendix A.

Two variations of the basic SR1 model are used: Proximity analysis and a wait-time factor. As previously mentioned the market area for a given modal service can be varied based on calculated highway driving time bands. For each of the modes tested, experimentation is performed with this function until the best prediction for a given pair is obtained.

A wait-time factor is incorporated into the model because of its tendency to overestimate demand. This factor, in effect, augments the $\alpha^{(1)}$ parameter. The calculation is based on the length of a normal service day and the frequency of daily service for a given pair.

$$\text{Wait Time} = \frac{\dfrac{\text{Length of Service Day} \times 60}{\text{frequency}}}{1/2}$$

If, for example, the service day for flights from Grand Rapids to Detroit is 16 hours and the daily frequency is nine trips, the wait-time per trip can be calculated as:

$$\text{Wait Time} = \frac{\dfrac{16 \times 60}{9}}{1/2} = 53 \text{ minutes}$$

Two different categories of analysis are applied to the model's modal prediction: A city size combination analysis and a distance segmentation analysis. Because of the wide range of city sizes in Michigan, a city size segmentation function, G, is in the model. The purpose of the city size analysis is to determine whether the G factor is properly accommodating city size variations. Thus, if certain city size categories reveal a consistent pattern of overestimation or underestimation a preliminary assumption can be made that recalibration of this function may be desirable. In order to perform this type of analysis, all the various cities used in model analysis are combined and the associated population statistics are accumulated using 1970 census estimates. The cities are then clustered into five categories based on the array of sizes. City size categories are shown in Table 1.

TABLE 1

CITY SIZE CATEGORIES

SIZE CATEGORY	CITY	1970 POPULATION	SIZE CATEGORY	CITY	1970 POPULATION
A	Detroit	1,514,063	E	Lowell	3,068
				Gaylord	3,012
B	Grand Rapids	197,649		Clare	2,639
	Flint	193,317		L'Anse	2,538
	Lansing	131,403		Brighton	2,457
	Ann Arbor	100,035		Imlay City	1,980
	Saginaw	91,849		Fowlerville	1,978
	Pontiac	85,279		Pellston	469
	Kalamazoo	85,035		New Hudson	N.A.
C	Jackson	45,484			
	Muskegon	44,631			
	Battle Creek	38,931			
	Port Huron	35,749			
	Midland	35,176			
D	Ypsilanti	29,538			
	Holland	26,479			
	Marquette	21,907			
	Mt. Pleasant	20,504			
	Traverse City	18,048			
	Owosso	17,179			
	Benton Harbor	16,481			
	Escanaba	15,368			
	Sault Ste. Marie	15,136			
	Alpena	13,805			
	Niles	12,988			
	Albion	12,112			
	Grand Haven	11,844			
	Menominee	10,748			
	Farmington	10,328			
	Cadillac	9,990			
	Coldwater	9,232			
	Ironwood	8,711			
	Iron Mountain	8,702			
	Charlotte	8,244			
	Manistee	7,723			
	Marshall	7,253			
	Tecumseh	7,120			
	South Haven	6,471			
	Lapeer	6,341			
	Mason	5,468			
	Hancock	4,830			
	Durand	3,678			

The second category of analysis is distance segmentation, In previous evaluations of the model, conclusions were made that it tended to overestimate short distance trips and underestimate long distance trips. In order to test for this, city pairs for all modes are categorized into nine segments, according to pair distance:

Trips $\leq$ 40 miles
$>$ 40 $\leq$ 60 miles
$>$ 60 $\leq$ 80 miles
$>$ 80 $\leq$ 130 miles
$>$ 130 $\leq$ 190 miles
$>$ 190 $\leq$ 250 miles
$>$ 250 $\leq$ 350 miles
$>$ 350 $\leq$ 450 miles
$>$ 450 miles

2. Rail Results and Analyses

The data used to test the SR1 model for the rail mode is from the Amtrak Origin-Destination records. Ms. Joyce A. Newell of the Statewide Transportation Planning Procedures Section collected information from the station manager of the Amtrak terminal in East Lansing, Michigan. Portions of daily and monthly traffic for nine months in 1974 and for the entire year of 1975 were collected. The author then coded this data for keypunching and transfer to a computer disc. Trip tables for intrastate travel were formed and the data was analyzed. Origin-destination data for stations in Albion and Ypsilanti were incomplete and the stations were omitted from consideration. It was determined that an average daily trip table from the months of May and October, 1975 would provide the best data for comparison with model predictions. Input data for the model was obtained from the Amtrak Fare Guide supplied by the Amtrak

District Offices in Chicago, Illinois. The Amtrak network is shown in Appendix D. A data set for all the origins and destinations is given in Appendix B.

Initial model calculations were performed by experimentation with various combinations of market areas for each pair. Market bands resulting in the best prediction for each origin-destination were chosen and are shown in Appendix B. In general, the market area for pair distances under 100 miles was set at (0,0). It is logical that travelers will not drive much distance to board a train for a destination under approximately 100 miles in that the highway travel time may require only 2 to 2½ hours. Likewise pair distances 150 miles and over required market area augmentation. This varied from (20,20) to a maximum of (30,30). Niles-Port Huron, the longest pair distance, was set at (40,40). In cases where city size varied significantly, the selected market area was disproportional; e.g., Niles-Detroit (30,0); Kalamazoo-Lapeer (10,20).

Analysis based on an absolute error calculation was performed on the model results according to distance segmentation and is given in Table 2. Examination of Table 2 shows the model severely overestimates demand in the first distance category and incrementally lessens this tendency in the next two categories. The last two categories reveal the opposite tendency and are also closest approximations to the survey data. City size analysis is shown in Table 3. No discernible pattern is evident from this analysis.

A wait-time factor based on a 12-hour service day was included in the calculations. Analysis on the results according to

TABLE 2

DISTANCE SEGMENTATION ANALYSIS
WITHOUT A WAIT-TIME FACTOR
ON
RAIL MODELING RESULTS

CITY PAIR	GENERATED	ACTUAL	ABSOLUTE ERROR
City Pair Distances ≤ 40 Miles			
Detroit-Ann Arbor	303	45.3	+257.7
Ann Arbor-Detroit	303	34.3	+268.7
Kalamazoo-Battle Creek	82.1	12.4	+ 70.2
Battle Creek-Kalamazoo	68	13.7	+ 54.3
Ann Arbor-Jackson	41.6	6.2	+ 35.4
Jackson-Ann Arbor	41	4.9	+ 36.1
Lansing-Durand	14.2	0.3	+ 13.9
Durand-Lansing	14.2	2	+ 12.2
Flint-Durand	42.2	0.5	+ 41.8
Durand-Flint	42.3	0.4	+ 41.9
Flint-Lapeer	11.9	0.1	+ 11.8
Lapeer-Flint	11.9	0.03	+ 11.9
Durant-Lapeer	0.2	.06	+ .1
Lapeer-Durand	0.3	.03	+ .3
	Total Absolute Error = 711.8%		
City Pair Distances > 40 ≤ 60 Miles			
Lansing-Flint	81.9	1.1	+ 80.7
Flint-Lansing	81.9	2.4	+ 79.5
Lansing-Battle Creek	17.7	12.5	+ 5.2
Battle Creek-Lansing	17.0	2.9	+ 14.1
Kalamazoo-Niles	6.6	4.2	+ 2.4
Niles-Kalamazoo	6.6	5.2	+ 1.4
Jackson-Battle Creek	9.3	5.5	+ 3.8
Battle Creek-Jackson	8.3	5.6	+ 2.7
Port Huron-Lapeer	1.1	0.03	+ 1.1
Lapeer-Port Huron	1.1	0.1	+ 1
	Total Absolute Error = 483.4%		

Table 2 (cont'd.)

CITY PAIR	GENERATED	ACTUAL	ABSOLUTE ERROR
City Pair Distances >60≤ 80 Miles			
Detroit-Jackson	28	8	+20
Jackson-Detroit	26.5	5.2	+21.3
Lansing-Kalamazoo	13.9	3.3	+10.6
Kalamazoo-Lansing	13.9	4.1	+ 9.8
Kalamazoo-Jackson	7	2.1	+ 4.9
Jackson-Kalamazoo	7.1	1.7	+ 5.3
Flint-Port Huron	11.9	0.1	+11.8
Port Huron-Flint	13.7	0.4	+13.3
Lansing-Lapeer	1	0.8	+ 0.2
Lapeer-Lansing	1	0.7	+ 0.3
Battle Creek-Niles	0.9	1.2	- 0.3
Niles-Battle Creek	0.8	1.1	- 0.3
Battle Creek-Durand	0.4	0.3	+ 0.1
Durand-Battle Creek	0.1	0.2	- 0.1
	Total Absolute Error = 342.5%		
City Pair Distances >80≤130 Miles			
Kalamazoo-Ann Arbor	11.9	9.5	+ 2.4
Ann Arbor-Kalamazoo	5.9	9.4	- 3.5
Flint-Kalamazoo	2.6	1.6	+ 1
Kalamazoo-Flint	2.6	2.4	+ .2
Ann Arbor-Battle Creek	5.6	4	+ 1.6
Battle Creek-Ann Arbor	5.2	2.5	+ 2.7
Lansing-Port Huron	3.2	2.6	+ 0.6
Port Huron-Lansing	3.5	2.5	+ 1
Flint-Battle Creek	2.6	1.1	+ 1.5
Battle Creek-Flint	2.9	0.7	+ 2.2
Kalamazoo-Durand	0.4	0.5	- 0.1
Durand-Kalamazoo	0.4	0.3	+ 0.1
Kalamazoo-Lapeer	0.6	0.8	- 0.2
Lapeer-Kalamazoo	0.6	0.6	0
Lansing-Niles	2.7	2.9	- 0.2
Niles-Lansing	3.7	3.7	0
Battle Creek-Detroit	8.7	4.3	+ 4.4
Detroit-Battle Creek	7.9	4.8	+ 3.1
Jackson-Niles	1	1.5	- 0.5
Niles-Jackson	1	1.4	- 0.4
Durand-Port Huron	1.4	1.6	- 0.2
Port Huron-Durand	1.5	1.5	0
Lapeer-Battle Creek	0.4	0.2	+ 0.2
Battle Creek-Lapeer	0.4	0.2	+ 0.2
	Total Absolute Error = 42.2%		

Table 2 (cont'd.)

CITY PAIR	GENERATED	ACTUAL	ABSOLUTE ERROR
City Pair Distances >130 Miles			
Detroit-Kalamazoo	13	14.7	- 1.7
Kalamazoo-Detroit	13	13.3	- 0.3
Detroit-Niles	6.6	4.2	+ 2.4
Niles-Detroit	3.3	4.2	+ 0.9
Port Huron-Kalamazoo	1.1	1.6	- 0.5
Kalamazoo-Port Huron	1.1	1.6	- 0.5
Ann Arbor-Niles	3.4	4.1	- 0.7
Niles-Ann Arbor	3.4	4	- 0.6
Flint-Niles	0.8	1.2	- 0.4
Niles-Flint	1.4	1.4	0
Battle Creek-Port Huron	1.3	0.2	+ 1.1
Port Huron-Battle Creek	1.3	1.6	- 0.3
Port Huron-Niles	0.7	0.6	+ 0.1
Niles-Port Huron	0.9	0.9	0
Lapeer-Kalamazoo	0.7	0.6	+ 0.1
Kalamazoo-Lapeer	0.6	0.8	- 0.2
Durand-Niles	0.1	0.2	- 0.1
Niles-Durand	0.4	0.3	+ 0.1
Lapeer-Niles	0.1	0.6	- 0.5
Niles-Lapeer	0.2	0.5	- 0.2

Total Absolute Error = 17.8%

TABLE 3

CITY SIZE ANALYSIS
WITHOUT A WAIT-TIME FACTOR
ON
RAIL MODELING RESULTS

	CITY PAIR	GENERATED	ACTUAL	ABSOLUTE ERROR
	City Size Analysis with Category A Origin			
A-B	Detroit-Ann Arbor	13.	14.7	- 1.7
	Detroit-Kalamazoo	303	45.3	+257.7
A-C	Detroit-Jackson	28	8	+ 20
	Detroit-Battle Creek	7.9	4.8	+ 3.1
A-D	Detroit-Niles	6.6	4.2	+ 2.4
	City Size Analysis with Category B Origin			
B-A	Kalamazoo-Detroit	13	13.3	- .3
	Ann Arbor-Detroit	303	34.3	+268.7
B-B	Kalamazoo-Ann Arbor	11.9	9.5	+ 2.4
	Ann Arbor-Kalamazoo	5.9	9.4	- 3.5
	Lansing-Kalamazoo	13.9	3.3	+ 10.6
	Kalamazoo-Lansing	13.9	4.1	+ 9.8
	Lansing-Flint	81.9	1.2	+ 80.7
	Flint-Lansing	81.9	2.4	+ 79.5
	Flint-Kalamazoo	2.6	1.6	+ 1
	Kalamazoo-Flint	2.6	2.4	+ 0.2
		Total Absolute Error = 553.7%		
B-C	Kalamazoo-Battle Creek	82.6	12.4	+ 70.2
	Kalamazoo-Jackson	7	2.1	+ 4.9
	Kalamazoo-Port Huron	1.1	1.6	- 0.5
	Ann Arbor-Jackson	41.6	6.2	+ 35.4
	Ann Arbor-Battle Creek	5.6	4	+ 1.6
	Lansing-Battle Creek	17.7	12.5	+ 5.2
	Lansing-Port Huron	3.2	2.6	+ 0.6
		Total Absolute Error = 286.9%		

Table 3 (cont'd.)

	CITY PAIR	GENERATED	ACTUAL	ABSOLUTE ERROR
	City Size Analysis with Category B Origin (cont'd.)			
B-D	Kalamazoo-Niles	6.6	4.2	+ 2.4
	Kalamazoo-Durand	0.4	0.5	- 0.1
	Kalamazoo-Lapeer	0.6	0.8	- 0.2
	Ann Arbor-Niles	3.4	4.1	- 0.7
	Lansing-Niles	2.7	2.9	- 0.2
	Lansing-Durand	14.2	0.3	+ 13.9
	Lansing-Lapeer	1	0.8	+ 0.2
	Flint-Niles	0.8	1.2	- 0.4
	Flint-Durand	42.2	0.5	+ 41.8
	Flint-Lapeer	11.9	0.1	+ 11.8
		Total Absolute Error = 432.7%		
	City Size Analysis with Category C Origin			
C-A	Jackson-Detroit	26.5	5.2	+ 21.3
	Battle Creek-Detroit	8.7	4.3	+ 4.4
C-B	Jackson-Battle Creek	9.3	5.5	+ 3.8
	Jackson-Ann Arbor	41	4.9	+ 36.1
	Battle Creek-Ann Arbor	5.2	2.5	+ 2.7
	Battle Creek-Kalamazoo	68	13.7	+ 54.3
	Battle Creek-Lansing	17	2.9	+ 14.1
	Battle Creek-Flint	2.9	0.7	+ 2.2
	Port Huron-Flint	13.7	0.4	+ 13.3
	Port Huron-Lansing	3.5	2.5	+ 1
	Port Huron-Kalamazoo	1.1	1.6	- 0.5
		Total Absolute Error = 207.7%		
C-C	Jackson-Battle Creek	9.3	5.5	+ 3.8
	Battle Creek-Jackson	8.3	5.6	+ 2.7
	Battle Creek-Port Huron	1.3	0.2	+ 1.1
	Port Huron-Battle Creek	1.3	1.6	- 0.3
C-D	Jackson-Niles	1	1.5	- 0.5
	Battle Creek-Niles	0.9	1.2	- 0.3
	Battle Creek-Durand	0.3	0.2	- 0.1
	Battle Creek-Lapeer	0.3	0.4	- 0.2
	Port Huron-Niles	0.7	0.6	+ 0.1
	Port Huron-Durand	1.5	1.5	0
	Port Huron-Lapeer	1.1	0.03	+ 1.1
		Total Absolute Error = 44.2%		

Table 3 (cont'd.)

	CITY PAIR	GENERATED	ACTUAL	ABSOLUTE ERROR
	City Size Analysis with Category D Origin			
D-A	Niles-Detroit	3.3	4.2	- 0.9
D-B	Niles-Kalamazoo	6.6	5.2	+ 1.4
	Niles-Lansing	3.7	3.7	0
	Niles-Ann Arbor	3.4	4	- 0.6
	Niles-Flint	3.7	3.7	0
	Durand-Kalamazoo	0.4	0.3	+ 0.1
	Durand-Lansing	14.2	2	+12.2
	Durand-Flint	42.3	0.4	+41.9
	Lapeer-Kalamazoo	0.7	0.6	+ 0.1
	Lapeer-Lansing	1	0.7	+ 0.3
	Lapeer-Flint	11.9	0.03	+11.9
		Total Absolute Error = 370.3%		
D-C	Niles-Battle Creek	0.8	1.1	- 0.3
	Niles-Jackson	1	1.4	- 0.4
	Niles-Port Huron	0.9	0.9	0
	Durand-Battle Creek	0.1	0.2	- 0.1
	Durand-Port Huron	1.4	1.6	- 0.2
	Lapeer-Battle Creek	0.4	0.2	+ 0.2
	Lapeer-Port Huron	1.1	0.1	+ 1
		Total Absolute Error = 39.3%		
D-D	Niles-Durand	0.4	0.3	+ 0.1
	Niles-Lapeer	0.2	0.5	- 0.3
	Durand-Niles	0.1	0.2	- 0.1
	Durand-Lapeer	11.9	0.1	+11.8
	Lapeer-Durand	0.3	0.03	+ 0.3
	Lapeer-Niles	0.1	0.6	- 0.5
		Total Absolute Error = 741.2%		

TABLE 4

DISTANCE SEGMENTATION ANALYSIS
WITH A 12-HOUR WAIT-TIME FACTOR
ON
RAIL MODELING RESULTS

CITY PAIR	GENERATED	ACTUAL	ABSOLUTE ERROR
City Pair Distances ≤ 40 Miles			
Detroit-Ann Arbor	58.8	45.3	+13.5
Ann Arbor-Detroit	58.8	34.3	+24.5
Kalamazoo-Battle Creek	13.3	12.4	+ 0.9
Battle Creek-Kalamazoo	6.3	6.2	+ 0.1
Ann Arbor-Jackson	0.6	0.3	+ 0.3
Jackson-Ann Arbor	1.3	0.5	+ 0.8
Lansing-Durand	0.4	0.1	+ 0.33
Durand-Lansing	6.3	5	+ 1.3
Flint-Durand	13.3	13.8	- 0.5
Durand-Flint	0.6	2	- 1.4
Lapeer-Flint	1.3	0.4	+ 0.9
Flint-Lapeer	0.4	0	+ 0.4
Durand-Lapeer	0	0	0
Lapeer-Durand	0	0	0
	Total Absolute Error = 40%		
City Pair Distances > 40 ≤ 60 Miles			
Lansing-Flint	7.2	1.2	+ 6
Flint-Lansing	7.2	2.4	+ 4.8
Lansing-Battle Creek	1.7	12.5	-10.8
Battle Creek-Lansing	1.7	2.9	- 1.2
Kalamazoo-Niles	2.2	4.2	- 2
Niles-Kalamazoo	2.2	5.2	- 3
Jackson-Battle Creek	2.0	5.5	- 3.5
Battle Creek-Jackson	1.9	5.7	- 3.8
Port Huron-Lapeer	0.1	0	+ 0.1
Lapeer-Port Huron	0.1	0.1	0
	Total Absolute Error = 89%		

Table 4 (cont'd.)

CITY PAIR	GENERATED	ACTUAL	ABSOLUTE ERROR
City Pair Distances > 60 ≤ 80 Miles			
Detroit-Jackson	9.6	8	+ 1.6
Jackson-Detroit	9.6	5.2	+ 4.4
Lansing-Kalamazoo	2.3	3.3	- 1
Kalamazoo-Lansing	2.3	4.1	- 1.8
Kalamazoo-Jackson	2.4	2.1	+ 0.3
Jackson-Kalamazoo	2.4	1.7	+ 0.7
Flint-Port Huron	1.5	0.7	+ 0.8
Port Huron-Flint	1.5	0.4	+ 1.1
Lansing-Lapeer	0.1	0.8	- 0.7
Lapeer-Lansing	0.1	0.7	- 0.6
Battle Creek-Niles	0.4	1.2	- 0.8
Niles-Battle Creek	0.4	1.1	- 0.7
Battle Creek-Durand	0	0.2	- 0.2
Durand-Battle Creek	0.1	0.2	- 0.1
	Total Absolute Error = 45%		
City Pair Distances > 80 ≤ 130 Miles			
Kalamazoo-Ann Arbor	5.4	9.5	- 4.1
Ann Arbor-Kalamazoo	5.4	9.4	- 4
Flint-Kalamazoo	2.3	1.6	+ 0.7
Kalamazoo-Flint	2.3	2.4	- 0.1
Ann Arbor-Battle Creek	1.9	4	- 2.1
Battle Creek-Ann Arbor	1.9	2.5	- 0.6
Lansing-Port Huron	0.7	2.6	- 1.9
Port Huron-Lansing	0.7	2.5	- 1.8
Flint-Battle Creek	0.6	1.1	- 0.5
Battle Creek-Flint	0.6	0.7	- 0.1
Kalamazoo-Durand	0.1	0.5	- 0.4
Durand-Kalamazoo	0.1	0.3	- 0.2
Kalamazoo-Lapeer	0.2	0.8	- 0.6
Lapeer-Kalamazoo	0.2	0.6	- 0.4
Lansing-Niles	2	4.1	- 2.1
Niles-Lansing	1	3.8	- 2.8
Battle Creek-Detroit	3.9	4.3	- 0.4
Detroit-Battle Creek	3.8	4.8	- 0.1
Jackson-Niles	0.5	1.5	- 0.1
Niles-Jackson	0.5	1.4	- 0.9
Durand-Port Huron	0.3	1.6	- 1.3
Port Huron-Durand	0.3	1.5	- 1.2
Lapeer-Battle Creek	0	0.2	- 0.2
Battle Creek-Lapeer	0	0.2	- 0.2
	Total Absolute Error = 43%		

Table 4 (cont'd.)

CITY PAIR	GENERATED	ACTUAL	ABSOLUTE ERROR
City Pair Distances >130 Miles			
Detroit-Kalamazoo	7	14.7	- 7.7
Kalamazoo-Detroit	7	13.3	- 6.3
Detroit-Niles	3.2	4.7	- 1.5
Niles-Detroit	3.2	4.2	- 1
Port Huron-Kalamazoo	0.4	1.6	- 1.2
Kalamazoo-Port Huron	0.4	1.6	- 1.2
Ann Arbor-Niles	2	4.1	- 2.1
Niles-Ann Arbor	2	4	- 2
Flint-Niles	0.4	1.2	- 0.8
Niles-Flint	0.5	1.5	- 1
Battle Creek-Port Huron	0	0.2	- 0.2
Port Huron-Battle Creek	0.4	1.6	- 1.2
Port Huron-Niles	0.3	0.6	- 0.3
Niles-Port Huron	1.4	1	- 0.4
Lapeer-Kalamazoo	0.2	0.6	- 0.4
Kalamazoo-Lapeer	0.2	0.8	- 0.6
Durand-Niles	0	0.2	- 0.2
Niles-Durand	0.1	0.3	- 0.2
Lapeer-Niles	0.1	0.6	- 0.5
Niles Lapeer	0.1	0.5	- 0.4

Total Absolute Error = 51%

TABLE 5

CITY SIZE ANALYSIS
WITH A 12-HOUR WAIT-TIME FACTOR
ON
RAIL MODELING RESULTS

	CITY PAIR	GENERATED	ACTUAL	ABSOLUTE ERROR
	City Size Analysis with Category A Origin			
A-B	Detroit-Ann Arbor	58.8	45.3	+13.5
	Detroit-Kalamazoo	7	14.7	- 7.7
A-C	Detroit-Jackson	9.6	8	+ 1.6
	Detroit-Battle Creek	3.8	4.8	- 1
A-D	Detroit-Niles	3.2	4.7	- 1.5
	City Size Analysis with Category B Origin			
B-A	Kalamazoo-Detroit	7	13.3	- 6.3
	Ann Arbor-Detroit	58.8	34.3	+24.5
B-B	Kalamazoo-Ann Arbor	5.4	9.5	- 4.1
	Ann Arbor-Kalamazoo	5.4	9.4	- 4.1
	Lansing-Kalamazoo	2.3	3.3	- 1
	Kalamazoo-Lansing	2.3	4.1	- 1.8
	Lansing-Flint	7.2	1.2	+ 6
	Flint-Lansing	7.2	2.4	+ 4.8
	Flint-Kalamazoo	2.3	1.6	+ 0.7
	Kalamazoo-Flint	2.3	2.4	- 0.1
		Total Absolute Error = 69%		
B-C	Kalamazoo-Battle Creek	13.3	12.4	+ 1.1
	Kalamazoo-Jackson	2.4	2.1	+ 0.3
	Kalamazoo-Port Huron	0.4	1.6	- 1.2
	Ann Arbor-Jackson	6.3	6.2	+ 0.1
	Ann Arbor-Battle Creek	1.9	4	- 2.1
	Lansing-Battle Creek	1.7	12.5	-10.8
	Lansing-Port Huron	0.7	2.6	- 1.9
		Total Absolute Error = 42%		

Table 5 (cont'd.)

	CITY PAIR	GENERATED	ACTUAL	ABSOLUTE ERROR
	City Size Analysis with Category B Origin (cont'd.)			
B-D	Kalamazoo-Niles	2.2	4.2	- 2
	Kalamazoo-Durand	0.1	0.5	- .4
	Kalamazoo-Lapeer	0.2	0.8	- .6
	Ann Arbor-Niles	2	4.1	- 2.1
	Lansing-Niles	2	4.1	- 2.1
	Lansing-Durand	0.6	0.3	+ 0.3
	Lansing-Lapeer	0.1	0.8	- 0.7
	Flint-Niles	0.4	1.2	- 0.8
	Flint-Durand	1.3	0.5	+ 0.8
	Flint-Lapeer	0.4	0.07	+ 0.33
		Total Absolute Error = 61%		
	City Size Analysis with Category C Origin			
C-A	Jackson-Detroit	9.6	5.2	+ 4.4
	Battle Creek-Detroit	3.9	4.3	- 0.4
C-B	Jackson-Battle Creek	2	5.5	- 3.5
	Jackson-Ann Arbor	6.3	5	+ 1.3
	Battle Creek-Ann Arbor	1.9	2.5	- 0.6
	Battle Creek-Kalamazoo	13.3	13.8	- 0.5
	Battle Creek-Lansing	1.7	2.9	- 1.2
	Battle Creek-Flint	0.6	0.7	- 0.1
	Port Huron-Flint	1.5	0.4	+ 1.1
	Port Huron-Lansing	0.7	2.5	- 1.8
	Port Huron-Kalamazoo	0.4	1.6	- 1.2
		Total Absolute Error = 32%		
C-C	Jackson-Battle Creek	2	5.5	- 3.5
	Battle Creek-Jackson	1.9	5.5	- 3.6
	Battle Creek-Port Huron	0.4	0.2	+ 0.2
	Port Huron-Battle Creek	0.4	1.6	- 1.2
C-D	Jackson-Niles	0.5	1.5	- 1
	Battle Creek-Niles	0.4	1.2	- 0.8
	Battle Creek-Durand	0	0.2	- 0.2
	Battle Creek-Lapeer	0	0.2	- 0.2
	Port Huron-Niles	0.3	0.6	- 0.3
	Port Huron-Durand	0.3	1.5	- 1.2
	Port Huron-Lapeer	0	0	0
		Total Absolute Error = 71%		

Table 5 (cont'd.)

	CITY PAIR	GENERATED	ACTUAL	ABSOLUTE ERROR
	City Size Analysis with Category D Origin			
D-A	Niles-Detroit	3.2	4.2	- 1
D-B	Niles-Kalamazoo	2.2	5.2	- 3
	Niles-Lansing	1	3.8	- 2.8
	Niles-Ann Arbor	2.4	4	- 2
	Niles-Flint	0.5	1.5	- 1
	Durand-Kalamazoo	0.1	0.3	- 0.2
	Durand-Lansing	0.6	.2	+ 0.4
	Durand-Flint	1.3	0.4	+ 0.9
	Lapeer-Kalamazoo	0.2	0.6	- 0.4
	Lapeer-Lansing	0.1	0.7	- 0.6
	Lapeer-Flint	0.4	0.03	+ 0.37
		Total Absolute Error = 63%		
D-C	Niles-Battle Creek	0.4	1.1	- 0.7
	Niles-Jackson	0.5	1.4	- 0.9
	Niles-Port Huron	1.4	1	+ 0.4
	Durand-Battle Creek	0.1	0.2	- 0.1
	Durand-Port Huron	0.3	1.6	- 1.3
	Lapeer-Battle Creek	0	0.2	- 0.2
	Lapeer-Port Huron	0.1	0.1	0
		Total Absolute Error = 64%		
D-D	Niles-Durand	0.1	0.3	- 0.2
	Niles-Lapeer	0.1	0.5	- 0.4
	Durand-Niles	0	0.2	- 0.2
	Durand-Lapeer	0	0.1	0
	Lapeer-Durand	0	0	0
	Lapeer-Niles	0.1	0.6	- 0.5
		Total Absolute Error = 76%		

distance segmentation is given in Table 4. Examination shows that the absolute error per distance category has been significantly reduced by the wait-time factor. In the first category demand is still overestimated but in the next two categories a mixture of overestimation and underestimation is evident. As in the analysis performed without a wait-time factor, the two long distance categories are characterized by consistent underestimation by the model.

City size analysis is shown in Table 5. Again, no discernible pattern is evident.

Comparison of the results from these analyses reveals that the wait-time factor greatly improves model predictive ability for the short distance pairs, but tends to add to the tendency for underestimation of longer distance pairs. Thus the non-wait-time calculations prove a better predictor for city pairs over 80 miles apart.

In analyzing the results for the Kalamazoo-Battle Creek service it was found without the wait-time factor, that the service characteristics of rail and the highway mode were very close, given that the frequency variable has minimal change impact. The rail mode was only 10 minutes longer and 0.28 higher than the highway mode. The wait-time factor in this case introduced the inconvenience factor of the mode and therefore provided a more realistic prediction.

Based on these results, it can be concluded that the model has a greater tendency to overestimate demand between short distance pairs than to underestimate demand between long distance pairs. Considering only these results, it seems advisable that a permanent distance segmentation factor should be added to the model.

The results from these analyses compares favorably with conclusions made by Billheimer and by Peat, Marwick and Mitchell that the model clearly overstates short distances and understates long distance pairs.

Preliminary consideration was given to whether generated demand was diverted or induced. In that the highway model is very finely tuned, the generated results and observed results for this mode were compared against generated and observed rail results when the model was run. In almost all cases very little change occurred in generated highway traffic even though rail traffic accounted for ten or more passengers. Examples of this analysis are shown in Table 6. These results appear to coincide with Billheimer and Peat, Marwick and Mitchell's conclusions that the model is failing to consider diverted demand and almost exclusively generates induced demand.

3. Bus Results and Analyses

The data used to test the SR1 model for the bus mode is from a ticket survey at the Lansing-East Lansing terminals conducted April 6, 1977. The survey was administered by Dennis Hill of the Mass Transportation Planning Section, Michigan Department of Transportation. A total of 211 ticket stubs (119 sold at Lansing, 92 at East Lansing) were obtained from management at the end of the service day. One hundred sixty-eight tickets

TABLE 6

EXAMPLES OF
INDUCED VERSUS DIVERTED DEMAND
FROM RAIL MODELING RESULTS

CITY PAIRS	MODE	GENERATED	ACTUAL
Battle Creek-Detroit	Highway	9.329	9.709
	Rail	3.784	4.250
Jackson-Detroit	Highway	46.866	48.260
	Rail	9.553	5.226
Lansing-Kalamazoo	Highway	58.157	58.470
	Rail	2.287	3.290

(79.6%) of the tickets sold were for intrastate travel. Bus origin-destinations are shown in Appendix D. A data set was constructed using Russell's Official National Motor Coach Guide, April, 1977. The data set is given in Appendix B. Cost data was obtained from station managers at the two terminals. Cost information for city pairs served by more than one bus line was averaged. The two terminals, for calculation purposes, were consolidated in that all buses service both stations. All city pair data was combined and input variables were adjusted accordingly.

Initial model calculations were performed by experimentation with various combinations of market areas for each city pair. Market bands resulting in the best prediction for each origin-destination were chosen and are shown in Appendix B. Due to the generally short distances traveled on bus only a minimum amount of driving bands was established.

Analysis based on an absolute error calculation was performed on the model results according to distance segmentation and given in Table 7. In accordance with the rail analyses, the model severely overestimates demand. This tendency decreases incrementally as distance decreases but unlike the rail results, consistent underestimation of longer distance is not evident. City size analysis is shown in Table 8. No discernible pattern is evident and all error magnitudes are assumed to relate to the distance function.

A wait-time factor based on a 12-hour service day was included in further calculations. Analysis on the results according

TABLE 7

DISTANCE SEGMENTATION ANALYSIS
WITHOUT A WAIT-TIME FACTOR
ON
BUS MODELING RESULTS

CITY PAIR	GENERATED	ACTUAL	ABSOLUTE ERROR
City Pair Distances ≤ 40 Miles			
Lansing/East Lansing-			
-Owosso	25.3	6	+19.3
-Charlotte	29.6	2	+18.7
-Fowlerville	6.7	2	+ 4.7
-Mason	29.9	1	+28.9
-Albion	1	1	0
	Total Absolute Error = 661.3%		
City Pair Distances > 40 ≤ 60 Miles			
Lansing/East Lansing-			
-Flint	63.4	5	+58.4
-Marshall	4.4	2	+ 2.4
-Battle Creek	2.4	2	+22.8
-Lowell	1.4	1	+ 0.4
-Farmington	2.5	4	+ 2.1
-New Hudson	11.6	1	+10.6
-Brighton	12.7	1	+11.7
	Total Absolute Error = 783.1%		
City Pair Distances > 60 ≤ 80 Miles			
Lansing/East Lansing-			
-Mt. Pleasant	7.3	11	- 3.7
-Grand Rapids	69.7	13	+56.7
-Saginaw	10.6	8	+ 2.6
-Ypsilanti	2.3	3	- 0.7
-Ann Arbor	17.6	10	+ 7.6
-Kalamazoo	19.8	3	+16.8
-Pontiac	4.1	2	+ 2.1
-Clare	1.2	2	- 0.8
-Tecumseh	2.3	1	+ 1.3
-Coldwater	1	1	0
	Total Absolute Error = 170.9%		

Table 7 (cont'd.)

CITY PAIR	GENERATED	ACTUAL	ABSOLUTE ERROR
City Pair Distances > 80 ≤ 130 Miles			
Lansing/East Lansing-			
-Detroit	63.1	59	+ 4.1
-Midland	2.4	3	- 0.7
-Muskegon	4.99	4	+ 0.99
-Port Huron	2	1	+ 1
-Cadillac	0.91	1	- 0.09
-Grand Haven	2	1	+ 1
-Holland	2.8	1	+ 1.8
-South Haven	2.3	2	+ 0.3
-Benton Harbor	0.96	1	- 0.04
-Imlay City	0.8	1	- 0.2
	Total Absolute Error = 170.9%		
City Pair Distances > 130 Miles			
Lansing/East Lansing-			
-Traverse City	1.1	1	+ 0.1
-Gaylord	0.17	1	- 0.23
-L'Anse	0	1	- 1
	Total Absolute Error = 64.3%		

TABLE 8

CITY SIZE ANALYSIS
WITHOUT A WAIT-TIME FACTOR
ON
BUS MODELING RESULTS

	CITY PAIR	GENERATED	ACTUAL	ABSOLUTE ERROR
	Lansing/East Lansing-			
A	-Detroit	63.1	59	+ 4.1
	Lansing/East Lansing-			
B	-Grand Rapids	69.7	13	+56.7
	-Saginaw	10.6	8	+ 2.6
	-Ann Arbor	17.6	10	+ 7.6
	-Kalamazoo	19.8	3	+16.8
	-Flint	63.4	5	+58.4
	-Pontiac	4.1	2	+ 2.1
		Total Absolute Error = 351.7%		
	Lansing/East Lansing-			
C	-Jackson	25.3	6	+19.3
	-Midland	2.4	3	- 0.6
	-Muskegon	4.99	4	+ 0.99
	-Port Huron	2	1	+ 1
	-Battle Creek	24	82	+22.8
		Total Absolute Error = 279.3%		
	Lansing/East Lansing-			
D	-Mt. Pleasant	7.3	11	- 3.7
	-Ypsilanti	2.3	3	- 0.7
	-Owosso	20.7	2	+18.7
	-Charlotte	29.6	2	+27.6
	-Marshall	4.4	2	+ 2.4
	-Cadillac	0.91	1	- 0.09
	-Mason	29.9	1	+28.9
	-Traverse City	1.1	1	+ 0.1
	-Tecumseh	2.3	1	+ 1.3
	-Albion	1	1	0
	-Grand Haven	2	1	+ 1
	-Holland	2.8	1	+ 1.8
	-Farmington	25.4	4	+21.4
	-South Haven	2.3	2	+ 0.3
	-Benton Harbor	0.96	1	- 0.04
	-Coldwater	1	1	0
		Total Absolute Error = 450.3%		

Table 8 (cont'd.)

CITY PAIR	GENERATED	ACTUAL	ABSOLUTE ERROR
Lansing/East Lansing-			
E -Clare	1.2	2	- 0.8
-Imlay City	0.8	1	- 0.2
-Fowlerville	6.7	2	+ 4.7
-Lowell	1.4	1	+ 0.4
-Gaylord	0.17	1	- 0.83
-L'Anse	0	1	- 1
-New Hudson	11.6	1	+10.6
-Brighton	12.7	1	+11.7

Total Absolute Error = 302.3%

TABLE 9

DISTANCE SEGMENTATION ANALYSIS
WITH A 12-HOUR WAIT-TIME FACTOR
ON
BUS MODELING RESULTS

CITY PAIR	GENERATED	ACTUAL	ABSOLUTE ERROR
City Pair Distances ≤40 Miles			
Lansing/East Lansing-			
-Jackson	8.3	6	+ 2.3
-Owosso	5.3	2	+ 3.3
-Charlotte	5.1	2	+ 3.1
-Fowlerville	0.8	2	- 1.8
-Mason	1.1	1	+ 0.1
-Albion	0.3	2	- 1.7
	Total Absolute Error = 82%		
City Pair Distances >40 ≤ 60 Miles			
Lansing/East Lansing-			
-Flint	36	5	+31
-Marshall	0.3	2	- 1.7
-Battle Creek	9.7	2	+ 7.7
-Lowell	0.1	1	- 0.9
-Farmington	5.3	4	+ 1.3
-New Hudson	2	1	+ 1
-Brighton	3	1	+ 2
	Total Absolute Error = 285%		
City Pair Distance >60 ≤80 Miles			
Lansing/East Lansing-			
-Mt. Pleasant	4.4	11	+ 6.6
-Grand Rapids	35.3	13	+22.3
-Saginaw	6.2	8	- 1.8
-Ypsilanti	1.2	3	- 1.8
-Ann Arbor	7.9	10	- 2.1
-Kalamazoo	12.3	3	+ 9.3
-Pontiac	2.3	2	+ .3
-Clare	0.5	2	- 1.5
-Tecumseh	0.3	1	- 0.7
-Coldwater	0.01	1	- 0.99
	Total Absolute Error = 87.87%		

Table 9 (cont'd.)

CITY PAIR	GENERATED	ACTUAL	ABSOLUTE ERROR
City Pair Distances >80 ≤130 Miles			
Lansing/East Lansing-			
-Detroit	45.6	59	-13.4
-Midland	1.2	3	- 1.8
-Muskegon	2.2	4	- 1.8
-Port Huron	0.8	1	- 0.2
-Cadillac	0.6	1	- 0.4
-Grand Haven	0.3	1	- 0.7
-Holland	1.1	1	+ 0.1
-South Haven	1.2	2	- 0.8
-Benton Harbor	0.7	1	- 0.3
-Imlay City	0.3	1	- 0.7
	Total Absolute Error = 27.3%		
City Pair Distances >130 Miles			
Lansing/East Lansing-			
-Traverse City	0.7	1	- 0.3
-Gaylord	0.6	1	- 0.94
-L'Anse	0.003	1	- 0.997

TABLE 10

CITY SIZE ANALYSIS
WITH A 12-HOUR WAIT-TIME FACTOR
ON
BUS MODELING RESULTS

	CITY PAIR	GENERATED	ACTUAL	ABSOLUTE ERROR
	Lansing/East Lansing-			
A	-Detroit	45.6	59	-13.4
	Lansing/East Lansing-			
B	-Grand Rapids	35.3	13	+22.3
	-Saginaw	6.2	8	- 1.8
	-Ann Arbor	7.9	10	- 2.1
	-Kalamazoo	12.3	3	+ 9.3
	-Flint	36	5	+31
	-Pontiac	2.3	2	+ 0.3
		Total Absolute Error = 163%		
	Lansing/East Lansing-			
C	-Jackson	8.3	6	+ 2.3
	-Midland	1.2	3	- 1.8
	-Muskegon	2.2	4	- 1.8
	-Port Huron	0.8	1	- 0.2
	-Battle Creek	9.7	2	+ 7.7
		Total Absolute Error = 86.3%		
	Lansing/East Lansing-			
D	-Mt. Pleasant	4.4	11	- 6.6
	-Ypsilanti	1.2	3	- 1.8
	-Owosso	5.3	2	+ 3.3
	-Charlotte	5.1	2	+ 3.1
	-Marshall	0.3	2	- 1.7
	-Cadillac	0.6	1	- 0.4
	-Mason	0.1	1	+ 0.1
	-Traverse City	0.7	1	- 0.3
	-Tecumseh	0.3	1	- 0.7
	-Albion	0.3	2	- 1.7
	-Grand Haven	0.3	1	- 0.7
	-Holland	1.1	1	+ 0.1
	-Farmington	5.3	4	+ 1.3
	-South Haven	1.2	2	- 0.8
	-Benton Harbor	0.7	1	- 0.3
	-Coldwater	0.01	1	- 0.99
		Total Absolute Error = 66.4%		

Table 10 (cont'd.)

CITY PAIR	GENERATED	ACTUAL	ABSOLUTE ERROR
Lansing/East Lansing-			
E -Clare	2.3	2	- 1.5
-Imlay City	0.3	1	- 0.7
-Fowlerville	0.8	2	- 1.8
-Lowell	0.1	1	- 0.9
-Gaylord	0.06	1	- 0.94
-L'Anse	0.003	1	- 0.99
-New Hudson	2	1	+ 1
-Brighton	3	1	+ 2

Total Absolute Error = 98.3%

to distance segmentation is given in Table 9. Examination shows that the absolute error per distance category has been significantly reduced. City size analysis is shown in Table 10. Again, absolute error functions do not appear to correlate to city size categories.

Comparison of the results reveals that the wait-time factor greatly improves model predictive ability for distances less than 80 miles. The model's tendency to reduce overestimation at long distances resulted in better predictions over 80 miles without the wait-time factor, as likewise in the rail analysis.

In analyzing the results from a specific pair, it was found without the wait-time factor, the service characteristics of rail and highway mode were very close. Between Lansing and Grand Rapids the bus mode was only 23 minutes longer and $1.50 higher than the highway mode. The wait-time factor in this case introduced the inconvenience factor of the node and, therefore, provided a more realistic prediction.

The results from bus analyses do not differ in general from those of the previous node and, thus, the recommendation for a permanent distance segmentation factor in the model still seems advisable. The results also coincide with the findings of Peat, Marwick and Mitchell in that consistent overestimation is evident in most city pair calculations.

Preliminary consideration was given to the source of bus passengers; i.e., whether travelers were diverted or induced to the mode. Examples of this analysis are shown in Table 11 and coincide with rail findings. The model appears to overestimate induced demand at the expense of diverted demand from the dominant mode, the automobile.

4. Aviation Results and Analyses

The data used to test the SR1 model for the air mode is from an airline passenger survey conducted by the Michigan Aeronautics Commission in conjunction with SR1. The survey was conducted January 24-30, 1972. Ticket accounts were accumulated at the end of the week by the State Airport System Planning Section. Mr. Edward Mellman of the Planning Section supplied to the author the survey data. Three Michigan airports were selected to be surveyed:

Lansing Capitol City Airport
Flint's Bishop Airport
Grand Rapids' Kent County Airport

Airlines included in the survey were:

Lansing	- United North Central
Flint	- United North Central
Grand Rapids	- Allegheny United North Central

Table 12 shows the number of intrastate travelers during the survey week per airport. Intrastate aviation movements are shown per airport in Appendix D.

The data was coded for keypunching and transferred to a computer disc. Trip tables were formed and the data was analyzed. Input variable data was then constructed utilizing the Official Airline Guide, North American Edition, September, 1973. This

TABLE 11

EXAMPLES OF
INDUCED VERSUS DIVERTED DEMAND
FROM BUS MODELING RESULTS

CITY PAIR	MODE	GENERATED	ACTUAL
Lansing-East Lansing-			
-Detroit	Highway	306.793	321.738
	Bus	45.56	59
-Grand Rapids	Highway	111.844	115.202
	Bus	35.2	13
-Saginaw	Highway	39.1	39.7
	Bus	6.236	8

TABLE 12

INTRASTATE AVIATION TRAVELERS
SURVEYED
JANUARY 24-30, 1972

AIRPORT	PASSENGERS
Lansing	1,218
Flint	111
Grand Rapids	3,151
Total	4,480

edition was the closest available information to the actual survey data. Information for both direct and indirect flights was obtained. In the creation of input variables for flights with connections not stated in the Airline Guide frequencies for a given origin and destination were calculated by first determining the shortest travel time and then only connections relatively close to this time were considered for input. In calculating travel time, care was taken to account for the two different time zones in Michigan. Cost figures were cross-checked on some routes with information obtained from Ms. Kay Lund, Director of Consumer Affairs, United Air Lines District Office, Chicago, Illinois. It is not unlikely, however, that connecting flights that were created but were not available for cross-checking may be slightly higher than the actual ticket price. A data set for considered origins and destinations is given in Appendix B.

Upon analyzing the trip tables it was noticed that many pairs had unexpected volumes; for example, Lansing to Marquette recorded 576 tirps. The survey data was cross-checked with the closest available origin-destination data for the subject pairs. Average weekly travel for the survey week and for 1975 is shown in Appendix C. Observation of the data reveals that flights to destinations in the Upper Peninsula are from two to six times higher than the weekly average. Given the calendar time of the survey, these volumes probably reflect ski trips to winter resorts. Another unexpected pair volume occurred from Grand Rapids to Detroit. The survey data is five times the weekly average. This variance may be due to conventions or other irregular events.

The survey data was received in a weekly aggregate per airport. The data was converted into daily volumes in that the SR1 model is designed for daily calculations. A slight amount of error was introduced into the analysis in that daily flights per a given pair on a weekend versus a weekday basis may differ. This, however, was not felt to unreasonably distort the data.

Initial model calculations were performed by experimentation with various combinations of market areas for each pair. Driving bands resulting in the best prediction for each origin-destination pair were chosen and are shown in Appendix B. In general, time bands for city pairs were distributed as follows:

City Pair Distance	Market Area
<80 miles	(0,0)
>80 ≤ 130 miles	(10,10)
>130 ≤ 250 miles	(20,20)
>250 - 500+ miles	(30,30)

It is logical for distances under 2-2½ hours auto driving times that travelers will not drive very far to get to an airport and that distances requiring from 5-10 hours driving time travelers will drive up to 30 minutes to board a plane.

Analysis based on absolute error calculations was performed on the model results according to distance, segmentation and is given in Table 13. Examination shows the model is predicting very poorly. For distances under 130 miles, volumes are severely underestimated. Because of the magnitude of error, individual distance segment error was not calculated. City pair analysis (not shown) reveals that city size interactions do not significantly contribute to error.

A wait-time factor based on a 16-hour service day was included in the model calculations to correct for overestimations. Results according to distance segmentation are shown in Table 14. Overestimation of volumes for pair distances under 130 miles were significantly reduced by the wait-time factor, but predictions still differ significantly from the observed.

Based on the results from these analyses, model adjustments are advisable. A permanent distance segmentation factor should be attached to the model to modify the tendency to overestimate short distance pairs and underestimate long distance pairs.

Many of the high volume destinations, particularly in the Upper Peninsula, do not reflect the socio-economic characteristics of the inhabitant but rather recreational attractions. The model as currently constructed is unable to accommodate such considerations. Moreover, to attempt to calibrate the current model construction to fit such variations would destroy its predictive capabilities for non-resort destinations. It is advisable that an additional variable sensitive to resort destination volumes be added to the model. In general, the special amenities of many Michigan cities in the northern Lower Peninsula and the Upper Peninsula introduce many complications in the modeling effort. This unique factor is particularly evident in the air mode due to the attractiveness of air travel in winter months.

TABLE 13

DISTANCE SEGMENTATION ANALYSIS
WITHOUT A WAIT-TIME FACTOR
ON
AVIATION MODELING RESULTS

CITY PAIR	GENERATED	ACTUAL	ABSOLUTE ERROR
City Pair Distances ≤40 Miles			
Flint-Saginaw	45.7	0.43	+45.3
Lansing-Jackson	0.38	0	+ .38
Grand Rapids-Muskegon	8.6	0	+ 8.6
City Pair Distances >40≤ 60 Miles			
Flint-Lansing	27.6	0	+27.6
Flint-Detroit	61.8	0.3	+61.5
Lansing-Flint	29.7	0	+29.7
Grand Rapids-Kalamazoo	0.46	0	+ 0.46
City Pair Distances >60 ≤ 80 Miles			
Flint-Jackson	1.77	0	+ 1.8
Lansing-Grand Rapids	6.9	0.14	+ 6.8
Lansing-Saginaw	2.3	0	+ 2.3
Lansing-Kalamazoo	0.8	0	+ 0.8
Grand Rapids-Lansing	50.9	0.3	+50.6
City Pair Distances >80 ≤ 130 Miles			
Lansing-Muskegon	34.1	0	+34.1
Lansing-Detroit	79	1.6	+77.4
Lansing-Benton Harbor	2	0	+ 2
Grand Rapids-Saginaw	17.4	3.4	+14
Grand Rapids-Manistee	1.4	0	+ 1.4
Grand Rapids-Benton Harbor	9	0	+ 9
Grand Rapids-Flint	2	0	+ 2
Grand Rapids-Jackson	0.12	0	+ 0.12
Flint-Kalamazoo	3.4	0.14	+ 3.2
Flint-Grand Rapids	6.9	0.4	+ 6.5
City Pair Distances >130 ≤ 190 Miles			
Flint-Muskegon	6	0	+ 0.6
Flint-Alpena	0.15	0.3	- 0.15
Flint-Traverse City	0.8	5.1	- 4.3
Flint-Benton Harbor	0.7	0	+ 0.7
Flint-Manistee	0.1	0	+ 0.1
Lansing-Traverse City	0.6	1.7	- 1.1
Lansing-Manistee	0.2	0	+ 0.2
Grand Rapids-Traverse City	4.5	0	+ 4.5
Grand Rapids-Detroit	170.4	333.7	-163.3

Table 13 (cont'd.)

CITY PAIR	GENERATED	ACTUAL	ABSOLUTE ERROR
City Pair Distances > 190 ≤ 250 Miles			
Flint-Pellston	0.1	0	+ 0.1
Lansing-Alpena	0.2	0	+ 0.2
Lansing-Pellston	0.1	0	+ 0.1
Grand Rapids-Pellston	0.02	0	+ 0.02
Grand Rapids-Alpena	0.2	0	+ 0.2
City Pair Distances > 250 ≤ 350 Miles			
Flint-Sault Ste. Marie	0.2	8.6	- 8.4
Lansing-Escanaba	0.6	19.3	-18.7
Lansing-Sault Ste. Marie	0.13	10	- 9.9
Grand Rapids-Sault Ste. Marie	0.43	2.1	- 1.7
City Pair Distances > 350 ≤ 450 Miles			
Flint-Marquette	0.3	0.6	- 0.3
Flint-Menominee	0.1	0	+ 0.1
Flint-Iron Mountain	0.2	0	+ 0.2
Flint-Escanaba	0.2	0	+ 0.2
Lansing-Menominee	0.1	2	- 1.9
Lansing-Marquette	0.6	82.3	-81.7
Lansing-Iron Mountain	0.3	33	-32.7
Grand Rapids-Escanaba	0.9	15.4	-14.5
Grand Rapids-Marquette	1	46.3	-45.3
Grand Rapids-Menominee	0.5	5.1	- 4.6
Grand Rapids-Iron Mountain	0.6	15.4	-14.8
City Pair Distances > 450 Miles			
Flint-Hancock	0.1	0	+ 0.1
Flint-Ironwood	0.1	0	+ 0.1
Lansing-Hancock	0.1	18	-17.9
Lansing-Ironwood	0.1	6	- 5.9
Grand Rapids-Hancock	0.2	28.3	-28.1
Grand Rapids-Ironwood	0.2	0	+ 0.2

TABLE 14

DISTANCE SEGMENTATION ANALYSIS
WITH A 16-HOUR WAIT TIME FACTOR
ON
AVIATION MODELING RESULTS

CITY PAIR	GENERATED	ACTUAL	ABSOLUTE ERROR
City Pair Distances < 40 Miles			
Flint-Saginaw	8.7	0.43	+ 8.3
Lansing-Jackson	0.04	0	+ 0.04
Grand Rapids-Muskegon	0.2	0	+ 0.2
City Pair Distances > 40 ≤ 60 Miles			
Flint-Lansing	0.6	0	+ 0.6
Flint-Detroit	15.3	0.3	+ 15
Lansing-Flint	0.6	0	+ 0.6
Grand Rapids-Kalamazoo	0.1	0	+ 0.1
City Pair Distances > 60 ≤ 80 Miles			
Flint-Jackson	0.1	0	+ 0.1
Lansing-Grand Rapids	5.2	0.14	+ 5.1
Lansing-Saginaw	0.2	0	+ 0.2
Lansing-Kalamazoo	0.4	0	+ 0.4
Grand Rapids-Lansing	7.7	0.3	+ 7.4
City Pair Distances > 80 ≤ 130 Miles			
Lansing-Muskegon	5	0	+ 5
Lansing-Detroit	30.5	1.6	+ 28.9
Lansing-Benton Harbor	0.4	0	+ 0.4
Grand Rapids-Saginaw	0.6	3.4	- 2.8
Grand Rapids-Manistee	0.4	0	+ 0.4
Grand Rapids-Benton Harbor	1.7	0	+ 1.7
Grand Rapids-Flint	0.2	0	+ 0.2
Grand Rapids-Jackson	0.03	0	+ 0.03
Flint-Kalamazoo	0.6	0.14	+ 0.5
City Pair Distances > 130 ≤ 190 Miles			
Flint-Muskegon	0.3	0	+ 0.3
Flint-Alpena	0.02	0.3	- 0.3
Flint-Traverse City	0.2	5.1	- 4.9
Flint-Benton Harbor	0.14	0	+ 0.14
Flint-Manistee	0.02	0	+ 0.02
Lansing-Traverse City	0.3	1.7	- 1.4
Lansing-Manistee	0.02	0	+ 0.02
Grand Rapids-Traverse City	0.2	0	+ 0.2
Grand Rapids-Detroit	95	333.7	-238.7

Table 14 (cont'd.)

CITY PAIR	GENERATED	ACTUAL	ABSOLUTE ERROR
City Pair Distances $>190 \leq 250$ Miles			
Flint-Pellston	0.02	0	+ 0.02
Lansing-Alpena	0.3	0	+ 0.3
Lansing-Pellston	0.2	0	+ 0.2
Grand Rapids-Pellston	0	0	0
Grand Rapids-Alpena	0.1	0	+ 0.1
City Pair Distances $>250 \leq 350$ Miles			
Flint-Sault Ste. Marie	0	8.6	- 8.6
Lansing-Escanaba	0.2	19.3	- 19.1
Lansing-Sault Ste. Marie	0.1	10	- 9.9
Grand Rapids-Sault Ste. Marie	0.1	2.1	- 2
City Pair Distances $>350 \leq 450$ Miles			
Flint-Marquette	0.1	0.6	- 0.5
Flint-Menominee	0	0	0
Flint-Iron Mountain	0	0	0
Flint-Escanaba	0	0	0
Lansing-Menominee	0	2	- 2
Lansing-Marquette	0.2	82.3	- 82.1
Lansing-Iron Mountain	0.1	33	- 32.9
Grand Rapids-Escanaba	0.4	15.4	- 15
Grand Rapids-Marquette	0.4	46.3	- 45.9
Grand Rapids-Menominee	0.1	5.1	- 5
Grand Rapids-Iron Mountain	0.1	15.4	- 15.3
City Pair Distances >450 Miles			
Flint-Hancock	0	0	0
Flint-Ironwood	0	0	0
Lansing-Hancock	0.1	18	- 17.9
Lansing-Ironwood	0	6	- 6
Grand Rapids-Hancock	0	28.3	- 28.3
Grand Rapids-Ironwood	0	0	0

The results from these analyses are more difficult to interpret due to the large error factor. It is apparent, however, that short distance pairs are overstated and long distance pairs understated. This conclusion is in concurrence with findings from previous modes. These results, however, differ from the conclusions of Peat, Marwick and Mitchell who found the air mode to be the most precise prediction of the three modes.

Table 15 shows the model, as discussed with previous modes, appears to attribute disproportionate values to induced demand.

TABLE 15

EXAMPLES OF
INDUCED VERSUS DIVERTED DEMAND
FROM AVIATION MODELING RESULTS

CITY PAIR	MODE	GENERATED	ACTUAL
Flint-Saginaw	Highway	1467.827	1470.688
	Air	8.7	3
Flint-Detroit	Highway	101.2	102.5
	Air	15.3	2
Lansing-Grand Rapids	Highway	135.9	136.6
	Air	5.1	1
Lansing-Detroit	Highway	356.2	368.4
	Air	30.5	11

V. SUMMARY

This research has evaluated and tested, using Michigan-based data, the Stanford Research Institute's Intercity Passenger Demand/Modal Split Model. Unfortunately only limited comparison of these results with other intercity modeling research was possible. Much transportation literature only discusses, in theory, statewide modeling. Research concerned with multi-modal modeling is usually characterized by a small data base. These results do compare favorably with two sources of published research on the model. It has been shown the model:

1. Overestimates demand for short-distance city pairs.
2. Underestimates demand for long-distance city pairs.
3. City size differences do not significantly affect the model's performance.
4. Bus demand is consistently overestimated.
5. Induced demand is overestimated to the detriment of derived demand.

Two variations of the SR1 model were used which served to augment it. Driving time bands increase the market area for a given model terminal and provide a more realistic measure of the attractiveness of the service to surrounding populations. A wait time factor based on the length of a common carrier mode's service day, tends to compensate for the model's tendency to overestimate demand and introduces into the model the inconvenience factor of the mode.

The model aggregates "quality" variables of the common carrier modes, such as comfort, safety, reliability, into one parameter in the formula. This aggregation may be too gross to reasonably reflect reality. The model considers both time and cost as input variables. Some degree of predictive ability is lost because of multi-collinearity; however, for policy-testing purposes, it may be necessary to retain both variables. Time and cost are treated as equal variables in terms of ability to influence changes in demand. Some studies, however, have shown time to be a significantly more important variable.

Finally, the socio-economic statistic used in demand forecasting by the model was families with incomes of $10,000 or more in 1970. This measure needs to be updated to reflect more current per capita income levels.

CONCLUSIONS

The conclusions found through this research may be summarized as follows:

1. The model needs a permanent distance segmentation function. In the results from all three modal modeling efforts, it was found that short distance pair demand was overestimated and that demand between long distance pairs was underestimated.

2. A measure to more adequately distribute induced versus derived demand is needed. Again, in all three modal results, it was discovered almost all the generated demand for non-highway modes come from induced demand. A minimal amount of demand was diverted from generated automobile demand to common carrier modes.

3. An additional variable sensitive to resort areas in Michigan needs to be augmented, especially with reference to air travel. Many of the high volume

destinations in air travel were found not to be a reflection of the socio-economic characteristics of the inhabitant, as the model presupposes but rather due to the special amenity factors of the area, such as ski facilities, water recreation opportunities, etc.

4. The city size adjustment factor, G, which segments pairs having large population products from those having smaller products, appears to be functioning adequately. In city size tests performed on all modal results, no consistent pattern of error was evident.

5. With appropriate adjustments the model can be used to forecast horizon-year modal volumes. The ease of changing levels of the input variables makes the model especially attractive for testing policy alternatives.

FUTURE RESEARCH NEEDS

In the conduct of this research several areas requiring additional investigation were discovered. Further work on this model should use as recent data as possible. Data in this research ranged from 1972 aviation data to 1975 rail data. It should not be difficult to cull recent rail data. Up-to-date aviation and bus data, however, may require time consuming passenger surveys. Effort should be exerted to correlate the time periods of the data as close as possible. A further refinement of the research herein would be to run the computer program simultaneously for all four modes so that more acceptable multi-modal comparisons can be performed. Experimentation with the adding of "quality" modal attributes, such as comfort, safety, time dependability, should be explored. This may result in the addition of other parameters to the equation. The use of a constant price elasticity in the model needs further research confirmation. The model assumes that a doubling of ticket price will affect all income groups similarly. This assumption does not appear to be reasonable. Finally, more evaluation on statewide modeling procedures is necessary so that more precise results are available as to wiether statewide aggregate modeling sufficiently reflects behavioral characteristics of the population. Disaggregate modeling proponents argue that much accumulated error is contained in aggregate modeling and that modeling results reflect peculiarities of a particular data set and prediction equations may not be transferred effectively to different data sets.

FOOTNOTES

[1]John W. Billheimer, Stanford Research Institute, The Michigan Intercity Passenger Demand Model, June, 1971.

[2]Transportation Research Board, Special Repot 146, Issues in Statewide Transportation Planning, (Washington, D.C.; National Research Council, 1974).

[3]Peter R. Stopher and Joseph N. Prashker, "Intercity Passenger Forecasting: The Use of Current Travel Forecasting Procedures", Transportation Research Forum, 1976.

[4]Philip I. Hazen, A Comparative Analysis of Statewide Transportation Studies (Evanston, Illinois: Northwestern University, 1971). An unpublished M.S. Thesis.

[5]Ibid., and Transportation Research Institute--Carnegie Mellon University and Pennsylvania Transportation and Traffic Safety Center--Pennsylvania State University; Methodological Framework for Comprehensive Transportation Planning, pp. 90-92.

[6]Robert A. Nelson, Paul W. Shuldiner, Myron Miller, Miller Stinchcombe and Robert L. Winestone, Northeast Corridor Transportation Project Report 209 (Washington, D.C.: U.S. Government Printing Office, April, 1970), pp. 8-20.

[7]David Arthur Brown, An Intercity Passenger Transportation Demand Model (Stanford, California, 1969), pp. 19-20.

[8]J. A. Josephs, D. M. Hill, N. A. Irwin, J. M. McLynn, R. H. Watkins and Arrigo Mongini, Northeast Corridor Transportation Project Technical Paper No. 7, Approaches to the Modal Split: Intercity Transportation (Washington, D.C.: U.S. Government Printing Office, February, 1967), pp. 32-33.

[9]Billheimer, loc. cit.

[10]Ibid., pp. 7-8; 11-12.

[11]Ibid., p. 15.

[12]H. C. W. L. Williams, "Travel Demand Models, Duelity Relations and User Benefit Analysis," Journal of Regional Science, 1976, p. 310.

Footnotes (cont'd.)

[13]John C. Bennett, Raymond H. Ellis and John C. Prokopy, Peat, Marwick, Mitchell and Co., A Comparative Evaluation of Intercity Modal Split Model (date not available): U.S. Department of Transportation.

[14]The following discussion derives from the seven listed publications of Richard E. Esch listed in the bibliography.

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APPENDIX A

APPENDIX A

HIGHWAY COST CALCULATIONS BASED ON AVERAGE LINK SPEED*

Unit: Dollars per 1,000 vehicle miles.

	RUNNING COST PER ITEM						
SPEED MPH	TIRES	ENGINE OIL	MAINTENANCE	DEPRECIATION	FUEL	GALLONS CONSUMED	TOTAL COST
25	1.60	1.64	6.25	16.67	21.75	43.5	47.37
30	1.32	1.60	6.60	15.55	21.40	42.8	46.47
35	1.60	1.59	6.97	14.64	21.65	43.3	46.45
40	1.90	1.58	7.37	13.91	22.35	44.7	47.10
45	2.23	1.55	7.77	13.32	23.40	46.8	48.27
50	2.61	1.49	8.19	12.83	24.80	49.6	49.92
55	3.03	1.37	8.64	12.43	26.60	53.2	52.07
60	3.53	1.43	9.13	12.08	28.80	57.6	54.97
65	4.12	1.61	9.67	11.78	31.55	83.1	58.75

Assumptions: 1) Level Grade
2) Gasoline = .50/Gallon

*Winfrey, Robley, Economic Analysis for Highways, Scranton, Pennsylvania: Inter=national Textbook Company, 1969. Table A-1, p. 680; Table A-26-M, p. 705.

APPENDIX B

APPENDIX B

DATA SET
FOR RAIL MODELING

CITY PAIR	FREQUENCY	COST (DOLLARS)	TIME (MINUTES)	MARKET AREA (DRIVING TIME BANDS)	DISTANCE (MILES)
NILES TO:					
Kalamazoo	4	2.75	60	(0,0)	47
Battle Creek	4	4.00	100	(0,0)	71
Detroit	3	10.50	230	(30,0)	190
Lansing	1	6.50	190	(20,20)	128
Flint	1	8.75	265	(15,15)	178
Lapeer	1	10.00	290	(20,20)	198
Port Huron	1	12.50	345	(45,45)	229
Ann Arbor	3	8.25	175	(25,25)	154
Durand	1	8.00	215	(20,20)	148
Jackson	3	6.50	140	(10,10)	116
KALAMAZOO TO:					
Niles	4	2.75	60	(0,0)	47
Durand	1	5.50	155	(10,10)	101
Lapeer	1	7.50	230	(20,20)	138
Battle Creek	4	1.50	40	(0,0)	24
Jackson	3	3.75	85	(0,0)	69
Detroit	3	7.75	160	(10,10)	143
Ann Arbor	3	5.75	120	(15,15)	127
Flint	1	6.50	205	(15,15)	127
Lansing	1	3.75	130	(0,0)	72
Port Huron	1	9.75	285	(30,30)	182
BATTLE CREEK TO:					
Niles	4	4.00	100	(0,0)	71
Kalamazoo	4	1.50	40	(0,0)	24
Jackson	3	2.50	55	(0,0)	45
Ann Arbor	3	4.50	90	(0,0)	83
Port Huron	1	8.50	235	(30,30)	158
Lapeer	1	6.25	190	(0,10)	114
Flint	1	5.25	165	(0,0)	94
Durand	1	4.25	125	(0,0)	77
Detroit	3	6.50	145	(0,0)	119
Lansing	1	2.50	80	(0,0)	48

Appendix B (cont'd.)

CITY PAIR	FREQUENCY	(DOLLARS)	(MINUTES)	MARKET AREA (DRIVING TIME BANDS)	DISTANCE (MILES)
JACKSON TO:					
Niles	3	6.50	140	(10,10)	116
Kalamazoo	3	3.75	80	(0,0)	69
Battle Creek	3	2.50	50	(0,0)	45
Ann Arbor	3	2.25	35	(0,0)	38
Detroit	3	4.00	90	(0,0)	74
LANSING TO:					
Niles	1	6.50	190	(15,15)	128
Kalamazoo	1	3.75	130	(0,0)	72
Battle Creek	1	2.50	80	(0,0)	48
Durand	1	2.00	40	(0,0)	29
Flint	1	2.75	75	(0,0)	46
Lapeer	1	3.75	105	(0,0)	66
Port Huron	1	6.25	155	(0,0)	110
ANN ARBOR TO:					
Niles	3	8.25	175	(25,25)	154
Kalamazoo	3	5.75	120	(15,15)	127
Battle Creek	3	4.50	90	(0,0)	83
Jackson	3	2.25	35	(0,0)	38
Detroit	3	2.25	55	(0,0)	36
DETROIT TO:					
Niles	3	10.50	230	(0,30)	190
Kalamazoo	3	7.75	160	(10,10)	143
Battle Creek	3	6.50	145	(0,0)	119
Jackson	3	4.00	90	(0,0)	74
Ann Arbor	3	2.25	55	(0,0)	36
PORT HURON TO:					
Flint	1	3.50	85	(0,0)	64
Lapeer	1	2.50	50	(0,0)	48
Durand	1	4.50	125	(20,20)	81
Lansing	1	6.25	155	(0,0)	110
Battle Creek	1	8.50	235	(30,30)	158
Kalamazoo	1	9.75	285	(30,30)	182
Niles	1	12.50	345	(40,40)	229

Appendix B (cont'd.)

CITY PAIR	FREQUENCY	COST (DOLLARS)	TIME (MINUTES)	MARKET AREA (DRIVING TIME BANDS)	DISTANCE (MILES)
FLINT TO:					
Niles	1	8.75	265	(10,20)	178
Kalamazoo	1	6.50	205	(15,15)	127
Battle Creek	1	5.25	165	(0,0)	94
Lansing	1	2.75	75	(0,0)	46
Durand	1	1.00	30	(0,0)	17
Lapeer	1	1.50	35	(0,0)	21
Port Huron	1	3.50	85	(0,0)	64
DURAND TO:					
Niles	1	8.00	215	(15,15)	148
Kalamazoo	1	5.50	155	(10,10)	101
Battle Creek	1	4.25	125	(0,0)	77
Lansing	1	2.00	40	(0,0	29
Flint	1	1.00	30	(0,0)	17
Port Huron	1	4.50	125	(20,20)	81
Lapeer	1	1.50	65	(0,0)	37
LAPEER TO:					
Niles	1	10.00	290	(20,10)	198
Kalamazoo	1	7.50	230	(20,10)	138
Battle Creek	1	6.25	190	(10,0)	114
Lansing	1	3.75	105	(0,0)	66
Flint	1	1.50	35	(0,0)	21
Durand	1	1.50	65	(0,0)	37
Port Huron	1	2.50	50	(0,0)	48

APPENDIX B

DATA SET
FOR BUS MODELING

CITY PAIR	FREQUENCY	COST (DOLLARS)	TIME (MINUTES)	MARKET AREA (DRIVING TIME BANDS)	DISTANCE (MILES)
LANSING/EAST LANSING TO:					
Detroit	10	5.20	165	(0,0)	85
Mt. Pleasant	6	5.20	120	(10,30)	658
Grand Rapids	6	4.15	90	(0,0)	65
Saginaw	5	4.90	155	(0,0)	70
Jackson	4	2.95	70	(0,0)	38
Ypsilanti	4	5.50	145	(0,0)	77
Ann Arbor	4	5.10	115	(0,0)	63
Midland	2	6.85	240	(10,10)	86
Muskegon	3	6.35	145	(0,0)	104
Kalamazoo	7	4.60	125	(0,0)	73
Flint	7	3.70	100	(0,0)	50
Owosso	4	2.50	50	(0,0)	31
Charlotte	4	1.55	30	(0,0)	20
Pontiac	4	6.00	220	(0,0)	69
Clare	3	5.40	135	(20,20)	88
Port Huron	2	8.40	220	(0,0)	119
Imlay City	2	6.00	175	(15,15)	84
Fowlerville	2	2.30	50	(0,0)	27
Marshall	1	3.00	60	(0,0)	45
Battle Creek	5	3.20	70	(0,0)	49
Cadillac	4	8.80	225	(30,30)	127
Lowell	1	4.00	80	(0,0)	53
Mason	1	1.25	35	(0,0)	10
Traverse City	3	12.30	280	(30,30)	171
Tecumseh	1	5.10	120	(0,0)	65
Albion	2	4.35	145	(0,0)	40
Gaylord	1	11.90	270	(30,30)	168
Grand Haven	1	6.10	130	(0,0)	96
Holland	3	5.90	135	(0,0)	88
L'Anse	1	31.00	1080	(45.45)	457
Farmington	2	4.45	85	(0,0)	59
South Haven	2	7.75	197	(30,30)	111
North Hudson	2	3.65	70	(0,0)	59
Brighton	3	2.90	60	(0,0)	42
Benton Harbor	5	7.85	220	(0,0)	123
Coldwater	1	6.15	120	(0,0)	69

APPENDIX B

DATA SET
FOR AVIATION MODELING

CITY PAIR	FREQUENCY	COST (DOLLARS)	TIME (MINUTES)	MARKET AREA (DRIVING TIME BANDS)	DISTANCE (MILES)
GRAND RAPIDS TO:					
Saginaw	1	22	25	(10,10)	116
Traverse City	1	24	30	(20,20)	139
Lansing	4	16	20	(0,0)	65
Benton Harbor	4	19	25	(10,10)	83
Muskegon	1	16	20	(0,0)	40
Manistee	1	21	30	(10,10)	119
Escanaba	3	35	130	(30,30)	368
Marquette	3	38	135	(30,30)	387
Menominee	2	29	105	(30,30)	423
Flint	1	38	130	(20,20)	104
Detroit	9	27	45	(20,20)	149
Alpena	2	55	190	(20,20)	247
Pellston	1	43	175	(10,10)	195
Jackson	1	49	270	(10,10)	98
Kalamazoo	1	39	150	(0,0)	50
Sault Ste. Marie	1	48	90	(30,30)	278
Iron Mountain	3	46	110	(30,30)	420
Hancock	1	42	240	(30,30)	492
Ironwood	1	52	140	(30,30)	532
LANSING TO:					
Flint	1	19	20	(0,0)	50
Grand Rapids	3	16	20	(0,0)	65
Muskegon	3	17	25	(20,20)	104
Escanaba	2	38	150	(30,30)	327
Marquette	2	42	165	(30,30)	391
Menominee	1	35	195	(30,30)	426
Detroit	8	17	25	(0,0)	83
Saginaw	1	36	95	(10,10)	70
Alpena	1	45	145	(20,20)	211
Pellston	1	53	240	(30,30)	212
Traverse City	4	45	140	(20,20)	171
Jackson	1	36	80	(0,0)	138
Kalamazoo	4	38	140	(0,0)	73
Benton Harbor	2	35	95	(20,20)	120
Manistee	1	37	125	(20,20)	171

Appendix B (cont'd.)

CITY PAIR	FREQUENCY	COST (DOLLARS)	TIME (MINUTES)	MARKET AREA (DRIVING TIME BANDS)	DISTANCE (MILES)
LANSING TO: (cont'd.)					
Sault Ste. Marie	3	58	230	(30,30)	282
Iron Mountain	2	49	135	(30,30)	423
Hancock	2	56	230	(30,30)	485
Ironwood	1	55	175	(30,30)	535
FLINT TO:					
Saginaw	6	16	20	(10,10)	36
Jackson	1	22	75	(0,0)	80
Lansing	1	20	20	(0,0)	50
Kalamazoo	2	26	90	(10,10)	123
Grand Rapids	1	22	90	(10,10)	104
Muskegon	3	42	210	(10,10)	144
Escanaba	1	65	235	(30,30)	369
Marquette	1	61	210	(30,30)	388
Menominee	1	60	215	(30,30)	424
Detroit	5	19	25	(0,0)	60
Alpena	1	41	165	(10,10)	173
Pellston	1	55	210	(20,20)	210
Traverse City	2	47	100	(20,20)	182
Benton Harbor	1	41	215	(20,20)	170
Manistee	1	43	270	(20,20)	182
Sault Ste. Marie	1	60	210	(30,30)	279
Iron Mountain	1	57	215	(30,30)	421
Hancock	1	71	300	(30,30)	483
Ironwood	1	75	255	(30,30)	533

APPENDIX C

APPENDIX C

COMPARISON OF AVIATION SURVEY DATA WITH 1975 ORIGIN-DESTINATION AVERAGES

CITY PAIR	SURVEY O-D VOLUME (WEEK)	1975* WEEKLY AVERAGE
LANSING TO:		
Flint	0	0.38
Escanaba	135	67.5
Menominee	14	17.3
Benton Harbor	0	8.6
Detroit	11	149
Hancock	126	72.7
Muskegon	0	3.7
Grand Rapids	1	3.7
Ironwood	42	14.6
Iron Mountain	231	44.2
Sault Ste. Marie	70	3.5
Traverse City	12	17.5
Manistee	0	0.4
Pellston	0	0.96
Marquette	576	91.7
FLINT TO:		
Lansing	0	0.38
Escanaba	0	0.96
Menominee	0	0.2
Detroit	2	57.3
Hancock	0	1.7
Marquette	4	2.5
Muskegon	0	5
Grand Rapids	3	80.4
Iron Mountain	0	0.96
Kalamazoo	1	0
Saginaw	3	0.38
Alpena	2	1.9

Appendix C (cont'd.)

CITY PAIR	SURVEY O-D VOLUME (WEEK)	1975* WEEKLY AVERAGE
GRAND RAPIDS TO:		
Lansing	2	3.7
Escanaba	108	26.5
Menominee	36	23.3
Benton Harbor	0	2.5
Detroit	2336	433.7
Hancock	198	34
Marquette	324	54.6
Ironwood	0	9.2
Iron Mountain	108	29.8
Sault Ste. Marie	15	12.7
Traverse City	0	22.3
Pellston	0	9.2
Saginaw	24	9.6
Flint	0	1.2

*Creighton, Roger. Michigan Scheduled Air Service Study, Final Technical Report, September, 1977.

APPENDIX D

Pocket has: 5 maps