IGAN STATE AIRPORT SYSTEM PLAN

INTERIM REPORT

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data collection and analysis methods

MICHIGAN AERONAUTICS COMMISSION
DEPARTMENT OF COMMERCE
in Conjunction With
STANFORD RESEARCH INSTITUTE
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Interim Report: Data Collection and Analysis Methods

STATE AIRPORT SYSTEM PLAN STUDY

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I INTRODUCTION

Among the currently accepted assumptions in planning future air carrier airports in the United States are the rapid growth of air passenger travel; the emergence of second, third, and fourth generations of wide-bodied aircraft; and the use of very large airports to serve major metropolitan areas. While recent years have seen a considerable reduction in passenger travel growth rates and appreciable financial distress on the part of air carriers, the long range outlook for aviation progress is still bright. One can visualize many 1980 and 1990 major hub airports serving from 50 million to 150 million passengers annually with high efficiency and superior service.

Although heavy emphasis must be placed on providing air service to major metropolitan areas, it is clear that air service needs of cities of 100,000 to 500,000 population also must be considered. In recent years, airport operators at some of these cities, while experiencing growth in air traffic, have also seen a reduction in service provided by certificated airlines. As aircraft size, payload, and speed have increased, air carriers have discovered that providing service to many of the smaller airports is economically marginal. Numerous cases can be cited in the recent past in which air carriers have reduced schedule frequency or discontinued service to specific cities. Therefore, the airport operator in these cities considers one of his problems to be maintaining service rather than planning for gigantic growth.

Another factor that has changed the competitive position of air service to small-to-medium sized metropolitan areas is the vast improvement in the nation's interstate highway network. This system is nearing completion, and intercity travel at average speeds of 60 miles per hour are now common, with a significant competitive impact on airlines, particularly at distances up to 300 or 400 miles.

The success of commuter airlines ("third-level" carriers) in providing service also has substantial impact on the small-to-medium sized city airport operator. Over the years, the history of financial and customer service performance of these carriers has been spotty. Some operators have achieved considerable success, while others have ceased operation. As larger aircraft become more prevalent in the fleets of first- and second-level carriers, however, future potentials for commuter airline service could increase significantly.

In many areas, less than desired air service at small-to-medium size cities is related to their proximity to neighboring cities of similar (or larger) size. Although civic pride is associated with having airline service at each of such cities, their combined traffic (at a regional airport) might generate better airline service.

Recognition of the merits of regional air carrier airports is not new. In 1961, the administrator of the Federal Aviation Agency (FAA) and the Chairman of the Civil Aeronautics Board (CAB) jointly issued a statement of policy with respect to the development and use of air carrier airports. The statement is quoted in part below.

> The Federal Aviation Agency and the Civil Aeronautics Board agree that the use of a single airport serving adjacent communities, where such action may result in a savings both to the federal government and the localities served, as well as improving the air service to the area, should be an increasingly important factor in considering applications for federal funds for airport construction purposes and applications for certified airline service.*

Airport Planning in Michigan

The need for considering regional airports has been recognized in Michigan for some time. Legislation in 1957 and 1958 permitted two or more governmental jurisdictions to incorporate into an airport authority for the planning, construction, acquisition, and operation of one or more airports. However, with this permissive legislation, regional airport authorities have not been popular. This has been attributable in part to weaknesses in the financial aspects of the legislation; it also can be traced to the fact that the required impetus for forming the regional authorities has not come from local levels.

Recognizing that many of its urban areas face the situation described above, the Michigan Aeronautics Commission (MAC) decided to undertake an analysis of the merits of providing increased air carrier service to Michigan residents through a system of regional airports. As a complement to the effort, legislation now before the Michigan State Legislature would provide specific incentive for counties to form regional air carrier airport districts by enabling them to generate tax revenue to support airport planning and development.

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* FAA advisory circular 150/5090-1, February 2, 1967.

To many local airport planners, the need for state planning assistance is questionable. However, it appears clear that state-level planning can provide two advantages not attainable through independent metropolitan or regional level planning. First, state-level planning permits an anlaysis of the interaction of a given airport with other airports. An analysis of this kind can provide insights that are helpful in resolving important problems, such as whether two regional airports located within 100 miles of each other may be feasible or whether a regional airport will divert enough traffic from nearby local airports to make service to the latter airports unattractive to commuter airlines. A second advantage of state-level planning is that it permits consistency and economy in data collection and analysis. In particular, analytical methods can be developed more comprehensively. The statewide results then provide coordinated framework for more detailed regional and local studies.

For these reasons, the Michigan Aeronautics Commission, in cooperation with Michigan's Interagency Transportation Council, applied for and received an FAA Airport Development and Planning grant in the summer of 1971. The resulting 20-month airport planning study, which commenced in October 1971, will analyze the feasibility of regional air carrier service and will also address itself to the provision of adequate airport capacity for general aviation operations.

Objectives of the Study

The objectives of this study are substantially in accord with guidelines provided by the FAA and the National Association of State Aviation Officials (NASAO).*

The fundamental question that will be addressed in the study relates to the role that the state will play in the development of improved air service to its residents and visitors. Included in this basic question are the following issues:

- Is the present system of air carrier airports the best that can be provided--in light of traveler, community, and air carrier interests, or could a regionalized system of airports provide better service by offering more frequent flights, or more nonstop flights.

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* FAA and NASAO, Planning and State Airport System, published by the FAA, December 1968 (under revision).

- If regional airports are justified: What is the best system of regional airports? How many regions should there be? Should all air carrier airports in the state be placed within this regional context?

- For areas in which regional airports are not justified, what improvements to the present airports would enhance their performance? What priorities should be associated with each project?

- What are the trade-offs between developing improved feeder service from individual airports to major hubs such as Chicago and Detroit and regionalizing the system? What is the role of computer airlines in the overall system?

- Would the optimal airport system for air carrier operations have an adverse effect on general aviation operations, or vice versa? How should the system be designed to take general aviation needs into account?

Study Approach

The study is planned as a comprehensive investigation. This comprehensiveness will be achieved by evaluating alternative plans against a wide range of criteria, including effects on the air traveler, travel by other modes, the community, the air carrier, the shipper and the state as a whole in terms of economic, financial, environmental, and institutional factors. Both quantitative and qualitative criteria will be used.

The study is being conducted as a joint effect of the Michigan Aeronautics Commission, other appropriate state agencies, and a contractor team of Stanford Research Institute; Howard, Needles, Tammen & Bergendoff; Howard W. Bevis; and Peat, Marwick, Mitchell & Co.

The approach that has been designed for the development of a statewide airport system plan for the state of Michigan entails 30 individual tasks that will be completed in a 20-month period. The 30 tasks are organized into five task groups:

- Task Group 1: Conduct liaison with advisory committee

- Task Group 2: Collect data and develop analysis methods

- Task Group 3: Describe and evaluate alternatives

- Task Group 4: Develop system plan
- Task Group 5: Forecast general aviation activity and system requirements.

The general relationships between these five task groups are shown in Figure I-1. Task Group 1 extends across the entire study period and interacts strongly with the other task groups. Task Group 5 interacts with Task Group 2 and 3, whereas Task Groups 2, 3, and 4 are conducted sequentially, ending with a final report that describes the Michigan airport system plan.

Objectives of the Interim Report

This interim report describes the results of Task Group 2 for the air carrier portion of Michigan's aviation system and documents corresponding results of Task Group 5 for general aviation. The principal purpose of the report is to apprise the Advisory Committee of progress so that its members can offer necessary guidance before subsequent portions of the study are undertaken.

Because the report describes a wide range of analysis methods necessary for the study and because the members of the Advisory Committee may wish to direct their attention to certain of these methods, the report is organized into essentially independent sections.

Section II outlines features of Michigan's 1970 aviation system. For study purposes, 1970 is the base year from which plans will be developed for the period from 1975 to 1990 and beyond.

Section III presents the method that has been followed to identify alternatives to the base year air carrier aviation system. It is expected that the alternatives presented in this section will be of general interest to the Advisory Committee. Section III also provides an overview of the analytical methods that will be used to evaluate and compare alternatives. These analysis methods are presented in greater detail in subsequent sections as follows:

TASK GROUPS
MICHIGAN AIRPORT SYSTEM PLANNING STUDY

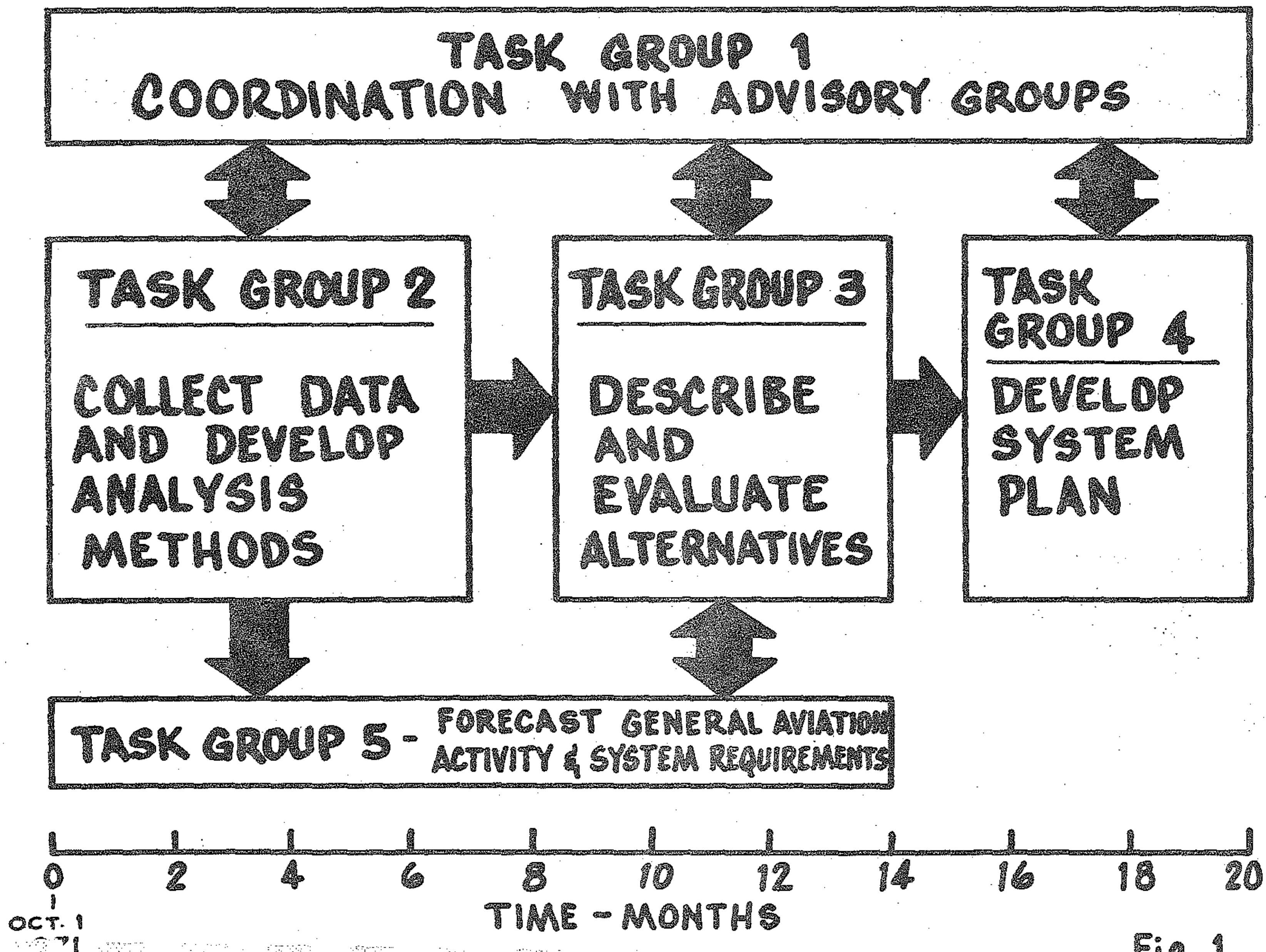

Fig. 1

IV Air Passenger Demand

V Air Cargo Demand

VI Aircraft, Airway, and Airport Technology

VII Institutional, Financial, and Environmental Considerations

VIII Economic Impact Analysis

IX System Operation and Evaluation Methodology

Sections IV through IX are written in a manner that presumes some technical expertise on the part of the reader.

Section X describes the planning methods to be used for general aviation during the portion of Task Group 5 that will parallel Task Group 3. General aviation and air carrier planning will be integrated during Task Group 4 of the study.

In spite of its length, this report does not fully document all of the study activities completed to date. Supplementary reports, on file with the MAC, include:

"Bibliography, Michigan Airport System Plan," completed in January 1972 by HNTB.

"Michigan Air Freight Data Collection Program," completed in May 1972 by the American Academy of Transportation.

"Airline Passenger Survey at Selected Michigan Airports," published in June 1972 by the MAC. (Distributed to the Advisory Committee.)

"Technological Trends: Aircraft, Airways, and Airports," now in preparation.

Nevertheless, we believe that this report is sufficiently complete to support Task 1.3 of the study:

> At the completion of Task Group 2, ... the Advisory Committee members will be asked to comment on the appropriateness of the work to date. Suggestions will be offered by the members as to possible additional system alternatives that should be considered in the balance of the study, or toward changes in emphasis or content of the work to be done.

II DESCRIPTION OF EXISTING SYSTEM

This section outlines briefly key features of Michigan's 1970 aviation system and provides information on Michigan's airports and the nature of air services in the state. The purpose is to document facilities and activities of the study base year. Moreover, the description provides a perspective for the study planning methods that are described in subsequent sections of the report. Because it serves as the basic accounting structure for the study, the study zonal system is described first.

Zonal System

For purposes of analysis, the State of Michigan has been divided into subareas or travel zones. The foundations for this division are the planning and development regions established by the Michigan Bureau of Planning and Program Development, Office of Planning Coordination. These thirteen regions are outlined in the map of Figure II-1. During prior SRI work for Michigan's Interagency Transportation Council, it was found that a further subdivision of the state was desirable to account appropriately for travel patterns. Thus, the 27 zone system shown in the map of Figure II-2 has been established. These zones permit aggregating travel and demographic data into a small number of groups, thus simplifying the analytical burden. The Michigan zones are named and 1970 population data are provided in Table II-1.

Travel zones also have been established for the remainder of the country. The principal bases for the subdivision are air travel patterns to and from Michigan. The boundaries of the out-of-state zones are shown in the map of Figure II-3. In each of these zones, one city has been chosen as representative and is the basis for measurement of travel times and costs. Generally, the representative city within each zone is the one with maximum traffic levels to and from Michigan. The representative cities selected for the zones outside Michigan and their population are provided in Table II-2.

Figure II-1

STATE PLANNING AND DEVELOPMENT REGIONS

State of Michigan – December 1970

Figure II-2

MICHIGAN ZONES

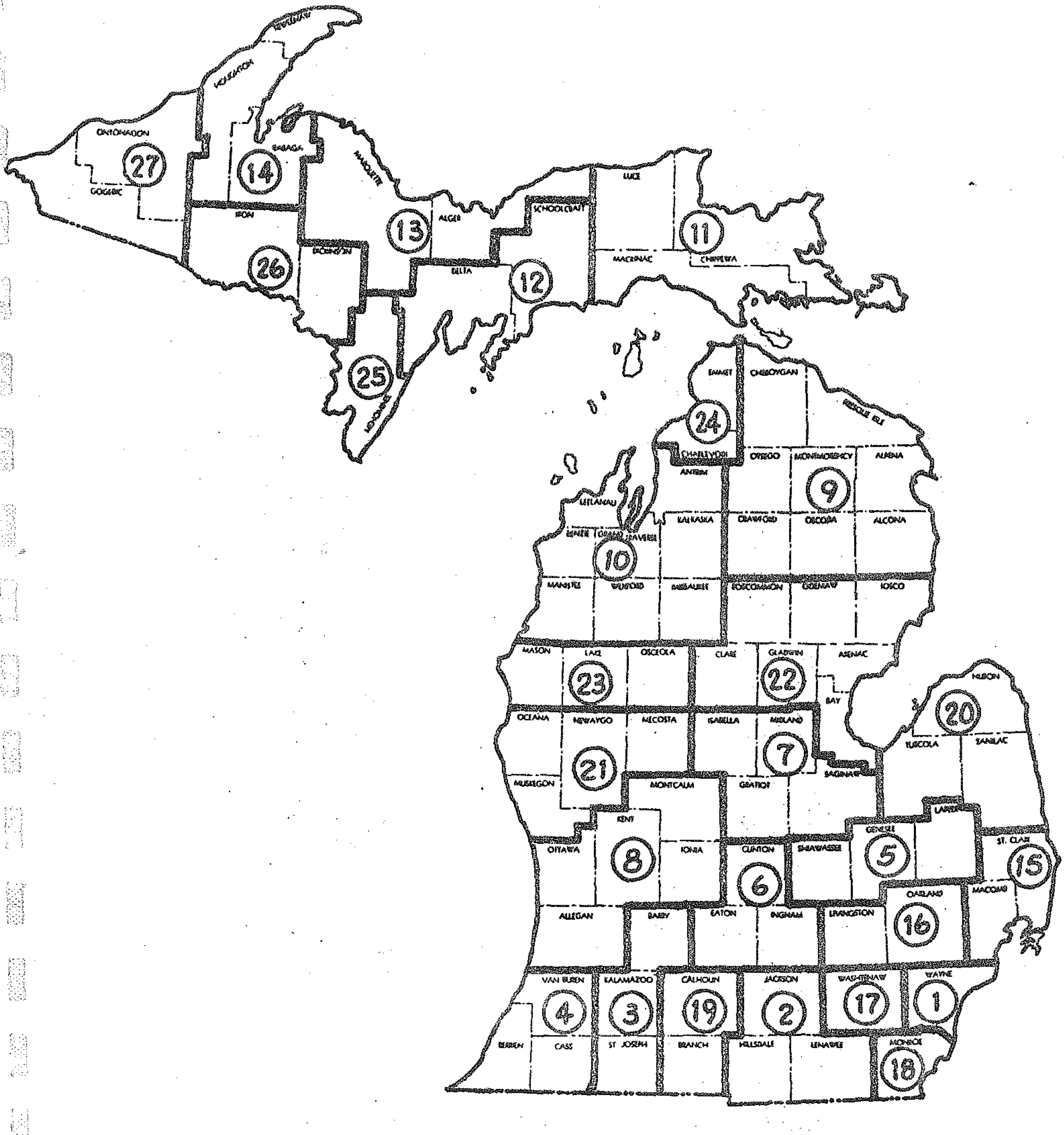

Table II-1

POPULATION OF MICHIGAN ZONES, 1970

Zone Number	Major City	1970 Population (thousands)
1	Detroit	2,667
2	Jackson	262
3	Kalamazoo	287
4	Benton Harbor	263
5	Flint	559
6	Lansing	378
7	Saginaw	368
8	Grand Rapids	692
9	Alpena	94
10	Traverse City	124
11	Sault Sainte Marie	49
12	Escanaba	44
13	Marquette	73
14	Houghton	45
15	Port Huron	745
16	Pontiac	967
17	Ann Arbor	234
18	Monroe	118
19	Battle Creek	180
20	Caro	118
21	Muskegon	231
22	Bay City	205
23	Ludington	43
24	Pellston	35
25	Menominee	25
26	Iron Mountain	38
27	Ironwood	31
State Total		8,875

Figure II-3 **STUDY ZONES OUTSIDE MICHIGAN**

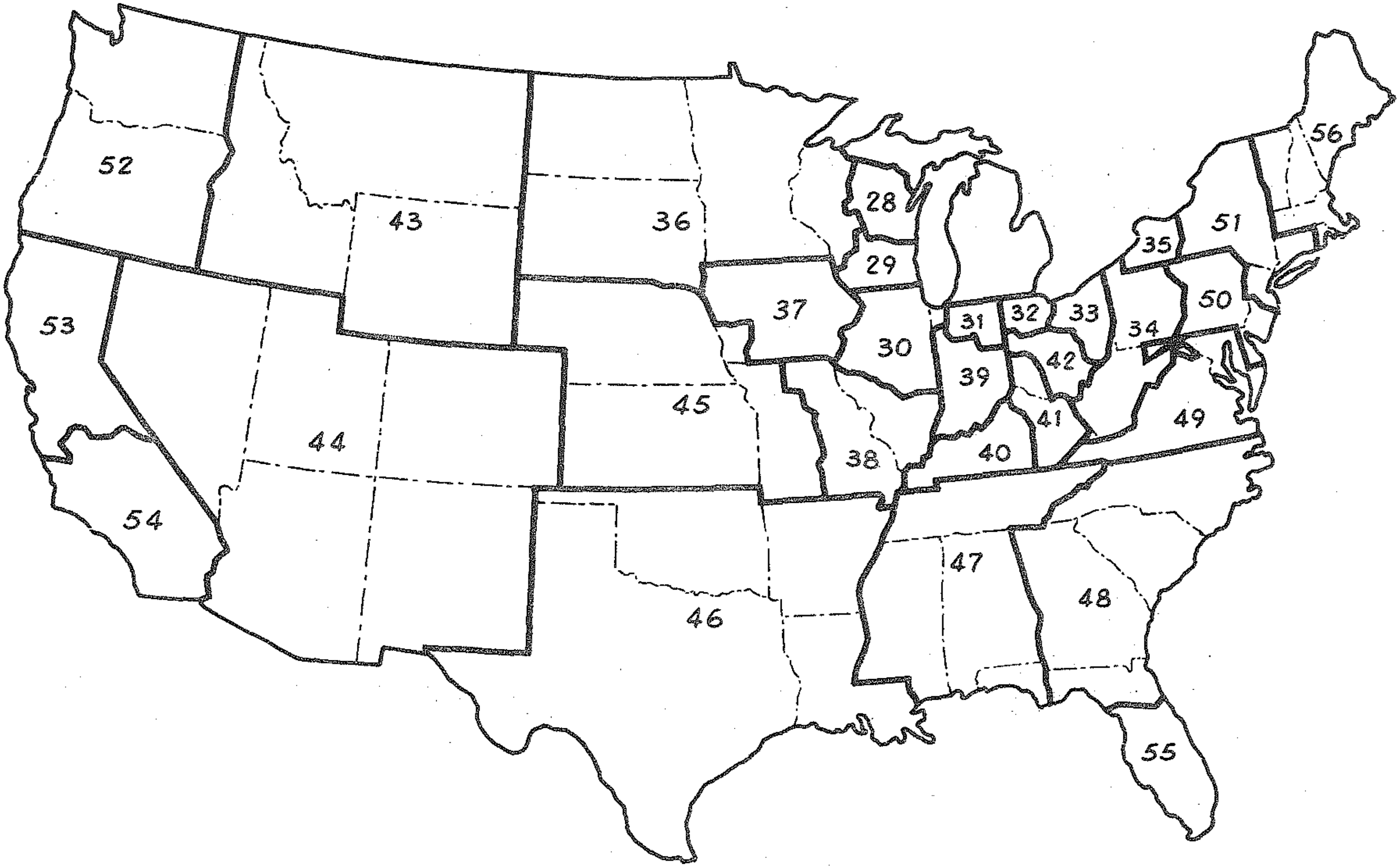

Table II-2

REPRESENTATIVE CITIES AND POPULATIONS
FOR ZONES OUTSIDE MICHIGAN

Zone Number	Representative City	Zone Population - 1970 (thousands)
28	Green Bay	1,004
29	Milwaukee	2,748
30	Chicago	10,328
31	South Bend	1,137
32	Toledo	997
33	Cleveland	4,815
34	Pittsburgh	6,357
35	Buffalo	2,854
36	Minneapolis	5,755
37	Des Moines	2,625
38	St. Louis	4,168
39	Indianapolis	3,189
40	Louisville	2,215
41	Cincinnati	3,340
42	Columbus	2,504
43	Billings	1,739
44	Denver	6,542
45	Kansas City	5,857
46	Dallas	19,320
47	Birmingham	10,080
48	Atlanta	13,304
49	Washington, D.C.	9,327
50	Philadelphia	9,214
51	New York	23,550
52	Seattle	5,500
53	San Francisco	7,168
54	Los Angeles	12,785
55	Miami	5,253
56	Boston	8,810

General Aviation

An inventory of Michigan's general aviation aircraft fleet by study zone is shown in Table II-3. Also provided is a count by zone of the airports that are open to the general aviation public.* In most Michigan zones, there is an airport served by air carriers. These airports are capable of serving essentially all general aviation aircraft, including those most demanding in terms of runway requirements. Relatively few other airports in the state have this capability--only 11 nonair carrier airports have paved runways more than 4,00 feet long. The bulk of Michigan's general aviation airports have shorter paved runways or turf runways. Of the 261 airports in this category, 173 are privately owned.

Air Carrier Airports

The 21 airports in Michigan that were served by certificated airlines in 1970 are located in the map of Figure II-4. Selected data on air carrier activity at these airports are provided in Table II-4. The air carrier activities at Detroit Metropolitan Airport clearly dominate those at all other airports in the state--for example, about 80 percent of 1970 passenger enplanements took place at Detroit "Metro."

Also, Table II-4 indicates that air carrier activities are dominant at only 11 of the 21 airports listed. As established by the FAA, an airport's airline service role is termed dominant to the general aviation role when its air carrier passenger enplanements exceed general aviation enplanements.

Table II-5 gives an inventory of selected airport facilities. These data represent only a very brief summary of information collected during Task Group 2 by the study subcontractor: Howard, Needles, Tammen and Bergendoff (HNTB).† To complete the inventory, HNTB used FAA data and MAC data. Much valuable information was also obtained from a questionnaire completed by airport managers during Task Group 2 of the study. The questionnaire was administered by HNTB and MAC staff.

When the runway lengths given in Table II-5 are compared with FAA planning guidance on required runway lengths by airline service operational role, the preliminary indication is that few Michigan airports could upgrade

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* Licensed airports and approved noncommercial (Class D) airports.

† Detroit Metropolitan Airport information was collected by MAC staff.

Table II-3

GENERAL AVIATION AIRCRAFT AND AIRPORTS, 1970

Zone Number	Michigan Zone	Registered General Aviation Aircraft	Airports Open to the General Aviation Public: Air Carrier	Other Paved Runway Over 4,000 ft	Other Paved and Turf: Publicly Owned	Other Paved and Turf: Privately Owned	Total
1	Detroit	819	1*	2*		3	6
2	Jackson	240	1*		2	9	12
3	Kalamazoo	264	1*	1	2	5	9
4	Benton Harbor	195	1		4	8	13
5	Flint	462	1*		1	12	14
6	Lansing	328	1*		2	12	15
7	Saginaw	223	1*	1	4	8	14
8	Grand Rapids	499	1*		9	15	25
9	Alpena	83	1	2	7	10	20
10	Traverse City	102	2	2	5	16	25
11	Sault Sainte Marie	50	1		7	6	14
12	Escanaba	24	1		1	2	4
13	Marquette	40	1		2		3
14	Houghton	18	1			2	3
15	Port Huron	259		1		10	11
16	Pontiac	871		1*	2	10	13
17	Ann Arbor	272			1	4	5
18	Monroe	159			1	8	9
19	Battle Creek	169	1*		2	1	4
20	Caro	116			4	11	15
21	Muskegon	124	1*		7	6	14
22	Bay City	138			11	11	22
23	Ludington	32		1	3		4
24	Pellston	51	1		6	3	10
25	Menominee	18	1				1
26	Iron Mountain	30	1		3	1	5
27	Ironwood	19	1		2		3
	State Total	5,605	21	11	88	173	293

* FAA Control Tower.

Source: MAC Records.

Figure II-4

MICHIGAN'S AIR CARRIER AIRPORTS 1970

Table II-4

AIR CARRIER AIRPORT ACTIVITY, 1970

				Annual Enplanements			Current Airline Service Operational Role		
City	Zone	Airport Name	CAB/DOT Hub Designation	Air Carrier Passengers (thousands)	Cargo Tons (thousands)	Annual Air Carrier Itinerant Operations (hundreds)	Aircraft Group*	Length of Haul†	Airline Service Role Dominates General Aviation Role
Alpena	9	Phelps-Collins		6		21	B	3	
Battle Creek	19	W. K. Kellog Airfield		27		64	C	3	
Benton Harbor	4	Ross Field		23		50	C	3	
Detroit	1	Detroit Metropolitan	Large	3,640	101	1,937	A	1	Yes
Escanaba	12	Escanaba Municipal		14		40	B	3	Yes
Flint	5	Bishop	Small	80	1	118	B	3	
Grand Rapids	8	Kent County	Small	216	3	246	B	3	Yes
Houghton	14	Houghton Co. Memorial		17		20	C	3	Yes
Iron Mountain	26	Ford		13		40	B	3	Yes
Ironwood	27	Gogebic Co.		9		30	C	3	Yes
Jackson	2	Reynolds Municipal		6		27	C	3	
Kalamazoo	3	Kalamazoo Municipal		60	1	88	B	3	
Lansing	6	Capital City	Small	118	1	180	B	3	Yes
Manistee	10	Manistee-Blacker		3		10	C	3	
Marquette	13	Marquette Co.		26		23	B	3	
Menominee	25	Menominee Co.		8		42	C	3	
Muskegon	21	Muskegon		63	1	90	B	3	Yes
Pellston	24	Emmet County		15		37	B	3	Yes
Saginaw	7	Tri-City	Small	139	1	147	B	3	Yes
Sault Sainte Marie	11	Sault Sainte Marie Mun.		9		14	C	3	
Traverse City	10	Cherry Capital		37		63	B	3	Yes

* Aircraft types typical of Group A: B-707, DC-8; of Group B: B-727, DC-9; of Group C: CV-580.

† Length of haul for Code 1: More than 1,500 miles; for code 3: 500 miles or less (for Code 2: 500 to 1,500 miles).

Table II-5

AIR CARRIER AIRPORT FACILITIES

Airport	Longest Runway (feet) Length	Longest Runway (feet) Width	Control Tower	Instrument Landing System	Vehicular Fire and Rescue Equipment	Air Carrier Gates	Air Carrier Terminal Area (1,000 ft^2)	Public Auto Parking Spaces
Alpena	9,000	150	Yes*		Yes	2	3	277
Battle Creek	7,000	150	Yes	Yes	Yes	3	10	112
Benton Harbor	5,100	100		Yes		2	11	300
Detroit Metro	10,500	200	Yes	Yes	Yes	51	570	6,417
Escanaba	6,500	100				1	8	92
Flint	7,200	150	Yes	Yes	Yes	3	64	520
Grand Rapids	8,600	150	Yes	Yes	Yes	7	81	973
Houghton	5,200	150				2	13	342
Iron Mountain	6,500	100				2	4	142
Ironwood	5,400	100				1	5	115
Jackson	5,300	150	Yes	Yes	Yes	2	10	85
Kalamazoo	5,300	150	Yes	Yes	Yes	4	14	200
Lansing	6,500	150	Yes	Yes	Yes	4	54	340
Manistee	5,500	100				1	2	30
Marquette	6,500	100				3	4	200
Menominee	5,100	100			Yes	2	6	104
Muskegon	6,500	150	Yes	Yes	Yes	3	12	470
Pellston	6,500	150			Yes	2	13	600
Tri-City	6,500	150	Yes	Yes	Yes	3	39	570
Sault Sainte Marie	5,000	100				1	1	10
Traverse City	6,500	150			Yes	1	33	100

* Operated by military. Remainder of control towers listed are operated by the FAA.

Sources: HNTB data and MAC data.

their present airline service role (see Table II-4) without runway improvements. The FAA lists runway planning lengths of more than 7,000 feet for jet aircraft service in lengths of haul of over 500 miles.*

Airline Service

Figure II-5 is a graphic rendering of scheduled airline service within Michigan and between Michigan and out-of-state points. The Michigan zones containing air carrier airports are listed as both rows and columns of the figure. Zones outside Michigan appear only as columns and are identified by their "representative city" name. For each zone pair (row/column intersection) the symbol for nonstop or direct (same plane) service appears when:

(1) Such flights were published in the last "Official Airline Guide" of 1970, and

(2) The Origin-Destination Passenger sample by the Civil Aeronautics Board indicates that more than 200 passengers flew between the zones during 1970.†

The symbols entered in the table represent a judgment as to the "predominant" service between zones. Thus, for example, no symbol appears for a zone pair where several connecting (change of planes) flights are listed but only one direct flight is available.

As indicated by Figure II-5, there are an abundance of nonstop flights for Detroit. However, the predominant air service for most Michigan/out-of-state zone pairs entails connections. For Michigan cities other than Detroit, nonstop and direct service is generally limited to the following:

Intrastate points	Cleveland
Detroit	Milwaukee
Chicago	Green Bay

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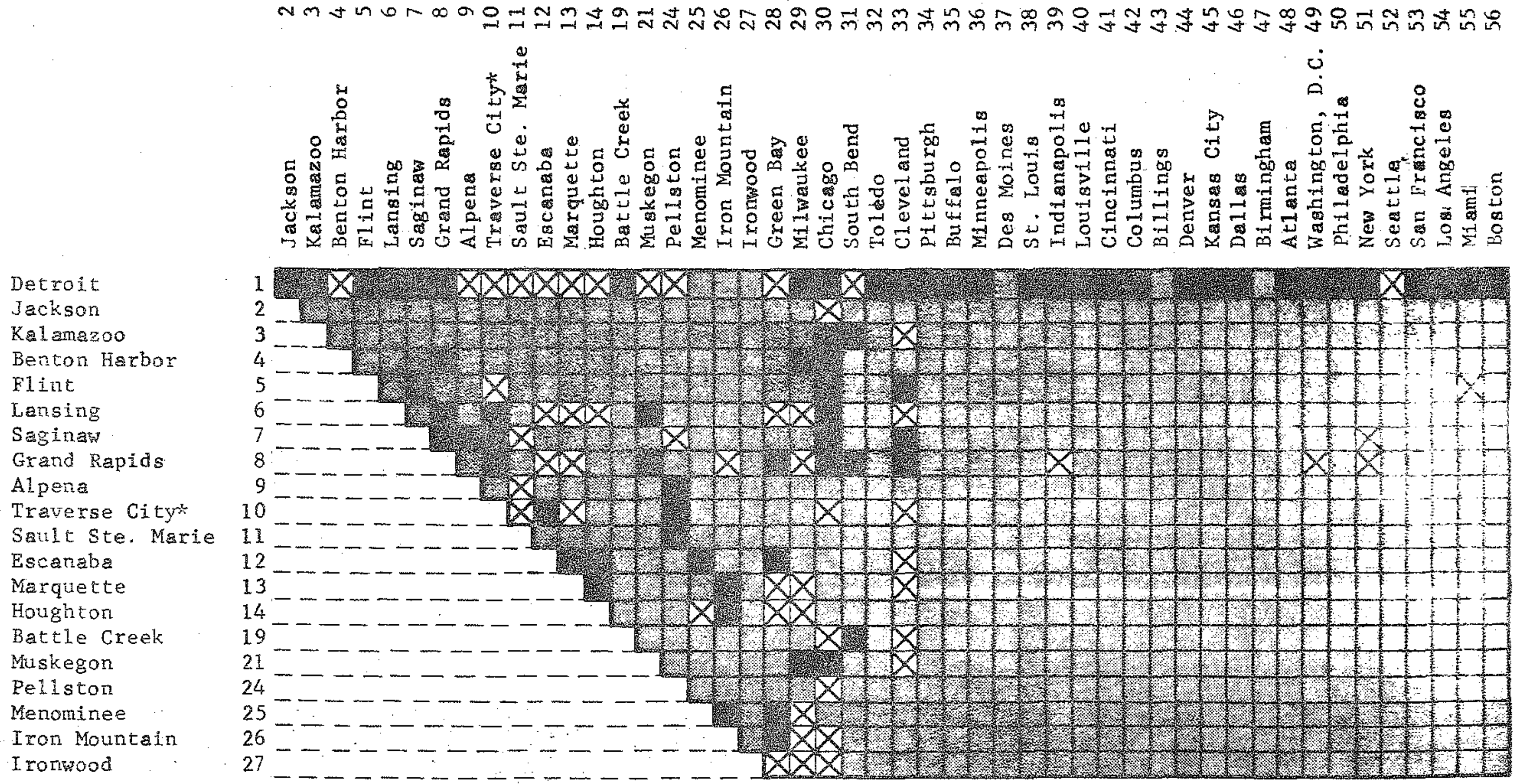
* FAA, "Formulation of the 1972 National Airport System Plan" Order 5090.3.

† Since commuter airline (e.g., Trans-Michigan Airlines) passenger traffic volumes are not collected in the CAB sample, this volume "cutoff" was not applied for commuter airlines.

Figure II-5

PATTERN OF AIR SERVICE, 1970



* includes service via Manistee

☒ direct (same plane) service

nonstop service

connecting service and/or negligible traffic

A partial explanation for this is given in Table II-6. Here, the 1970 CAB Origin-Destination air passenger statistics pertaining to Michigan have been grouped into "passengers per day" levels. As indicated by the table, relatively few city pairs have high traffic density--for the majority of pairs, in fact, fewer than ten passengers travel in each direction during an average day.

The fragmentation (diversity) of air passenger demand suggested by Table II-6 (for Michigan airports other than Detroit) is a basic concern in the present study. The potential means by which these demands might be consolidated are discussed in the next section.

Table II-6

CITY PAIR AIR PASSENGER VOLUMES

Average Originating Passengers Per Day (one-way)	All City Pairs		All City Pairs Except Those from Detroit to Out-of-State Points	
	Percentage of City Pairs	Percent of Air Passenger Originations	Percentage of City Pairs	Percentage of Air Passenger Originations
0	12	0	12	0
Less than 1	55	2	57	7
1 to 9	24	9	25	37
10 to 49	6	10	5	41
50 to 99	1	7	1	15
100 to 199	1	20	0	0
200 or more	1	52	0	0
	100	100	100	100

Note: A city pair is defined here as either a Michigan airport pair, or a Michigan airport/external zone pair. By this definition, the study encompasses 819 city pairs.

Source: 1970 Origin-Destination passenger sample, CAB.

III AIRPORT ALTERNATIVES: FORMULATION AND ANALYSIS METHODS

This section presents the method that has been followed to identify the airport system alternatives that will be examined in the study, together with a basis for reducing the potential alternatives to a manageable number. This section also presents an overview of the analytical methods that will be used to evaluate and compare airport system alternatives.

Throughout this report, the term "airport system alternative" is used to describe a combination of existing and postulated airports that together serve all of Michigan's commercial passenger and air cargo needs.* The description includes size and location of air carrier airports and the type and frequency of service at each airport. Thus, the present system of air carrier airports that was described in Section II constitutes one airport system alternative. Other alternatives can be described by postulating entirely new locations and services for all Michigan communities. However, such alternatives would require wholesale abandonment of existing airport facilities and therefore are not very likely possibilities. More plausible airport system alternatives are variations in the present system in which some of the existing airports are replaced by one or more regional airports or in which types of service and service levels among existing airports are modified to give some airports a regional character.

Characteristics of Airport System Alternatives

Table III-1 presents a general description of the characteristics that specify an airport system alternative. The characteristics are grouped into airport, air carrier service, and airport access characteristics.

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* Although general aviation is an important part of the aviation system, for simplicity, airports that serve only general aviation will not be included in the formal descriptions of airport system alternatives during Task Group 3. Integration of air carrier and general aviation planning will be emphasized in Task Group 4.

Table III-1

CHARACTERISTICS THAT SPECIFY AN AIRPORT SYSTEM ALTERNATIVE

Characteristic	Description
Airport locations	Expressed in terms of distance from zonal centroids and from other airports. Specific geographic locations are used for existing airports; general locations are used for potential new airports.
Air carrier service	Number of flights offered per day; travel time and air fare between each airport and all other airports serving both internal and external zones. Types of service (nonstop, direct, and connecting) are also specified.
Airport access	Travel time and travel cost from each zone to specified airports (there may be more than one airport that can be used), and from a destination airport to the destination zone. Access travel time includes an allowance for airport waiting times, both at the origin and destination airports. Access travel costs include fares, operating costs, and parking costs.

New airport system alternatives are postulated by modifying one or more of the three major system characteristics. Thus we may begin by postulating one or more new airport locations. New types of intensities of service can then be postulated for each location. Finally, alternative means of access between zones and airports are specified.

A specific set of airport system alternatives has been developed in terms of the characteristics of Table III-1 and are summarized in Table III-2. These alternatives, subject to amendment by the Advisory Committee, will be analyzed and evaluated in Task Group 3.

Airport Locations

The airport locations of interest are restricted to those of existing airports plus postulated new regional airports. Each airport system alternative can include all or most of the existing airports, together with such new regional airports as may appear advantageous.

The term "regional airport" is intended to identify an airport that would take the place of two or more existing airports. Thus, a regional airport may be a new location between two existing airports, or it may be located at an existing airport site. The individual airports that were shown in the right-hand column of Table III-2 are the airports now being considered for regional service. These regional airport sites and the existing air carrier airport sites are shown in Figure III-1. Together, these 31 sites constitute the scope of air carrier airport locations for the study.

Air Carrier Service

The description of an airport system alternative requires specification of the airline service provided between most pairs of airports in the system.* In the analysis, this service is defined by a value for each of the following:

- Travel time
- Frequency (number of flights per day)
- Cost (fare)

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* Between pairs of Michigan airports and between Michigan and external airports. Except for those external airports that serve as connecting points for Michigan travel, service between external pairs of airports is not considered.

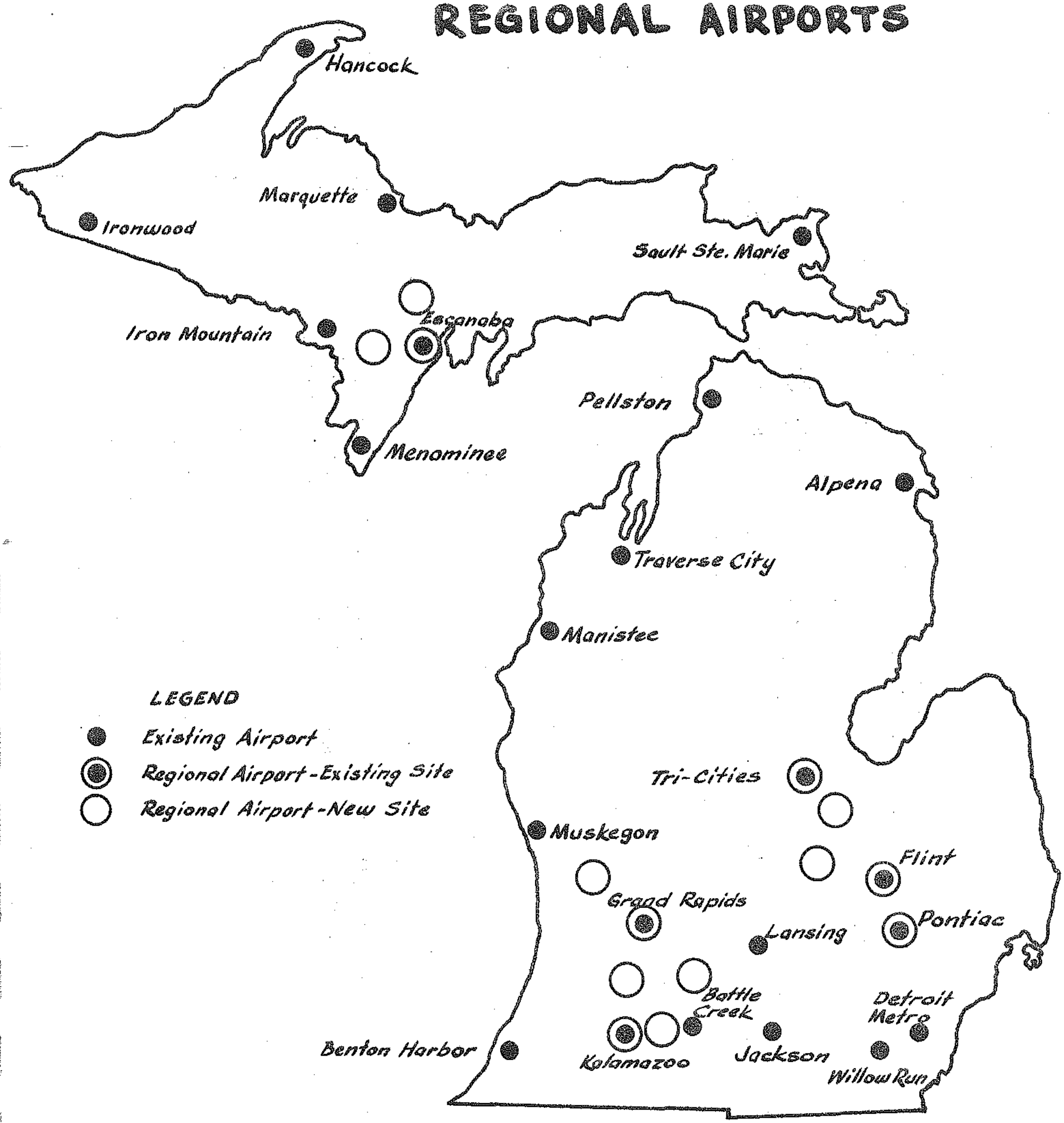
Table III-2

SUMMARY OF AIRPORT ALTERNATIVES

Alternative Number	Reduce Service at:	Introduce Regional Service at:
1	Muskegon	Grand Rapids
2	Battle Creek	Kalamazoo
3	Tri-Cities	Flint
4	Flint	Tri-Cities
5	Muskegon, Battle Creek	Grand Rapids, Kalamazoo
6	Muskegon, Battle Creek, Flint	Grand Rapids, Kalamazoo Tri-Cities
7	Muskegon, Battle Creek, Tri-Cities	Grand Rapids, Kalamazoo, Flint
8	Muskegon, Battle Creek, Kalamazoo	Grand Rapids
9	Muskegon, Battle Creek, Kalamazoo, Tri-Cities	Grand Rapids, Flint
10	Muskegon, Battle Creek, Kalamazoo, Flint	Grand Rapids, Tri-Cities
11	Menominee, Iron Mountain Marquette	Escanaba
12	Muskegon, Grand Rapids,	New airport, Ottawa County
13	Muskegon, Grand Rapids, Kalamazoo, Battle Creek	New airport, Allegan County
14	Muskegon, Grand Rapids Kalamazoo, Battle Creek, Lansing	New airport, Barry County
15	Kalamazoo, Battle Creek	New airport, Kalamazoo County
16	Tri-Cities, Flint	New airport, Saginaw County
17	Tri-Cities, Flint, Lansing	New airport, Shiawassee County
18	Tri-Cities, Flint	New airport, Oakland County
19	Flint	New airport, Oakland County
20	Escanaba, Menominee, Iron Mountain	New airport, Menominee County
21	Escanaba, Menominee, Iron Mountain, Marquette	New airport, Delta County
22	Muskegon, Grand Rapids, Kalamazoo, Battle Creek, Tri-Cities, Flint, Lansing	New airport, Allegan County and new airport, Shiawassee County
23	Muskegon, Grand Rapids, Kalamazoo, Battle Creek, Tri-Cities, Flint, Lansing	New airport, Barry County and new airport, Saginaw County

Figure III-1

EXISTING & POTENTIAL REGIONAL AIRPORTS



Some underlying attributes of actual service affect these values directly. For example, aircraft types will have some effect on travel time because of differences in operating speeds. Thus, the travel times used in the analysis will reflect not only existing aircraft but also any new aircraft that are projected in the technology analyses (Section VI) to provide higher speeds. Also, while fares generally will be those in effect today, adjustments for future technological changes will be considered.

The type of airline service offered between airports has a significant influence on time, frequency, and cost values although it is less direct than that of type of aircraft. The types of airline service to be considered in the analysis are categorized for ease of reference as:

- Nonstop--single plane service with no stops enroute between airports
- Direct--single plane service with intermediate stops between origin and destination airports
- Connecting--an intermediate stop and change of planes during the traveler's trip

Specification of one of these types for an airport pair is intended to reflect the predominant service offered. In practice, a traveler will generally find a combination of types of service offered--he may be able to choose among a number of nonstop flights, direct flights, and connecting flights. To account for such combinations, a means of translating their differing costs, times, or frequencies into an equivalent single set of values is used. This technique is described in Section IV. Thus, the single reference made to type of service should not be interpreted to mean that only one type is offered for an airport pair.

Specification of the level (type and frequency) of air carrier service will not be made arbitrarily, because a feasible level of air service depends on the amount of air passenger demand. Also, passenger demand depends on the level of service offered. This interaction of level of service and passenger demand requires an iterative approach, as follows: a level of service will be postulated and then passenger demand will be estimated. This is followed by a comparsion of service level and demand. If occupancy rates are unusually high or low, a new service level will be postulated.

Airport Access

Travelers currently gain access to airports by a number of surface modes of transportation, including private automobile, rental automobile, taxi, limousine, and bus. However, in the analysis, surface access between a zone and an airport is defined by a single value for (1) travel time and (2) travel cost. Access cost will include allowances for parking costs, and access times will include waiting times at the airports. The passenger access times and costs will be estimated for each zone to individual airports. The detailed method of arriving at these values for each Michigan zone/airport pair is described in Section IV. In summary, data collected during the airline passenger survey of this study have allowed for appropriate weighting of the cost and time values for the various surface modes. These cost and time values will be used for most alternatives.

Later in the study, the possibility of new modes of surface transportation to provide airport access will be considered, such as a high-speed rail service. This analysis will consider access systems in two roles--in providing local service, such as from downtown Grand Rapids to Grand Rapids Airport, and in longer haul service, such as from Flint to Detroit Metropolitan Airport.

Air Feeder Service

Another means of airport "access" is via air transportation. This concept applies to a zone whose airport's air carrier service (to most destinations) will have been assumed by a new regional airport. Airport location alternative 1 is representative of the situation. Here, it is postulated that Grand Rapids assumes a regional airport role--and that its air services would eclipse those at Muskegon. In such case, the means by which Muskegon residents travel to airports must be considered. For the analysis, their choice will not be limited to surface access to Grand Rapids, Chicago, and Detroit. Rather, in some variations of the alternative, air service also will be provided from Muskegon's airport to the regional airport at Grand Rapids and to Chicago and Detroit. To distinguish this type of transportation from air carrier service and surface access, the term air "feeder" service will be used.*

Development of a Set of Alternatives

The concept of total statewide service is vital to the evaluation of each alternative. For example, in the discussion above on location alternative 1, interest centered on the effect that regional airport service at Grand Rapids would have on Muskegon. However, because of its improved services, Grand Rapids would also tend to draw some passengers from the Lansing area. The extent to which Lansing traffic is affected also would be reflected by the quality of service offered at other airports. If Flint, for example, were also a regional airport offering improved service, it would affect the number of Lansing passengers using the Grand Rapids Airport.

In considering statewide combinations of regional airport locations, variations in types of service, and service levels, it is necessary to progress through the spectrum of alternatives in a logical and efficient manner. The method chosen progresses through variations in the following characteristics:

- Airport location alternative
- Assumed air feeder service for airport(s) whose services had otherwise been replaced by a regional airport
- Type of service at the regional airport(s)
- Frequency of service at the regional airport(s).

Table III-3 presents an example of the way in which variations in these characteristics can be assembled into a spectrum of alternatives for one regional airport location set. Location alternative 1 is again the basis for the example. Table III-3 also presents an alternative designation code: the first symbol in the designation (a number) specifies the airport

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* This term has been chosen in preference to the terms "local service," or "commuter airline service," to avoid implication that any airport alternative entails the provision of service by a particular CAB-defined class of carrier. If, in the analysis, a particular type of service appears attractive, it will be assumed that a carrier could be found to provide the service. The validity of such assumptions will be tested later, in the implementation and institutional analyses of Task Groups 3 and 4.

Table III-3

EXAMPLE OF VARIATIONS IN AIR FEEDER SERVICE AND
TYPE AND FREQUENCY OF SERVICE
FOR ALTERNATIVE 1

Alternative	Description
1	Reduce air carrier service at Muskegon
1A	Provide no air feeder service from Muskegon
1B	Provide air feeder service between Muskegon and Grand Rapids
1C	Provide air feeder service between Muskegon and Chicago
1D	Provide air feeder service between Muskegon and Grand Rapids and Muskegon and Chicago
1-1	Provide no higher type of service at Grand Rapids
1-2	Provide higher type of service to Grand Rapids: Increase nonstops from 10 to 14; provide direct service to 3 additional cities
1-3	Provide higher type of service to Grand Rapids: Increase nonstops from 9 to 15: Increase direct service from 6 to 12
1--a	Provide no increase in frequency of service at Grand Rapids
1--b	Increase frequency of service at Grand Rapids by 20% or 2 flights for all nonstops and direct flights
1--c	Increase frequency of service at Grand Rapids by 40% or 4 flights for all nonstops and direct flights.

location alternative, the second symbol (a capital letter) specifies air feeder services relationships with one or more nearby airports, the third symbol (a number) specifies the level of service at the regional airport, and the fourth symbol (a lower case letter) specifies the steps in frequency of service. A dash indicates that all variations in that symbol apply to the other features (symbols) describing the alternative. In other words, the table indicates that there are 36 variations (4 X 3 X 3) in airport location alternative 1.

For each of the location variations shown in Table III-2, a set of types of service variations, and frequency of service variations will be postulated in a manner similar to that shown in Table III-3. Combination of the Table III-2 airport location variations and the Table III-3 service variations provide the complete set of alternatives. Thus, the number of alternatives that can be examined in the study totals in the hundreds.

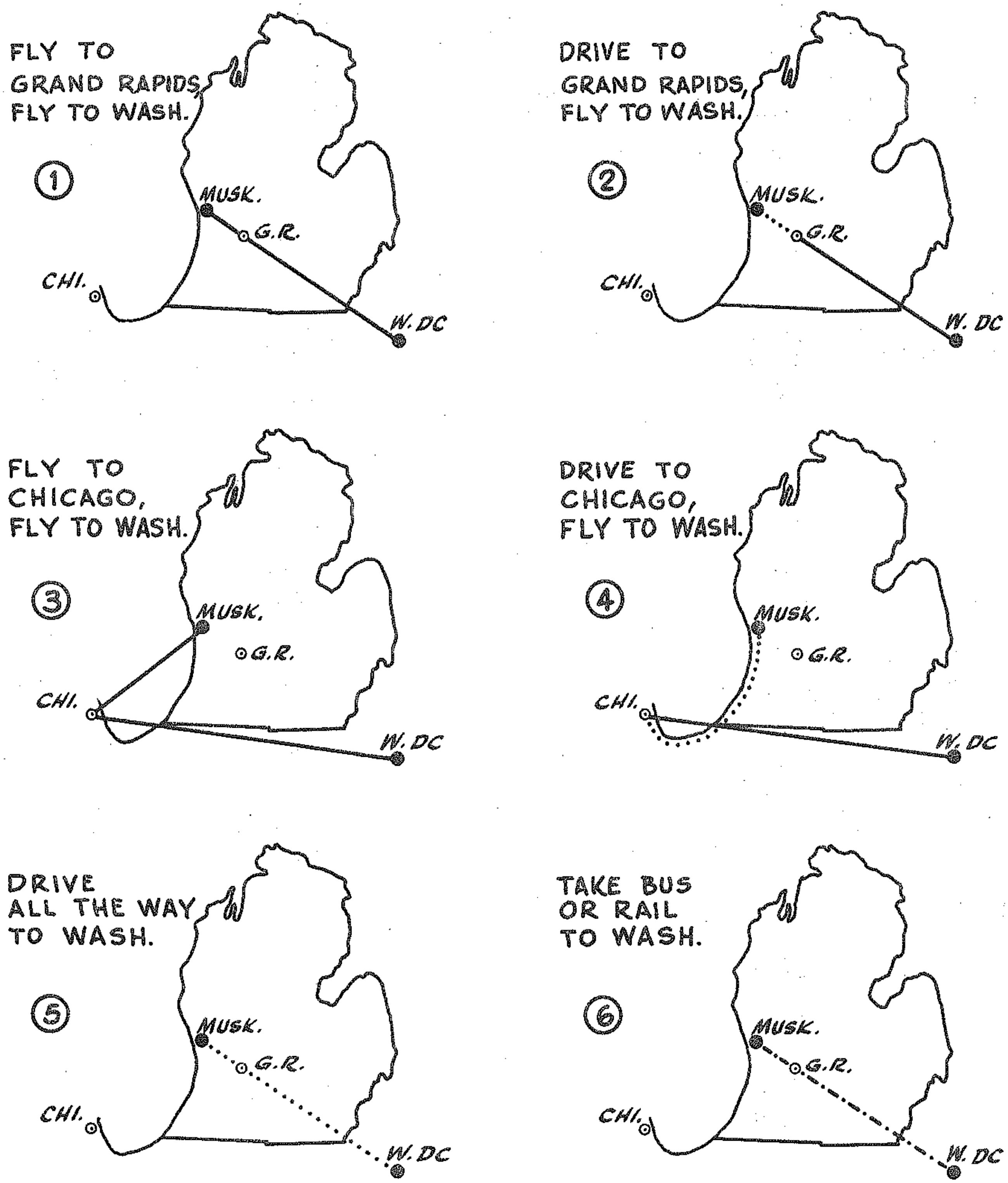
Available time and funds will not permit evaluating all possible alternatives. Therefore, a means must be developed to search efficiently among the possible alternatives and "narrow in" to those that appear to have attractive potentials.

The method used will be to first select a number of system alternatives for a first analysis that are substantially different from one another. The alternatives need to be substantially different in terms of the type of service and the frequency of service, as well as the size of city or cities served. Second, these alternatives will be evaluated and attractive possibilities will be identified based on the evaluation. Third, another set of alternatives will be specified that represent minor variations from the survivors of the first screening. These alternatives will then be evaluated. This process will be continued until the anticipated improvement from proceeding to another step is judged to be minor.

To further explain how a system alternative is structured, consider Alternative 1D, which provides frequent short-haul service from Muskegon to Grand Rapids and Chicago in addition to offering expanded service at a regional airport at Grand Rapids. Under this alternative, a passenger wishing to travel from Muskegon to Washington, D.C., for example, has a number of choices among access travel to airports, air travel, and bus or rail transportation. Figure III-2 displays the methods of travel available. The model system being used in the study will take account of these possible choices and will estimate the number of travelers choosing each possibility.

Figure III-2

METHODS OF TRAVEL
MUSKEGON TO WASHINGTON D.C.
(Regional Airport at Grand Rapids)



Another example of the way in which alternatives will be structured is presented in Table III-4. This shows more detail of the base case and alternative 1D2b of Table III-3. In alternative 1D2b, both higher types of service (more nonstop and direct flights) and higher frequencies of service are offered compared with the base case.

Analytical Method

Passengers and freight movements are analyzed separately. Despite the fact that air cargo traffic is growing nationally at a rate faster than passenger traffic, the present and expected future levels of air cargo demand at Michigan local and potential regional airports are not likely to exceed the "belly space" that will be available in passenger aircraft. Therefore, it is possible to analyze passengers and freight separately. Passenger service is analyzed first to establish service levels, and then freight service is analyzed to assure that available cargo space is not exceeded.

Passenger Analysis

The analytical method focuses on quantitative comparisons between pairs of airport system alternatives. Figure III-3 illustrates the general framework for passenger analysis by showing the relationships among the different major activities. The circled activities represent the preparation for the data inputs that are needed to perform the analysis. The activities in rectangular boxes entail use of specific analytical models. The last and key step is evaluation, which is performed with the evaluation model that determines service, economic, and financial impacts and prepares measures of performance.

Three classes of input data are required to perform a complete passenger analysis: (1) airport system data, (2) alternative mode data, and (3) geographic/demographic data. Airport systems data consist of a complete description of the airport system alternative under study. Each analysis will be based on a different airport system alternative. Alternative mode data were assembled and organized in Task Group 2, but they are not described in this report.* For the most part, the nature, quality

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* Alternative mode data have been thoroughly reviewed with MAC. Because of their volume and complexity, a display here would merely detract from the value of this report.

Table III-4

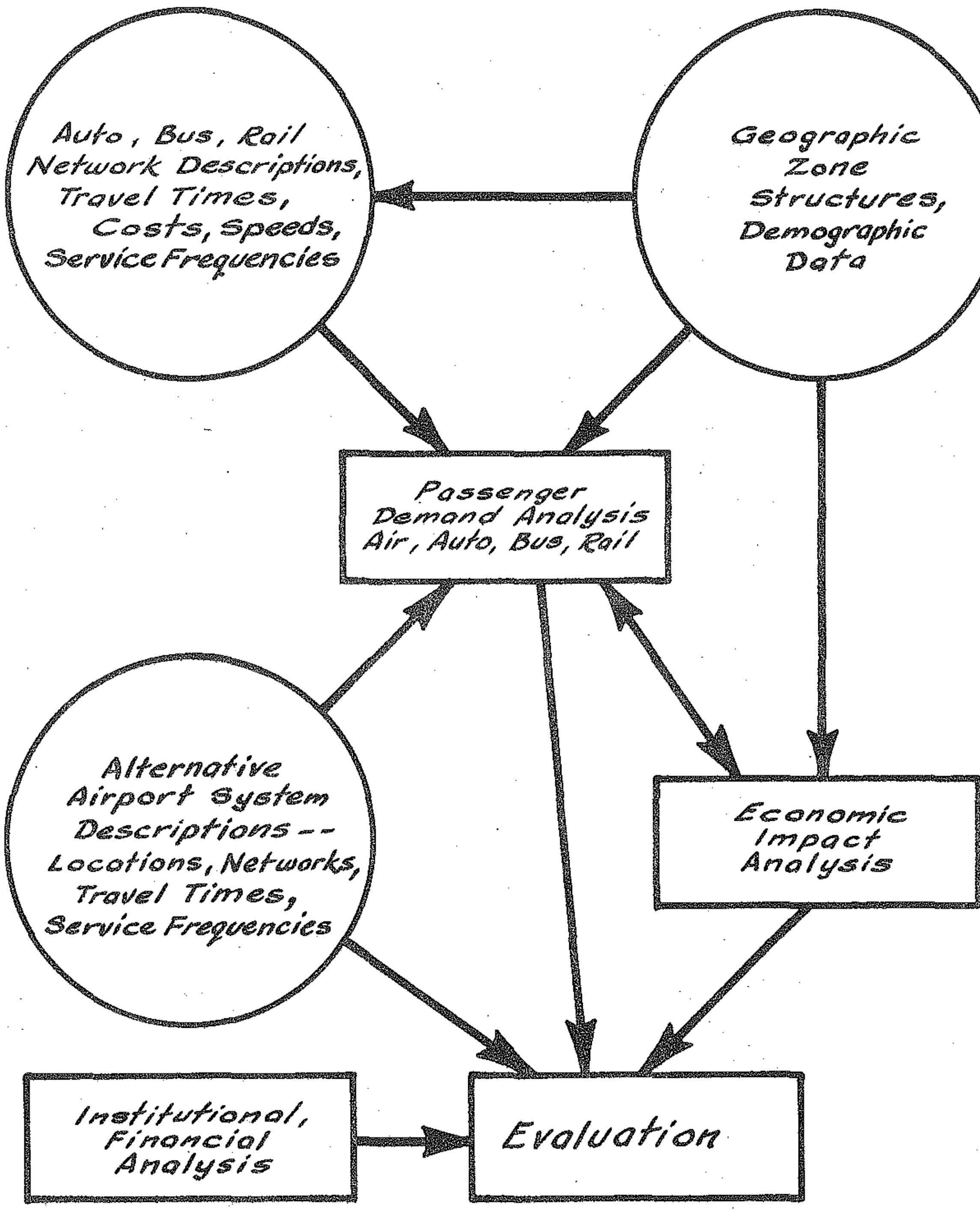
DETAILED DESCRIPTION OF SUBALTERNATIVES FOR
THE GRAND RAPIDS REGIONAL AIRPORT ALTERNATIVE

	Daily Service Provided At			
	Muskegon		Grand Rapids	
	City	Frequency	City	Frequency
Base Case				
Nonstop service	Milwaukee	4	Traverse City	1
	Chicago	3	Muskegon	2
	Lansing	2	Green Bay	3
	Grand Rapids	2	Chicago	8
			South Bend	1
			Detroit	4
			Benton Harbor	4
			Flint	1.
			Lansing	5
			Saginaw	2
Direct service	Cleveland	2	Escanaba	2
	Detroit	4	Marquette	3
			Iron Mountain	1
			Milwaukee	3
			Cleveland	4
			Indianapolis	1
			Washington, D.C.	1
			New York	1
Alternative 1D2b				
Nonstop service	Chicago	4 *	Traverse City	3
	Grand Rapids	6 *	Muskegon	6
			Green Bay	5
			Chicago	10
			South Bend	3
			Detroit	6
			Benton Harbor	6
			Flint	3
			Lansing	6
			Saginaw	4
			Milwaukee	5
			Cleveland	6
			Indianapolis	3
			New York	4
Direct service			Escanaba	4
			Marquette	5
			Iron Mountain	3
			Minneapolis	6
			Washington, D.C.	4
			Miami	7

* Air feeder service

Figure III-3

METHOD OF PASSENGER ANALYSIS



and cost of competitive surface modes will not change for different airport system alternatives. The geographic/demographic data have also been assembled and organized as part of Task Group 2. Some of these data are summarized in Section II.

The passenger demand model, which is described in Section IV, provides estimates of air passenger travel between pairs of zones (both internal and external) in response to a particular airport system alternative. In this model, travel demands are estimated and assigned to air travel and competing modes on the basis of mode selection criteria that include travel time and perceived cost. The model considers complete trips from origin to destination, including, in the case of air travel, access and egress time and cost to and from the originating and terminating airports, waiting time and other service characteristics. The passenger demand model also considers airport selection (airport-split analysis) by individual travelers. Thus, the analysis will assess how many travelers choose surface transportation, how many use a local or regional airport, and how many choose to travel by auto to Chicago or Detroit and fly to their destination from there.

The economic impact analysis, with the aid of the economic impact model, will estimate future population, economic activity and income for the different Michigan zones. This analysis will provide a major input to the passenger demand model. Future economic activity will also be influenced by the nature and extent of transportation service, the division of traffic among modes and the division of air traffic among airports. These procedures are described in Section VIII.

The institutional and financial analysis will measure the impact of different airport system alternatives on state and local governments, individual and corporate taxes, bonding requirements, airline operations and other airport-related commercial activities. This analysis is described in Section VII.

All the steps of the passenger analysis focus on evaluating the airport system alternatives with the evaluation model. This step provides the measure of "goodness" of each airport system alternative studied. The evaluation model provides both quantitative and qualitative data on:

- Traveler impacts
- Air carrier impacts
- Airport operator impacts
- Economic impacts
- Institutional, financial and environmental impacts.

The evaluation model, which is described in Section IX, reflects the overall Michigan aviation goals and objectives as set forth in the National Transportation Planning Study.*

Cargo Analysis

The approach used to analyze air cargo is illustrated in Figure III-4. The general nature of the method is similar to that described for passenger analysis. However, there are two important differences. One difference is that no modal split analysis is performed. Air cargo is a sufficiently small fraction of all cargo movements that a quantitative modal split analysis would not be meaningful--even small modal split errors would result in enormous air cargo differences. The other difference is that cargo analysis is treated in less detail than passenger analysis for four principal reasons: (1) cargo activities at local and regional airports are not likely to be large in comparison to passenger activities, (2) no reliable air cargo traffic data exist that give present origins and destinations by airport and that give true origins and destinations, (3) no reliable air cargo traffic data are broken down by commodity so that specific industry growth can be examined, and (4) the volume of air cargo moving through a particular airport will be heavily influenced by the decisions of airlines and operating agencies to build cargo facilities and promote their use.

The approach that has been adopted is based on factoring national statistics and applying them to Michigan operations. However, the technique does reflect circumstances at local airports and the choice that shippers have between shipping by air from a local airport and shipping by surface to a large hub airport. The use of national statistics merely suggests that future air cargo operations in Michigan are likely to be neither more nor less important relative to other modes than they are for the nation as a whole. Although general in nature, this approach still recognizes air cargo growth that will result from diversion from surface modes, changes in shipper attitudes, and new product movements.

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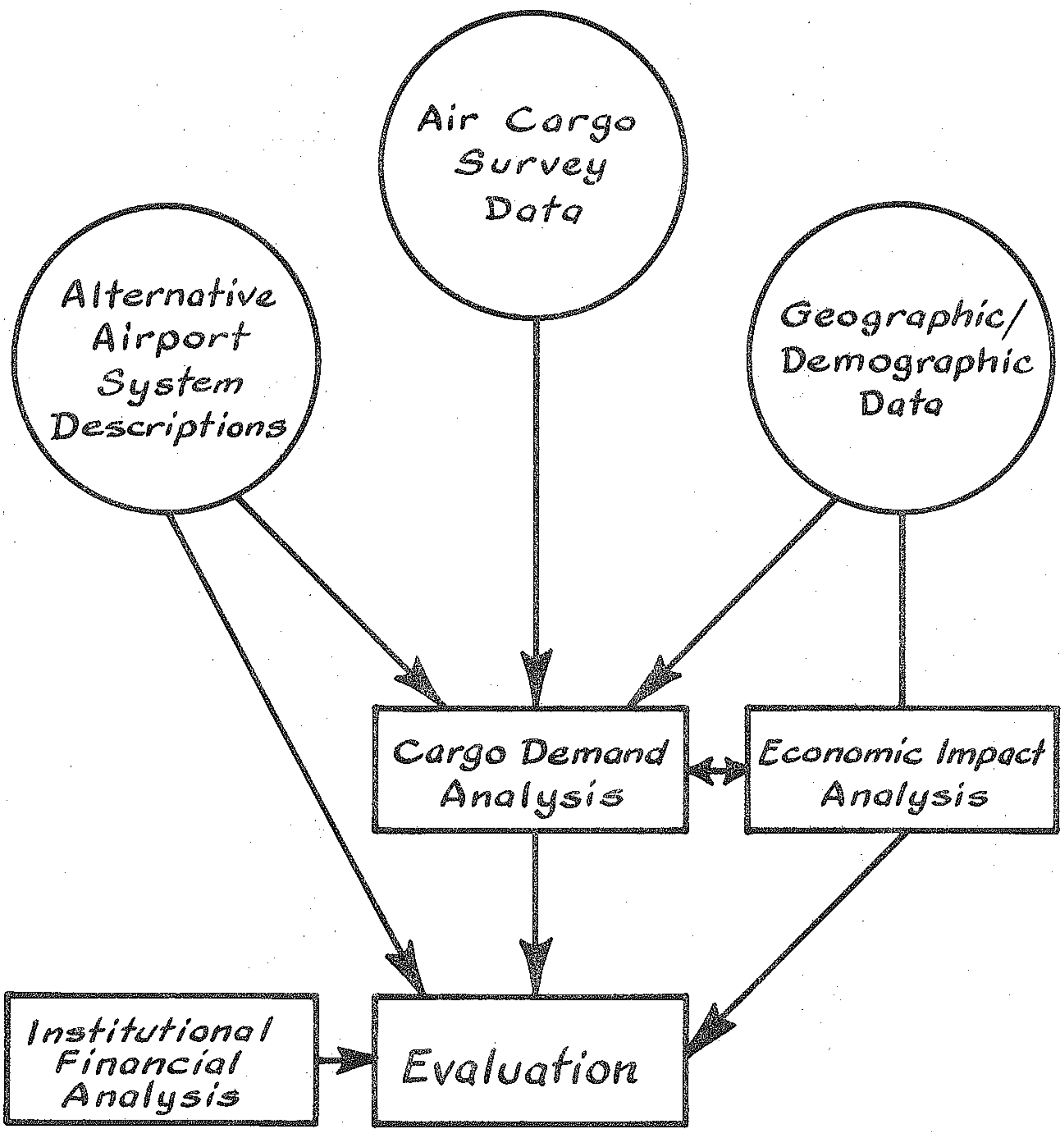
* National Transportation Planning Study: Phase One--Aviation Goals for the State of Michigan, prepared by Michigan Department of Commerce, Aviation Commission, February 1971.

Figure III-4

METHOD OF CARGO ANALYSIS



IV AIR PASSENGER DEMAND

This section presents the final formulation and calibration of the multimode intercity passenger demand that will be used in the study to predict air passenger demand. The model is basically the one that SRI developed and applied in prior studies for the Michigan Interagency Transportation Council.* However, the model has been modified (to extend its capabilities) and recalibrated for use in this study.

Demand Model Formulation

The demand model is a system of equations. For travel between two zones by mode m, a measure of travel "conductance," w_m, is calculated as:

$$w_m = a_m t_m^{\alpha_m(1)} c_m^{\alpha_m(2)} \left[1 - \exp(-0.12 f_m)\right]^{\alpha_m(3)} \qquad (1)$$

where

t_m = the travel time between zones by mode m

c_m = cost of travel

f_m = daily frequency of service.

These three measures--time, cost, and frequency--are termed travel impedance measures and reflect a sum for the access, line-haul, and egress portions of the traveler's trip.

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* Billheimer, John W., The Michigan Intercity Passenger Demand Model, Final Report No. 2, project MSH-8476, Stanford Research Institute, June 1971.

The remaining terms in equation 1 are calibration parameters. The α values are weightings for the impedance measures to account for the traveler's perceived importance of each measure. The α values do not vary among zone pairs and do not vary appreciably among modes.* The a_m values do not vary by zone pair, but do vary by mode, such that the model's predicted allocation of traffic among modes properly replicates observed (actual) allocations.

A measure of total travel conductance between two zones, W, is obtained by summation of the w_m values for all possible models of travel

$$W = \sum_{\text{all } m} w_m \quad . \tag{2}$$

The modes considered are auto, bus, rail, and air. As discussed later, several different air modes (routings) are treated, depending on a traveler's available choice among airports.

Total predicted passenger travel, D, between two zones is treated as a function of the W value calculated in equation 2.

$$D = \beta_i \beta_j (P_i P_j) W^{0.9} \tag{3}$$

where

P_i = the population of zone i

P_j = the population of zone j.

The β (β_i and β_j) coefficients are zone specific constants. They are included to compensate for factors that affect the amount of passenger travel originating and terminating in a zone--factors that are not explicitly included in the model. Thus, the β values help to correct for

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* The exception is the α value that applies to frequency of service by automobile. Here, the formulation is such that infinite frequency of service is assumed.

unexplained differences in travel for two seemingly similar zones. For the external zones, and especially for those larger zones located farthest from Michigan, the zone specific constants also adjust travel to allow for the use of a single airport in each such zone to represent several major airports at different locations (cities) within that zone. In addition, the β coefficients serve as scale factors for the demand equation.

Equation 3 represents the only significant change in formulation of the demand model. Instead of total zone population, the model previously used a variable "number of families with annual incomes exceeding $10,000." The modification was made to improve the interface between the demand model and the economic impact model (see Section VIII). The economic impact model is able to provide more accurate estimates of the "population" variable than of the "families" variable.

The final equation of the demand model allocates total passenger demand for a zone pair (as calculated in equation 3) among the available modes of travel. The travel "conductance" measures calculated in equations 1 and 2 are used:

$$D_M = \frac{w_m}{W} D \quad . \tag{4}$$

As is clear from the formulation of the passenger demand model, the predictions of air passenger travel to be made in this study will depend on a number of factors.

- The competitive position of the air modes, versus other modes, as measured by travel time, cost, and frequency. To the extent that air service improves, passengers will be diverted from surface to air transportation (i.e., different w_m values in equation 1).

- Zone population changes--as they influence total passenger demand (equation 3).

- Induced traffic as air service improves (i.e., air service effects on the W value in equations 2 and 3).

There is another influence on air passenger growth that requires treatment. Demand for air service has exhibited a "natural" growth in the past--a growth in excess of that accounted for by service improvements and population increases. The approach to be taken in this study will be to estimate this added incremental growth rate over time on the basis of nominal growth projections for air travel within the United States during the time period of interest. The a_m values for air travel in equation 1 will then be modified to reflect this growth estimate.

During Task Group 2, demand model work has concentrated on development of values for model variables and parameters for the 1970 base year. The remainder of this section describes how these values have been established. The methods used to obtain modal time, cost, and frequency values are described followed by a description of the development of values for the several calibration parameters.

Modal Impedance Values

Required data include network and system operating characteristic data (e.g., times, costs, distances, speeds, frequencies of service, fares) for each of the four basic modes of intercity travel and access data (mode of access, times, costs, distances).

Highway System

The first step was to identify a highway network for the study zonal structure. The auto network was coded in terms of links and nodes--the links representing highway routes and the nodes representing the junction of two or more highways. This network, closely following the major structure of the Michigan highway system, consisted of 272 one-way links and 93 nodes and provided extensive highway service between all pairs of Michigan zones and between Michigan zones and external zones. Centroids were determined for each zone, and access links were specified from these centroids to appropriate nodes on the auto network.

Distances were assigned to each link representing the lengths of the corresponding segments in the highway network. These highway (nonaccess) links were then coded as either (1) two-lane highway, (2) four-lane divided highway with free access, or (3) four-lane freeway, depending on the predominant facility type as existed in 1970 for each link. Speeds, operating costs, and capacities were assumed for each of these three types of links, as shown in Table IV-1, as well as for access links in Michigan and external zones. The operating costs consist of the costs that can be directly related to mileage such as gas, oil, times, maintenance, and a small amount of depreciation. The value of 5 cents per mile represents the most recent estimate available and varies less than 5 percent (on the

Table IV-1

ACCESS AND HIGHWAY LINK CHARACTERISTICS

Facility Type	Distance (miles)	Speed (mph)	Cost (cents per mile)
Access link			
Michigan zone	Variable	20-30	5¢
External zone	20	30	5
2-Lane highway	Variable	50	5
4-Lane divided--free access	Variable	55	5
4-Lane freeway	Variable	60	5

average) for the most intercity auto travel.* Travel times were determined for the individual links based on the assigned distances and speeds.

On the basis of these auto time and cost values for individual network links, zone-to-zone auto times and costs were generated by summation along the minimum time path between each zone pair.

Bus System

The bus network was generally assumed to contain the same links as those in the auto network. Times, costs, distances, and frequencies of service were developed for all zone pairs.† All major zone-to-zone bus routes were considered in arriving at these average time, cost, distance, and total frequency values. Access times and costs were determined from each zone centroid to the nearest appropriate bus terminal and added to

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* Curry, David A. and Dudley G. Andersen, Procedures for Estimating Highway User Costs, Air Pollution, and Noise Effects, NCHRP Project 7-8, Stanford Research Institute, April 1972.

† The major data collection effects for both the bus and rail networks were conducted by the Michigan Aeronautics Commission staff. Data collected under Contract 1-1970 to the Michigan Interagency Transportation Council were also used.

the fare and time matrices to get the necessary total zone-to-zone time and cost matrices. The access costs were assumed to include all direct "out-of-pocket" costs (fares, running, parking costs) associated with access to the nearest bus terminal. Delay times of 30 minutes and 15 minutes were assumed at the origin and destination bus terminals, respectively.

Rail System

Matrices of time, cost, distances, and frequency of service were developed defining approximate 1970 rail service between zone pairs. Instead of determining all individual terminal-to-terminal fares for Michigan--external zone pairs, relationships were established between fare rates (fare-per-mile) and the different rail carriers servicing each region of the United States. An approximate fare matrix was then readily obtained. Access times and costs were determined as for the bus system--from the zone centroid to the nearest appropriate rail terminal--and delay times of 30 and 15 minutes were assumed at the origin and destination rail terminals, respectively.

Air System

The air system consisted of 21 airports within Michigan providing scheduled airline service during the 1970 base year. Only the major airports associated with the centroid cities were considered for the external zones, a total of 29 external airports. Thus, for example, only the Denver airport in zone 44 was included in the analysis. To have included all major airports within each zone in the analysis, such as Phoenix, Las Vegas, Salt Lake City, and Albuquerque for zone 44, would have unduly expanded the data and computational requirements of the study.

Airport-to-airport flight times, fares (tourist or standard), and daily frequencies were coded for nonstop, direct, and connecting flights from data in the Official Airline Guide.* The flight times coded for each flight category--nonstop, direct, connect--were generally taken to be the average times for all flights within that category. Special flights operating on a nondaily basis (normally one day per week) were omitted from the analysis.

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* The November 1, 1970 Domestic Quick Ref. Ed. of the Official Airline Guide.

Appropriate consideration and development of air times, costs, and frequencies required converting the nonstop, direct, and connecting flight impedance measures to a single set of measures when the several flight categories are offered for an airport-to-airport pair. The problem of converting these multiple times, costs, and frequencies to a single set of values was resolved through the use of what might be termed the "equivalent value principle" (see Appendix). The procedure changes one or more of three parameters (travel time, out-of-pocket cost, and frequency of service) so that the sum for various flight category values yields a proper w_m value for the demand model.

For several airport pairs, there is no published flight information. In these cases, it was necessary to fashion impedance measures by specifying an intermediate connecting airport. Connections between airlines flights were allowed at all airports within Michigan and at the Green Bay and Chicago airports. The total cost of the air portion of the journey was assumed to be the sum of the individual flight segments for connecting flights, and the air travel time was considered to be the sum of the individual flight times plus a transfer delay time for changing planes. This transfer delay time was calculated as roughly equivalent to assuming that the arriving flights arrive uniformly over a 12-hour period of the day and that departing flights leave uniformly over the same 12-hour period. Finally, the frequency of service for these airport pairs entailing unpublished connects was assumed to be the smaller of the frequencies for the separate flights constituting the airport-to-airport trip.

After the airport-to-airport impedance measures were obtained, as described above, the remaining steps in establishing zone-to-zone air travel impedance measures were to:

- Establish impedance measures to surface travel between zone centroids and airports

- Establish alternative air modes (routings) in recognition of the potential competition for a zone's travelers that exists among the zone's own airport, and airports in Chicago and Detroit.

These developments are described in the paragraphs that follow.

At the outset of the study, it was observed that a separate mode split model might be required to account for a traveler's choice among alternative surface modes of airport access (e.g., private auto, taxi, bus). However, analysis of the data collected during the passenger survey of Task Group 2 indicated that a simplified approach would yield access impedance measures of adequate precision. The passenger survey data indicated that a minimum of 80 percent of airport access trips to the four airports surveyed were by private auto. The remaining trips were made largely by rental auto and taxi. As a result of this dominance by the private auto in accessing Michigan airports, it was decided to forego development of formal access modal split model. Instead, a fixed modal split was assumed to all airports in the following percentages:

Private auto--parked at airport	25%
Private auto--driven away by others	60
Rental auto	7
Taxi	5
Other (e.g., bus, courtesy car)	3

The direct effect of this assumption is on access costs and parking costs--access times are assumed to be roughly the same for all modes and are based on those of the private auto. An average access cost is determined by assuming that the cost of access by rental auto is roughly twice that of the private auto (assuming that the primary reason for renting the auto was not solely for access to the airport, hence only marginal costs are relevant), the cost of a taxi is roughly four times that of private auto, and the cost of the other modes are about the same as the private auto. Then, the total access cost will be about 1.22 times that of the private auto. Assuming a private auto cost of 5 cents per mile results in a total access cost of 6.1 cents per mile. Average parking cost per trip is also calculated from the fixed modal split percentages. Assuming an average parking cost of $0.40 per auto parked results in an average cost for all autos of $0.10 per auto trip.

Zone-to-airport distance and time measures were calculated in a manner similar to that described above for highway network access, but the investigation was more detailed. First, access times and costs were calculated directly for trips from many individual Michigan counties to nearby airports.* These times and costs were then weighted by county populations to obtain average times and costs for access to an airport from a zone. In cases not covered by county data, access times and costs were either estimated directly from the zone to the airport (e.g., based on distances, speeds, population distributions) or by calculating auto access times and costs via the auto network. These procedures yielded access times that agree closely with actual access time data, as obtained in the passenger survey.

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* These access data for each county were generated by staff of the Michigan Aeronautics Commission and Interagency Transportation Council.

Additional values included in airport access impedance measures were delay times of 30 minutes at the origin airport--for parking, ticketing, and check-in--and 15 minutes at the destination airport--for baggage pickup.

The competitive interrelationships of relatively close airports were included in the analysis by treating airport-to-airport pairs as separate air modes. For intra-Michigan air travel, each traveler is allowed the opportunity to depart from either of the two airports nearest his origin zone and to arrive at either of the two airports nearest his destination zone--a total of four separate air mode possibilities. Figure IV-1 indicates the four possible air modes for travel within Michigan. All flights between departure and arrival airports are allowed that include one or no connections (i.e., at an intermediate airport not shown in Figure IV-1).

Air trips including a zone external to Michigan are forced to use the airport designated for the external zone, thus reducing the number of basic air modes to two. However, an additional air mode concerning auto access (egress) to the nearest of the Chicago or Detroit airports was allowed for trips between Michigan and external zones, thus adding a third air mode to the Michigan-external zone analysis. Figure IV-2 depicts these three air modes.

Demand Model Calibration

The process of model calibration deals with the specification of values for the model's calibration parameters--a_m, α, and β. The intended result is that the model's predictions of 1970 air passengers agree closely with actual 1970 air passenger data.

While the model predicts zone-to-zone air passengers (and travelers by other modes as well), the most comprehensive actual data available are airport-to-airport statistics.* These statistics served as the primary benchmark for calibration. Other data used for calibration included:

- 1970 modal impedance values (the development of which is described above)

- Population Census data for 1970

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* Civil Aeronautics Board, Domestic Origin-Destination Survey of Airline Passenger Traffic, 1970 year, Washington, D.C., 1971.

Figure IV-1

ALTERNATIVE AIR MODES FOR FLIGHTS WITHIN MICHIGAN

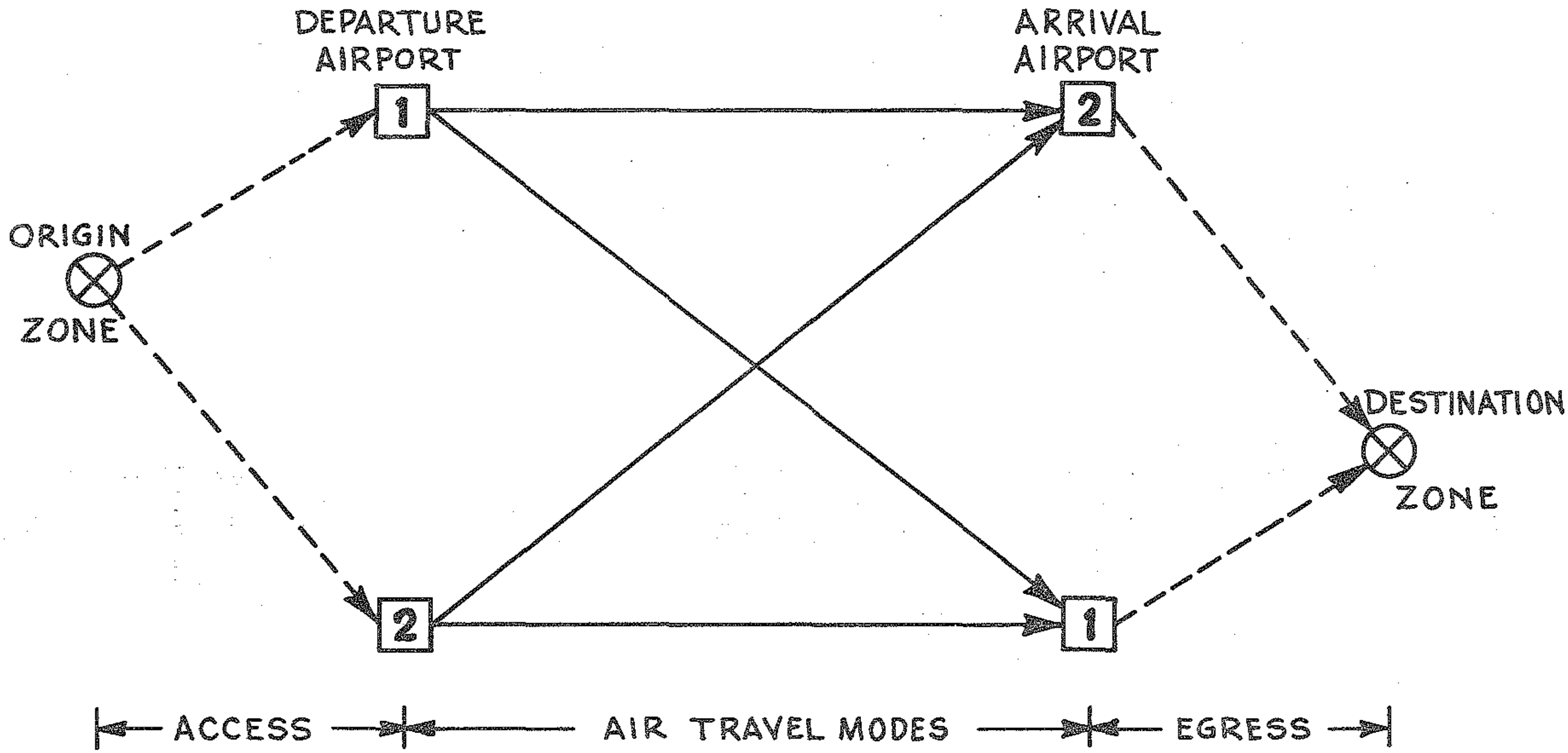
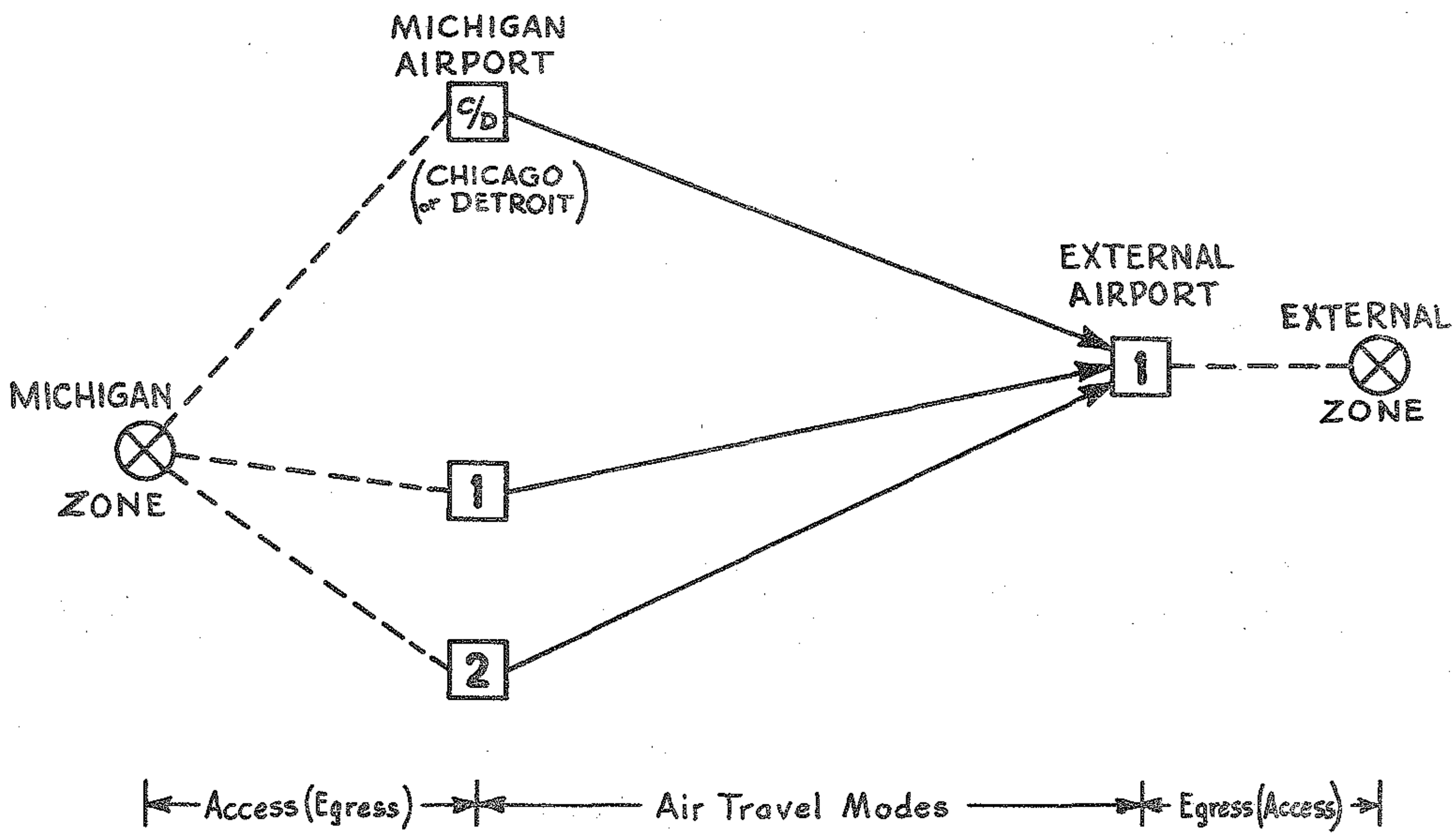


Figure IV-2

ALTERNATIVE AIR MODES FOR FLIGHTS TO (FROM) EXTERNAL ZONES



- Data from the passenger survey conducted during Task Group 2 of this study

- National data on traveler behavior from the 1967 Census of Transportation

- An origin-destination cordon survey of Michigan travelers.*

- Data from a variety of individual airport surveys, conducted in various years (e.g., Detroit Metropolitan, Chicago-O'Hare, Kalamazoo/Battle Creek).

Because the demand model was previously calibrated (and yielded good results) in applications for Michigan's Interagency Transportation Council, many of the calibration parameter values have been used without change in this study. Thus, the a_m and α values for the air, bus, and rail modes are those determined in the original calibration efforts. The a_m and α values for the auto mode were changed, however, to provide for better agreement between the model's prediction of auto travel and actual data from the most recent (1967) Census of Transportation. The calibrated values for all the "mode specific" parameters are given in Table IV-2.

Table IV-2

VALUES FOR MODE SPECIFIC CALIBRATION PARAMETERS

Mode m	a_m	$\alpha_m(1)$	$\alpha_m(2)$	$\alpha_m(3)$
Auto	13.76	-1.6	-1.6	0
Bus	1.50	-1.5	-1.5	0.3247
Rail	1.50	-1.5	-1.5	0.3247
Air--except Detroit-Chicago	1.50	-1.5	-1.5	0.3247
Air--Detroit-Chicago	0.75	-1.5	-1.5	0.3247

* The data collected by Michigan are reported on in Final Report No. 2 of the ITC Study referenced previously.

The procedure for estimating the β values used an iterative method that compared total predicted trip arrivals and departures at each airport with the values obtained from the CAB airport-to-airport data. Air trips were first predicted on a zone pair basis using initial estimates for the coefficients, β_i^o. These trips were loaded on the air network, and arrivals and departures were totaled at each airport. The β-value estimates were then updated using the ratios of actual to predicted arrivals and departures at each airport, the distributions by origin (destination) zone of total actual trip departures (arrivals) at each airport, and the distributions of actual trips between competing airports for each zone. Although the exact method is complex, it need not be described in further detail.

Table IV-3 lists the "zone specific" (β) calibration coefficients obtained through the iterative procedure described above. These coefficients resulted in 82 percent of the predicted airport departures and arrivals differing by less than 10 percent from the actual values and 62 percent differing by less than 5 percent. Comparison of total daily predicted arrivals and departures with actual trips are presented in Figure IV-3 for the 21 Michigan airports and indicate the close "fit" of the demand model to the actual data.

While the results portrayed in Figure IV-3 satisfy the basic objective of demand model calibration, other measures of the model's predictive ability are also noteworthy. These relate to predictions of traveler choice among airports (i.e., "airport split"). The mode's airport split results in the Detroit and Chicago airports (access by nonair modes) drawing roughly from 2 to 10 percent of the total Michigan-external zone pair air trips between 200 and 500 miles and from roughly 10 to 40 percent of the trips exceeding 500 miles. (These are average figures for all Michigan zones except those considering Detroit or Chicago to be their nearest airport.) These values compare favorably with Detroit Metropolitan's observed 35 percent share of regional air traffic originating in the Tri-City area of Saginaw, Bay City, and Midland.* The competition between the nearest and next-nearest airports results in values of from less than 1 percent to greater than 20 percent of all travel bypassing the nearer airport for the better service provided from the farther airport. These values are averages based on distances and do not reflect individual zone pair values, which varied even more widely. The average of all trips bypassing the nearer airport was about 4 percent, quite close to the 2.3 percent value observed in the airport passenger survey conducted in connection with this study.

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* Reported on in Final Report No. 2 of the ITC Study referenced previously.

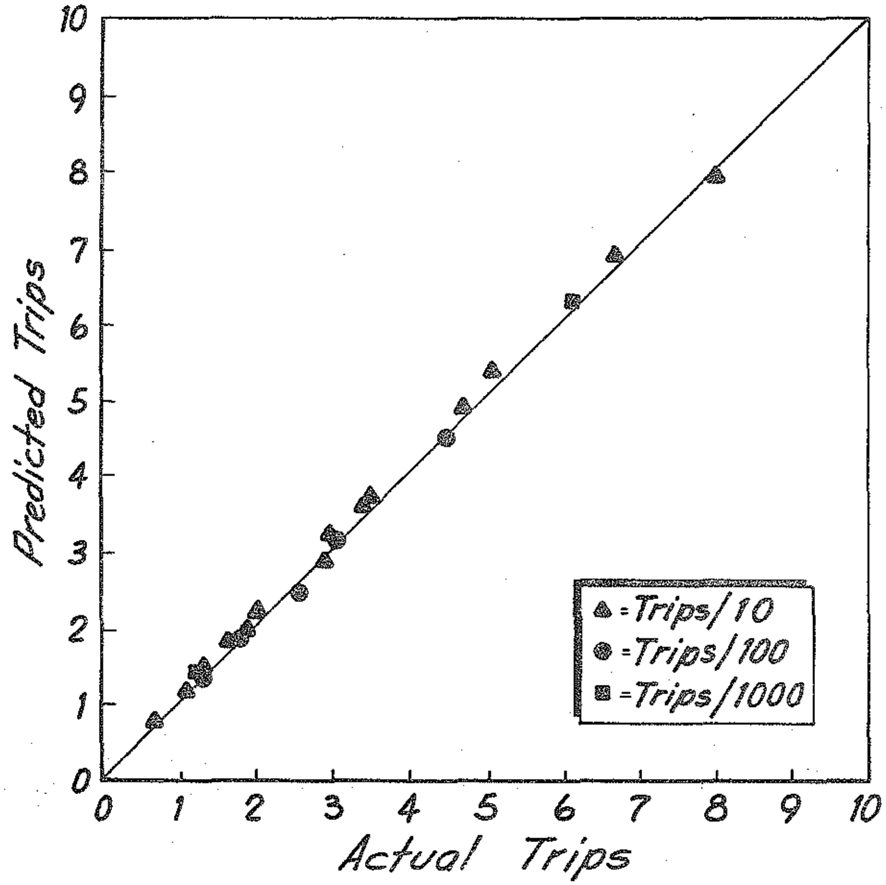
Table IV-3

VALUES FOR ZONE SPECIFIC CONSTANTS

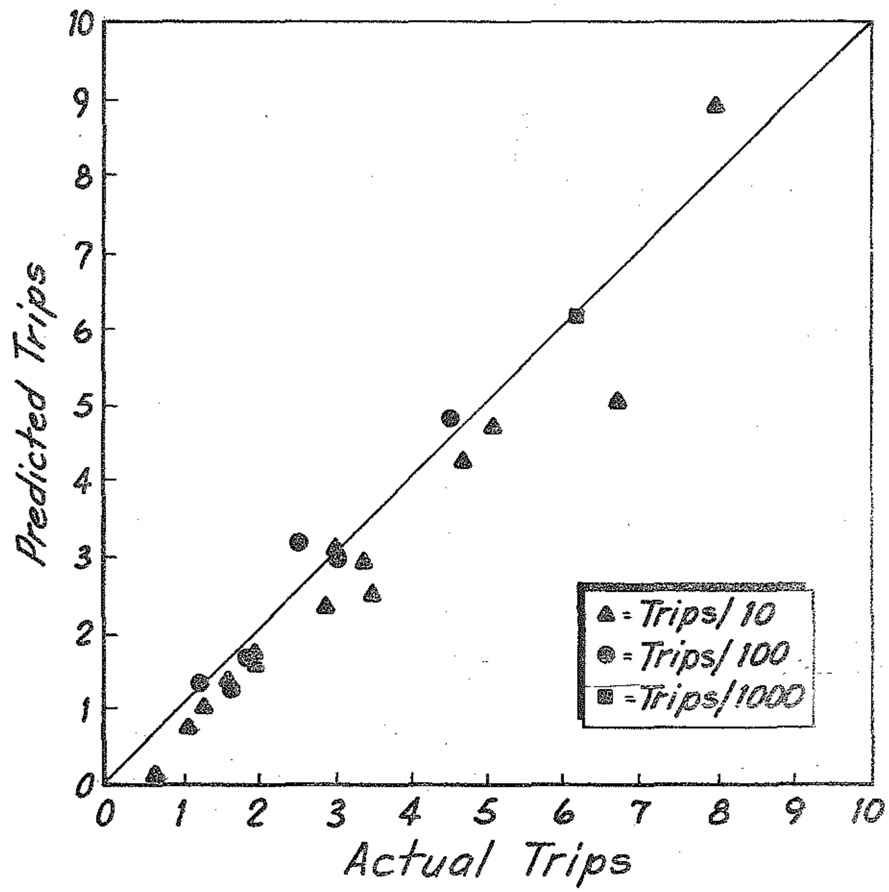
Michigan Zone	Zone Specific Constant β_i	External Zone	Zone Specific Constant β_i
1	11.2781	28	5.1724
2	.9797	29	7.8693
3	3.8043	30	9.4486
4	2.5926	31	6.0086
5	5.8987	32	1.1157
6	10.6473	33	2.2891
7	7.1548	34	3.0938
8	8.5056	35	5.1966
9	4.8737	36	10.0470
10	14.8787	37	4.6111
11	20.4432	38	11.0010
12	11.3413	39	5.3399
13	23.9605	40	11.1527
14	32.0010	41	4.4724
15	11.2774	42	2.9447
16	11.2777	43	5.8133
17	11.2794	44	36.2354
18	2.6553	45	8.7830
19	7.1882	46	9.9018
20	7.4348	47	1.9353
21	7.5060	48	3.7557
22	6.9481	49	9.4470
23	4.0425	50	9.1171
24	36.1346	51	13.6945
25	75.1983	52	49.8675
26	30.5706	53	69.7623
27	31.8079	54	74.6702
		55	120.976
		56	11.7483

Figure IV-3

DAILY AIRPORT DEPARTURES AND ARRIVALS - 1970



A. DAILY AIRPORT DEPARTURES



B. DAILY AIRPORT ARRIVALS

V AIR CARGO DEMAND

Considerable effort has been expended during Task Group 2 to gain an understanding of current air cargo flows. On the basis of the data collected, it was determined that the methods used to predict air cargo demand must differ substantially from the methods used for predicting air passenger demand. Moreover, it is clear that regardless of the method adopted, predictions of future air cargo flows will be subject to rather large forecasting errors. The outlooks and actions of individual airport managements, air carriers, freight forwarders, and cargo interests (shippers and consignees) will have strong influences on the amounts of air cargo handled at each of the Michigan airports. Methods are described below for predicting demand for the two classes of air cargo: the first class is air freight (including air express), the second class is mail--air mail and other classes of mail that move by air.

Air Freight

In past work for the Michigan Interagency Transportation Council, SRI demonstrated the use of an air freight model that generates air freight demand in essentially the same manner that passenger demands will be developed in the current study. This air freight model requires that the origin-destination flows of "air potential" freight be specified--including flows that now move entirely by surface modes (truck or rail). On the basis of the cost and time performance of the competing modes, the model developed a "mode split," that is, a prediction of the percentage of "air-potential" traffic that actually would be transported by air. This percentage would vary as alternative improvements to the air system are postulated (e.g., new regional airports). The freight model's cababilities suggested its application in the current study; however, analaysis of the freight data collected in this task group suggested that another approach would be more meaningful. The principal shortcoming to use of the freight model is lack of "air potential" and other data at the statewide level that are sufficiently complete to calibrate the model. Origin-destination statistics on flows are not available for air freight as they are for air passengers. The effort to collect adequate information of this kind would far exceed project resources. Moreover, use of the freight model would require projections of origin-destination data by commodity for selected surface movements.

Overall, it was judged that likely errors in freight flow inputs would seriously degrade the validity of the model's air freight predictions.

The approach that is adopted for predicting total Michigan air freight demand through the study planning horizon will be based on a consensus of national predictions of air freight growth (e.g., ATA Airline Airport Demand Forecasts; FAA's Ten Year Plan, 1973-82). Michigan's share of this growth will be assumed to correspond to its past participation, modified as appropriate by outputs of the economic input model that relate Michigan economic growth to that of the nation (see Section VIII). By this approach, three significant factors in air freight growth will be taken into account. They are:

- Diversions among modes because of changes relative to service quality.

- Diversions among modes because of changes in the way that shippers and consignees perceive transportation costs as a part of total distribution costs

- Future demands placed on the air system by new product movements.

It remains to establish the method for allocating total Michigan air freight traffic among the airports constituting the State system (those of the existing system or those specified in the alternative system as described in Section III). In the Michigan context, this is a topic of some complexity. At the outset, it was recognized that air freight shipments originating or terminating in a Michigan community frequently are not routed through that community's local airport. Instead, surface movement to or from a more distant large airport is used. An understanding of this "local airport diversion" was judged critical to the cargo demand task.

The American Academy of Transportation (AAT) was retained by the MAC to gather data on the nature and extent of local airport diversion. This work was completed during Task Group 2. It is documented in AAT's report "Michigan Air Freight Data Collection Program" and summarized here. The AAT sent mail questionnaires to a carefully selected sample of Michigan companies. In addition, numerous field interviews were conducted with:

- Airport managements
- Airlines
- Air freight forwarders

- Motor carriers handling air freight shipments
- Postal officials.

The principal results of AAT's work are portrayed in Table V-1 and V-2. Table V-1 deals with air freight originating in Michigan during the study base year (1970) and Table V-2 deals with terminations. The unit of measure is millions of pounds. The columns of the tables represent Michigan's existing air carrier airports plus Willow Run and Detroit City airports. One additional column is provided for Chicago's O'Hare Airport. The rows of the tables list all Michigan study zones. An additional row, "Other," portrays air freight volumes that move by surface between their ultimate origin or destination outside the state and a Michigan airport. Entries within the tables represent surface movements of air freight between zones and airports. For example, Table V-1 shows that an estimated 11.24 million pounds of air freight originated in the Lansing zone in 1970. Of this, 1.22 million pounds was enplaned at the Lansing (Capital City) Airport. The substantial remainder moved by truck to Detroit Metro and Willow Run for subsequent air movement.

The format of Tables V-1 and V-2 facilitates discussion of the steps to be followed in the air freight demand analysis. The total Michigan air freight volume that will be derived from national forecasts corresponds to the entry in the lower right-hand cell of each table. The state total will be allocated among Michigan zones (i.e., among the cells of the right-most column) in accordance with zonal income and population data that are taken from the economic impact model.* The final step is to allocate each zone's total air freight among airports. For reasons discussed below, this final step of estimating future "local airport diversion" will be largely subjective.

To predict future "local airport diversion," the extent and causes of present diversion must be identified. In this, the AAT work has been largely successful. The results in Tables V-1 and V-2 clearly portray significant diversions of air freight from local Michigan airports to Chicago and Detroit facilities, notably for the following zones:

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* An alternative method would be to allocate the state total directly to airports--along the bottom row of the table. This method would not account for differing rates of economic growth among Michigan zones. Moreover, the alternative method is not appropriate in the case of the system alternatives that include postulated new regional airports.

Table V-1

1970 OUTBOUND AIR FREIGHT & EXPRESS (Millions of Lbs.)

AIRPORT (ORIGIN)

ZONE		Detroit Metro	Willow Run	Detroit City	Jackson	Kalamazoo	Benton Harbor	Flint	Lansing	Saginaw	Grand Rapids	Battle Creek	Muskegon	Alpena	Traverse City	Manistee	Pellston	Sault Ste. Marie	Escanaba	Marquette	Hancock	Menominee	Iron Mountain	Ironwood	Chicago	TOTAL
Detroit	1	114.41	32.76	0.80																						147.97
Port Huron	15	4.19	2.05																							6.24
Pontiac	16	9.78	10.24	0.09																						20.11
Ann Arbor	17	4.76																								4.67
Monroe	18	2.52																								2.52
Jackson	2	1.80			0.13				0.01																0.14	2.08
Kalamazoo	3	2.40				1.24																			1.18	4.82
Benton Harbor	4						0.49																		0.60	1.10
Flint	5	10.35	15.01					1.63	0.03																	27.02
Lansing	6	4.56	5.46						1.22																	11.24
Saginaw	7	6.79	2.04						0.01	1.53																10.37
Grand Rapids	8	0.89	0.68						0.05		5.47		0.65												0.19	7.93
Battle Creek	19	0.91										0.17													0.42	1.50
Caro	20																									
Muskegon	21										0.11		1.96													2.07
Bay City	22	0.98								0.51																1.49
Alpena	9													0.29			0.07									0.36
Traverse City	10														0.53	0.09										0.62
Ludington	23															0.01										0.01
Pellston	24																0.19									0.19
Sault Ste. Marie	11																0.01	0.03								0.04
Escanaba	12																		0.10						0.01	0.11
Marquette	13																			0.19					0.01	0.20
Houghton	14																				0.23					0.23
Menominee	25																					0.17			0.03	0.20
Iron Mountain	26																						0.13			0.13
Ironwood	27																							0.02		0.02
Other		3.83					0.01											0.01				0.06	0.01			3.91
TOTAL		168.08	68.24	0.89	0.13	1.24	0.50	1.63	1.32	2.04	5.58	0.17	2.61	0.29	0.53	0.10	0.27	0.04	0.10	0.19	0.23	0.23	0.14	0.02	2.58	257.15

Table V-2

1970 INBOUND AIR FREIGHT & EXPRESS (Millions of Lbs.)

AIRPORT (DESTINATION)

ZONE		Detroit Metro	Willow Run	Detroit City	Jackson	Kalamazoo	Benton Harbor	Flint	Lansing	Saginaw	Grand Rapids	Battle Creek	Muskegon	Alpena	Traverse City	Manistee	Pellston	Sault Ste. Marie	Escanaba	Marquette	Hancock	Menominee	Iron Mountain	Ironwood	Chicago	TOTAL
Detroit	1	113.60	15.36	1.27																						130.23
Port Huron	15	2.11																								2.11
Pontiac	16	10.54	0.85	0.14				0.06																		11.59
Ann Arbor	17	3.60	0.51																							4.11
Monroe	18	1.39																								1.39
Jackson	2	1.21			0.46				0.02																0.12	1.81
Kalamazoo	3	1.41				1.47																			0.26	3.14
Benton Harbor	4						0.65																		0.96	1.61
Flint	5	6.65	0.34					2.95	0.04																	9.98
Lansing	6	3.14							2.00																	5.14
Saginaw	7	2.16						0.06		1.14																3.36
Grand Rapids	8	0.71							0.11		5.60		0.31												0.10	6.83
Battle Creek	19	1.16										0.65													0.23	2.04
Caro	20																									
Muskegon	21										0.11		0.92													1.03
Bay City	22	1.21								0.49																1.70
Alpena	9													0.24			0.06									0.30
Traverse City	10														0.53	0.10										0.63
Ludington	23															0.03										0.03
Pellston	24																0.17									0.17
Sault Ste. Marie	11																0.01	0.13								0.14
Escanaba	12																		0.22						0.01	0.23
Marquette	13																			0.37						0.37
Houghton	14																				0.39					0.39
Menominee	25																					0.15			0.01	0.16
Iron Mountain	26																						0.55			0.55
Ironwood	27																				0.02			0.13		0.15
Other		4.31					0.01											0.02				0.05	0.03	0.01		4.43
TOTAL		153.20	17.06	1.41	0.46	1.47	0.66	3.07	2.17	1.63	5.71	0.65	1.23	0.24	0.53	0.13	0.24	0.15	0.22	0.37	0.41	0.20	0.58	0.14	1.69	193.62

Jackson	Lansing
Kalamazoo	Saginaw
Benton Harbor	Grand Rapids
Flint	Battle Creek
	Bay City

Smaller diversions, in terms of absolute volume and percentage of zone air freight, are shown for three Upper Peninsula zones--Escanaba, Marquette, and Menominee.

Diversions from the Upper Peninsula to Chicago result primarily from shipments that cannot be loaded into the types of aircraft currently serving the local airports. Such diversions will be directly influenced by the aircraft types used in future service to the Upper Peninsula. For study purposes, the specification of future aircraft will be based on results of the technology assessment, described in Section VI.

A significant cause of local airport diversion in the lower one-third of the Lower Peninsula is the routing of air freight through Willow Run Airport. This is a specialized "all-freight" activity that does not rely on scheduled air carriers. The AAT has found that use of Willow Run is dictated primarily by corporate policies that focus on this airport as a consolidation point for geographically diverse manufacturing and distribution activities in Michigan. In view of the large-volume transport economies achieved in this manner and the private investments already made for facilities at Willow Run, this diversion can be expected to continue through the study planning horizon. Moreover, it will be assumed that the Willow Run diversions will remain a constant share of the affected zones' future air freight volumes.

It is the remaining Lower Peninsula diversions through Detroit Metro and Chicago-O'Hare that will prove most difficult to treat in the study. These diversions represent about 10 percent of total Michigan air freight (outbound and inbound). Contrary to expectations, the choice between a local airport and these large hub airports does not result from different shipment transit times or costs. Instead, shipper responses to the AAT mail questionnaire disclose that origin-destination shipment transit times differ very little between local airport and large hub airport routings. Although truck pickup and delivery times are a few hours longer to the hub airports than to the local Michigan airports, it appears that this disadvantage is compensated for by better flight frequencies at the large hub airports. Similarly, there is little difference in the rate structures for local airport versus large hub airport routings.

Figure V-1 displays a typical comparison of rates for shipment from a mid-Michigan city (e.g., Lansing). The solid line, representing the rate structure for a local airport routing, is the sum of the local truck pickup charge and the air line-haul rate. The dashed line, for a hub airport routing (e.g., Detroit) includes higher truck pickup charges but, as is typical, somewhat lower air line-haul rates. For shipments of fewer than about 120 pounds, rates are strongly influenced by minimum charges (for both drayage and air movement) and the local airport enjoys a noticeable advantage in the cents-per-pound shipment cost. However, this translates to only a few dollars--at most--in charges for the shipment. For shipments of more than about 200 pounds, the rate structures are quite close, with the large hub airport generally enjoying a very slight advantage.

All available evidence suggests that diversion from Lower Peninsula local airports to Detroit Metro and Chicago-O'Hare is based on a greater capability to consolidate shipments at these airports. Through consolidation, for example, three individual shipments of 80 pounds each would be merged for their airport-to-airport trip, such that the shipment cost for each would approximate the cost per pound at the point labeled "B" in Figure V-1.* Thus, the desirability of consolidation is based on the difference in shipment cost between the points "A" and "B" rather than the inherent differences in the local and large hub airport rate structures. If it were as easy to consolidate at the local airports as at the large hub airports, it is likely that diversion from local airports would be minimized.† Unfortunately, the information required to make such an assessment--either for the present or as part of a future prediction of diversion--depends on many factors. These include:

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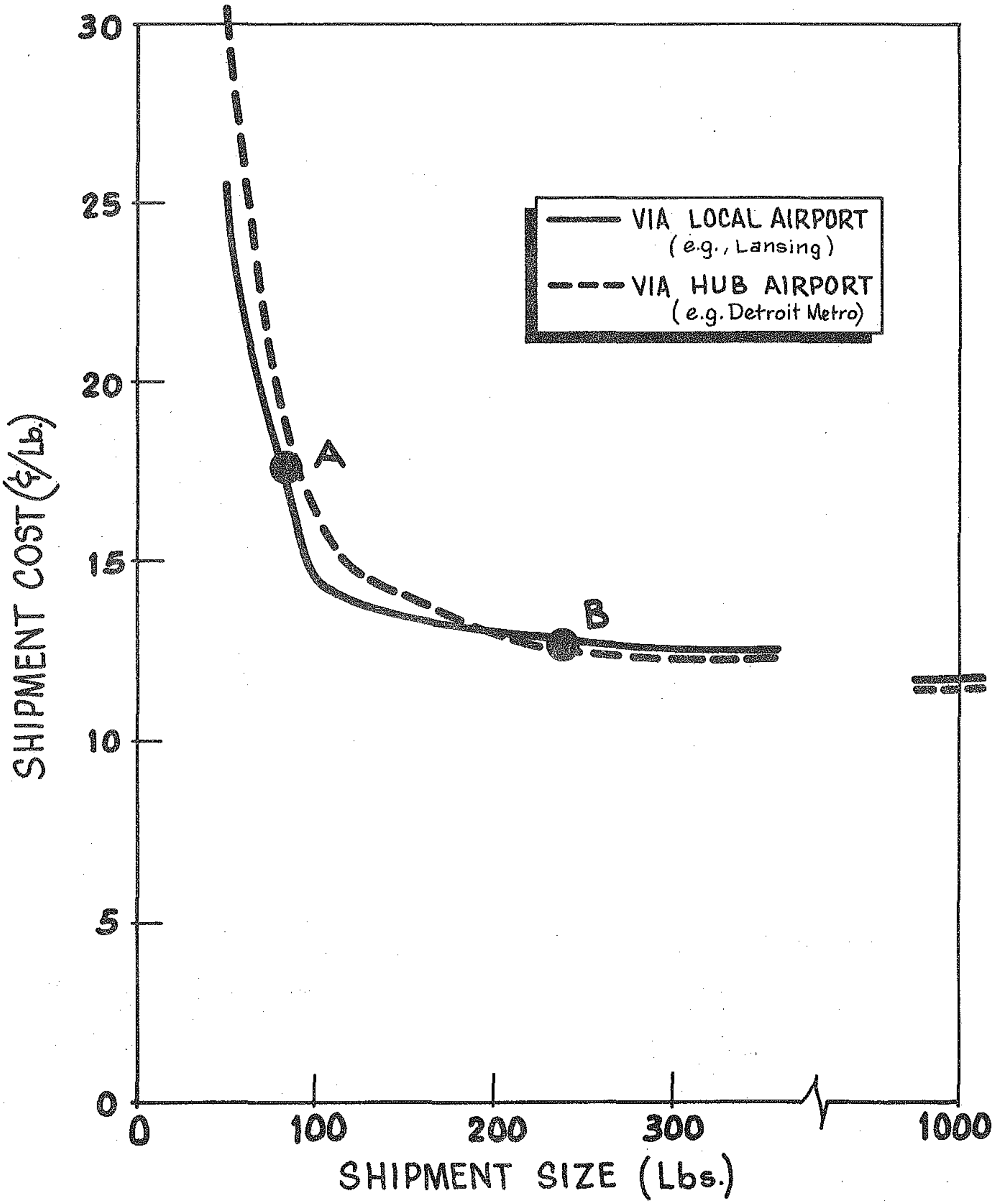
* The precise rate per pound paid by the shipper would depend on the extent of consolidation available for drayage to the airport and the share of the consolidated savings accruing to a freight forwarder if he performs the surface and air consolidation.

† It appears that the converse is also true: when it is as difficult to consolidate via a large hub airport routing as via a local airport routing, the local airport's share of its zone's freight is high. Comparison of Table V-1 and V-2 shows higher local airport shares for inbound freight than for outbound. The AAT work suggests that shipment sizes and diversity of origins for the inbound freight often preclude its consolidation.

Figure V-1

TYPICAL AIR FREIGHT RATE COMPARISON*



*600 Mile Air Shipment From A Mid-Michigan City. Shipment Cost Includes Truck Pickup Charge And Air Freight Rate. See Text For Points Labeled A & B

- The volume of originating and terminating traffic

- The number of shipments by size distribution--this is determined primarily by nontransportation related considerations

- The ability to match origins and destinations of shipments

- The outlook of companies and freight forwarders as to the "best point of consolidation."

If all else were equal, one might hypothesize that total zone air freight volume would be a good index of consolidation potential at a local Lower Peninsula airport--the greater the volume, the higher the likelihood of local consolidation. As a test of this concept, Table V-3 summarizes some of the data from Tables V-1 and V-2. Selected Michigan zones are listed in ascending order by the percentage of their outbound air freight* that is routed via a local airport. Corresponding percentages for inbound air freight are also listed. As evident from the lack of a pattern in zone cargo amounts from row to row in the table, the hypothesis that total zone cargo is a good index of consolidation potential must be rejected. A better correlation is obtained, although it explains little, using the distance between the local airport and the nearest large hub airport as an index.†

As a result of this analysis, the basic study approach to local airport versus hub airport routing of air freight in the Lower Peninsula will be to assume the same diversion percentages in the future as were found by AAT for the base year. That is, in allocating a zone's total air freight between local and hub airports, the percentage figures in Table V-3 will be used. For alternatives where a new regional airport is postulated--which thereby becomes the "local" airport for more than one zone--each of these zone's diversion percentages will be used without change.

A significant implication of the overall approach toward air freight is that the cost and time of shipments will not vary in any measurable way among alternative airport systems. Thus, as described in Section IX, shipper and receiver benefits will be treated only qualitatively in the evaluation of alternatives.

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* Because it represents a special case, air freight routed via Willow Run Airport is not included in Table V-3.

† If, in fact, distance does explain the phenomenon, then the assumption of constant future diversion percentages is strengthened.

Table V-3

AIR FREIGHT SHARES FOR LOCAL AIRPORTS IN THE LOWER PENINSULA

Zone	Outbound Air Freight: Percent via Local Airport	Outbound Air Freight: Zone Volume	Inbound Air Freight: Percent via Local Airport	Inbound Air Freight: Zone Volume	Approximate Highway Mileage to Nearest Large Hub Airport*
Jackson	6	2.1	26	1.8	55
Flint	14	12.0	31	9.6	75
Lansing	21	5.8	39	5.1	90
Saginaw and Bay City	21	9.8	34	5.1	110
Kalamazoo and Battle Creek	23	6.3	47	3.1	110
Benton Harbor	45	1.1	40	1.6	115
Grand Rapids	86	7.3	89	6.8	150

Note: Zone volumes and percentages do not include shipments via Willow Run Airport. Zone volumes are millions of annual pounds (1970).

* Chicago-O'Hare or Detroit Metropolitan.

Mail by Air

The AAT survey efforts for mail--both air mail and "first-class airlift" mail--disclose that routing patterns were changing during the 1970 base year. In addition to the long established method of using the services of certificated air lines as common carriers, the U.S. Postal Service (USPS) was implementing "Air Taxi Service" in Michigan--companies operating under contract to the USPS and restricted exclusively to hauling mail.

Although it was not possible to obtain sufficient data for preparation of tables on mailing routings like those for air freight (Tables V-1 and V-2), the AAT work did provide some significant insights:

- Mail transported by air tends to be enplaned at the airport closest to true origin and deplaned at the airport closest to ultimate destination. Very little "local airport diversion" occurs.

- For planning purposes, it can be assumed that the predominant use of Air Taxi Service in Michigan will be to and from the following nine postal Section Centers: Detroit, Flint, Grand Rapids, Iron Mountain, Jackson, Kalamazoo, Lansing, Saginaw, and Traverse City.

These insights, together with MAC data on airport mail volumes for various years, were used to develop the adjusted estimate of base year mail traffic in Table V-4.*

A relatively simple approach for predicting future mail volumes has been judged adequate for purposes of this study. In general, national projections of growth in mail transportated by air will be applied directly to the total airport volume of Table V-4. In instances where the system alternatives call for discontinuance of air carrier services at a Sectional Center city, it will be assumed that air taxi services are expanded to handle the total projected volume. That is, the mail service would not be transferred in such cases to a new regional airport. In instances where it is postulated that air carrier service would be discontinued at a non-Sectional Center city, transfer of the affected volume to the new regional airport will be assumed.

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* Although 1970 was a year of transition, large fluctuations have occurred in the volumes of mail transported by air in more "normal" years. This results from differing allocations of first-class mail between surface and air transport.

Table V-4

ESTIMATED BASE YEAR MAIL TRAFFIC
(Thousands of Pounds)

Airport	Inbound	Outbound
Alpena	10	15
Battle Creek	100	500
Benton Harbor	50	210
Detroit Metro	25,000	25,000
Excanaba	30	40
Flint	250	380
Grand Rapids	820	820
Houghton	30	30
Iron Mountain	125	20
Ironwood	3	15
Jackson	250	100
Kalamazoo	520	500
Lansing	700	600
Manistee	3	15
Marquette	95	80
Menominee	15	25
Muskegon	140	300
Pellston	15	15
Saginaw	700	600
Sault Sainte Marie	60	40
Traverse City	120	50
Total	29,036	29,355

VI TECHNOLOGY*

The purpose of the studies described in this section was twofold: to review technological trends in transport aircraft, aircraft engines, airspace, and airports; and to determine the impacts of these trends on the planning parameters to be used in Task Groups 3 and 4. The task effort was limited to a review and analysis of existing information; no new basic research was undertaken.

In each of the four parts of the analysis (aircraft, engines, airspace, and airports), the focus was placed on factors likely to have a bearing on airport planning. Particular emphasis was placed on the impacts of engine technology on the environmental/community-relations problems of aviation noise and atmospheric pollution in areas adjacent to airports.

Because of space limitations in this report, the content of Section VI is limited to highlights and general conclusions from a more detailed supplementary report now being prepared for the MAC.

Aircraft

An examination of present and future aircraft types provides a context for the assessment of trends affecting airport planning and the assessment of possible voids in Michigan service patterns.

Aircraft Types

Today's domestic airline fleet can be classified in seven broad aircraft categories, each containing types that are well known to the experienced traveler:

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* In the preparation of this section, the author relied heavily on commentary on airspace prepared by Dr. R. S. Ratner of SRI and on commentary on airports prepared by Mr. Saul Jacobs of Howard, Needles, Tammen and Bergendoff.

- Widebody jets (B-747, DC-10, L-1011)

- Conventional four-engine jets (B-707, B-720, DC-8, CV-880, CV-990)

- Conventional three-engine jets (B-727)

- Conventional two-engine jets (B-737, DC-9)

- Turboprop-powered aircraft (CV-580 and 640, Viscount, F-27, FH-227B, Electra, Swearengen Metro)

- Piston-powered aircraft--older types (DC-7, DC-6, DC-4, DC-3, Lockheed Constellation series, CV-440, M-404)

- Piston-powered aircraft--other (Beech 99, DeHaviland Otter).

Future trends in the number and kinds of aircraft types in the U.S. commercial fleet are indicated in the 10-year FAA forecast shown in Table VI-1 below.

Table VI-1

FORECAST AIR CARRIER AIRCRAFT

Type	Number 1971 (actual)	1976	1981
Jet	2,096	2,504	3,268
Turboprop	325	261	161
Piston	142	59	39
Totals	2,563	2,824	3,468

<u>Supersonic and Hypersonic Transports</u>

There is little likelihood that, following the much publicized discontinuance in 1971 of the U.S. SST program (featuring the Boeing 2707), there will be another U.S. entry in the SST field that is ready for service before the middle or late 1980s. Two other SST types are expected to be placed in commercial use in the next few years: the British-French Concorde and the Russian Tuoplev-144 (TU-144). Interior airports in the United States will probably see little if any service from these or any other SST types in the next decade. No known solution to the sonic boom problem exists. Operation of the aircraft at subsonic speeds over land areas (to prevent the sonic boom) generates substantially higher aircraft costs per airplane mile and reduces competitive speed advantages over conventional jets. Fare differentials over existing jets are high (estimated at 50 percent at comparable seating configurations). Risks of harmful environmental impacts other than sonic boom effects have not been evaluated to the satisfaction of many leading environmentalists.

From time to time, dramatic descriptions of future hypersonic air travel at speeds of Mach 3 to Mach 7 are published in the trade press, Sunday supplements, and other media. While it is technically possible to develop aircraft capable of achieving such speeds, the economic costs of the program would be very high. Whether such transports will be developed for commercial use during the time span covered in this study (1972-2000) cannot be determined. Present evidence suggests, however, that if such use occurs it will not be on a large scale.

High-Subsonic and Transsonic Transports

Probably the principal performance improvement in the next generation of conventional jet transports will be the capability to cruise at speeds up to and slightly exceeding Mach 1 without creating a sonic boom. The new designs, sometimes called high-technology designs, will have a silhouette noticeably different from that of the present jets, the differences being caused principally by the supercritical wing and the "coke bottle" fuselage. These aircraft will not have enough speed advantage over present jets to permit substantial reductions in passenger and cargo trip times on most flights. However, if seat-mile operating costs of the aircraft design can be maintained at levels not greatly higher than those of present jets, airlines will probably begin ordering them to accommodate market growth beginning in the 1980s. Present evidence suggests that the initial design will call for a range of from 250 to 500 passenger seats.

Additions to Present Generation of Jets

A number of "new" jet transports are currently being developed or planned that will not represent technological breakthroughs of great significance. These transports therefore can be looked upon, in a sense, as additions to the present generation of jets. In some cases, manufacturers' goals will be to provide greater size, which will be accomplished by "stretching" and "doubledecking" widebody jets when structural and cost considerations permit. In other cases, manufacturers' goals will be to fill capacity/range/performance voids that exist in the present generation of transports; forthcoming examples include the McDonnell-Douglas "Twin DC-10," the European twin-engine A-300 (Airbus), the Boeing 747-200SR (short range), the long-range L-1011, and the Dassault Mercure twin-jet. In some cases, the decision to manufacture a new aircraft type seems to have been prompted by the manufacturer's desire to gain competitive strength in the air transport market, since some entries largely duplicate the functional performance of other aircraft.

No firm plans presently exist to produce a new very-high-capacity jet, although a number of preliminary studies have been made of aircraft having gross weights in excess of one million pounds and seat capacities up to 1,000. Serious attempts to design and manufacture such an aircraft will probably occur only after the alternative of enlarging existing designs has been fully exploited. The next such design may be an all-cargo aircraft having a payload capacity of 300 to 500 thousand pounds. If produced, this aircraft will be treated as one element in a fully integrated ground-air cargo transportation system that features modernized all-cargo terminals with a high degree of mechanization and containerization.

Until the next generation of all-cargo aircraft is put into service at some indefinite time in the future, air cargo will be carried in all-cargo versions of existing transports and the belly pits of combination passenger/cargo aircraft. [The belly pits of the B-747 are capable of carrying 40,000 pounds of baggage and cargo--more than the capacity of the largest all-cargo aircraft of the pre-jet era (the DC-7C).]

STOL and VTOL Aircraft

Problems of noise, economics, air traffic control, and systems integration--among others--will prevent STOL type aircraft from being operated on short runways in highly developed urban areas for the foreseeable future. Future technology may make STOL applications in an environment of this type feasible in eight to 12 years. The most imminent future STOL development is basically a simple aircraft featuring mechanical high-lift devices and capable of operating on runways up to 4,000 feet in length, instead of a more exotic STOL or VTOL design.

Trends Affecting Airport Planning

Number of Aircraft to be Handled

Although substantial future growth is forecast in the air travel market, the capacity of the average aircraft will also continue to grow due to the greater use of large aircraft in the fleet mix. Therefore, the number of airline flights to be handled at airports will not increase nearly as much in proportion to increases in passenger and cargo traffic.*

Runway Lengths

Despite increased emphasis on larger aircraft, the trend toward longer runways has leveled off because aircraft designers have been able to counteract higher gross weights with improvements in technology such as increased bypass-ratio engines, better flaps, and other high-lift devices. For the most part, the trend in runway lengths will remain stable for the foreseeable future. However, smaller airports that grow into a need for larger aircraft may require runway length adjustment, depending on the types of aircraft involved.

Runway Strengths

Although aircraft wheel loadings have been increasing through the years, these increases in the past few years have been attained without exceeding prior runway strength requirements through the use of wide lateral and longitudinal wheel spacings, and large tires. The industry will make strong attempts to keep future wheel loadings within the bounds of pavement strengths required by existing aircraft.

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* In the 1972-81 National Aviation System Plan, the FAA forecast that scheduled domestic air revenue passenger miles will treble and that revenue cargo ton miles will more than quadruple in the period 1971-81. For the same time span, the number of aircraft in the U.S. air carrier fleet was forecast to increase by only 36 percent.

Ramp Area Requirements

As medium and small airports continue to grow and require larger planes, the ramp and gate area needed per plane will increase dramatically. This tendency can be partially offset by assigning specific gate and parking positions exclusively to larger aircraft.

Passenger Terminal Size and Accommodations

Passenger terminal size and accommodations are influenced strongly by the number of passengers handled during peak periods; and there is reason to believe that peaking patterns will become more pronounced rather than less pronounced in the future. This will be due to the strong competitive pressure on airlines to accommodate passenger time-of-day pressures and the obvious impacts of the "bunching" of numbers of large aircraft. (The same influences will apply to parking lots, access routes, etc.)

Availability of Aircraft Types Needed for Michigan Service

A recent analysis of trip lengths of air travelers to and from Michigan indicated that 50 percent traveled distances of 400 miles (one way) or less, 30 percent traveled distances from 401 to 1,000 miles, and 20 percent traveled distances over 1,000 miles. Aircraft types will be available to cover the major needs of these air travelers, with one major exception: a strong need will exist for a good aircraft type or types to serve the low-density, short-haul markets that constitute an important component of air travel into, within, and out of the state.

Present versions of commuter aircraft do not represent the optimum solution to this problem. Two new aircraft sizes in this category may be required to give proper levels of service and schedule frequency to a number of Michigan airports: a 20-to-30-seat aircraft and a 40-to-50-seat aircraft. One of the goals of Task Group III of the Study should be to develop more specific information on the functional specifications of aircraft needed in this category.

Engines

The principal purpose of a review of engine technology in an airport systems planning study is to provide insights into trends in aviation-generated noise and atmospheric pollution in the vicinity of airports. Aircraft noise (most of which is produced by engines) and pollution from engine emissions constitute the two most serious environmental/community relations issues in the industry. The discussion of technology in this section provides an information base supporting subsequent commentary on environmental factors in Section VII of the report.

Engine Types

As previously indicated, most of the commercial transport aircraft of the future will be jet powered. Table VI-2 presents in summary form the major types of jet engines associated with today's major commercial transport aircraft. Table VI-3 gives further details on these engines and the aircraft with which they are associated.

Table VI-2

AIRCRAFT AND ASSOCIATED ENGINES

Aircraft	Engine*
B-707 and DC-8 (earlier versions)	P&W JT3C series
B-707 and DC-8 (later versions)	P&W JT4A series
"Stretched" DC-8 (60 series)	P&W JT3D series
Boeing Trijets and Boeing and Douglas Twinjets (B-727, B-737, DC-9)	P&W JT8D series
L-500 (proposed commercial version of C-5A)	GE GF39-GE-1
Widebody jets (B-747, DC-10, L-1011)	P&W JT9D series, GE CF6-6 series and RR RB-211 series

* P&W: Pratt and Whitney
GE: General Electric
RR: Rolls Royce.

Sources: Aircraft manufacturers, Jane's All the World's Aircraft, and SRI.

Table VI-3

SELECTED DATA ON AIRCRAFT ENGINES

Engine Manufacturer and Type	Thrust per Engine (lbs)	B-747-100	B-747-200	DC-10-10	DC-10-20	DC-10-30	L-1011-8	L-500 (C5A)	DC-8-10	DC-8-20	DC-8-30	DC-8-40	DC-8-50	DC-8-62	DC-8-63	B-707-120	B-707-220	B-707-320	B-727-100	B-727-200	B-737-100	B-737-200	DC-9-11-1	DC-9-11-2	DC-9-20	DC-9-30	DC-9-40
PW JT9D-3	43,500	✓	✓																								
JT9D-3W	45,000	✓	✓																								
JT9D-7	45,500	✓	✓		✓																						
JT9D-7W	47,000	✓	✓																								
GE CF6-6	40,000			✓																							
CF6-50A	49,000					✓																					
TF39-GE-1	41,000							✓																			
RR RB-211-56	53,000						✓																				
PW JT3C-6	13,500								✓							✓											
JT3D-1	17,000												✓														
JT3D-3	18,000												✓	✓													
JT3D-7	19,000														✓												
RR Conway	17,000											✓															
PW JT4A-3	15,800									✓							✓										
JT4A-9	16,800										✓																
JT4A-11	17,500																	✓									
JT8D-1	14,000																							✓			
JT8D-5	12,250																						✓				
JD8D-7	14,000																		✓	✓	✓					✓	
JT8D-9	14,500																					✓			✓		✓

Sources: Engine manufacturers, Jane's All the World's Aircraft, and SRI.

Noise

Although measurements of the impacts of airport-related noise are as yet crude, they point forcefully to the conclusion that the noise problem is a serious one that can affect up to hundreds of thousands of people in a single urban area. One of the problems associated with the assessment of noise impacts is that given levels and kinds of noise do not produce the same effects among different people. The principal noise impact measurements used thus far are the Composite Noise Rating (CNR) and the Noise Exposure Forecast (NEF). The latter measurement attempts to reflect not only absolute noise levels, but also maximum tone, noise duration, and position in the noise spectrum--to result in an "Effective Perceived Noise Level" (EPNL), for which one expression is perceived decibels (EPNdB). When EPNL is combined with other factors, including time of day, the result is an NEF reading. For purposes of background, rough comparisons of CNR and NEF ratings required to produce different levels of annoyance are given below.

CNR Rating	Equivalent NEF Rating	Percent of Those Exposed Who Report "High Annoyance"
95 and under	20 and under	11
115 and over	40 and over	67

The complexity of the noise reduction problem is indicated by some basic but not-well-known facts. A reduction in noise level by 10-dB is sensed by most people as reducing noise by about half (a characteristic of the rating system). Less than one-half of one percent of the total energy of the jet engine is radiated as noise. The reduction of engine energy output in relation to the reduction in noise output is very high: a 10-dB reduction in noise in a typical engine requires a reduction of engine power output by 90 percent; and a 20-dB reduction in noise requires a power reduction of 99 percent. Some types of noise are more responsive than others to remedial acoustical treatments in engine nacelles and to changes in the size and shape of the nacelles themselves.

Under the authority of Congressional legislation, the FAA has promulgated Part 36 of Federal Aviation Regulations (FAR-36). FAR-36 provides noise level standards for use in type certification of subsonic transports. The regulation requires no retrofitting of any existing aircraft, but the FAA has indicated that further noise reduction will be required in these aircraft as technology progresses.

Selected noise data for Boeing and Douglas narrowbody turbofan aircraft are compared with that of widebody jets in Table VI-4. The data in the table reflect the fact that widebody jets are noticeably quieter than their predecessors, even though engines of the former generate from two to three times as much power per unit. A primary reason for the improvement is that major emphasis was given to noise reduction at the design stages of widebody jet engine development.

The extent to which noise reduction can be accomplished in pre-widebody jet engines through retrofit modifications is limited at the present state of the art. The problem is compounded by the fact that the cost of such modifications is relatively high. The airlines have taken the position that benefits associated with noise reduction in these aircraft may not be worth the economic costs.

Table VI-4

NOISE DATA IN EPNdB

Aircraft	Flyover (takeoff)	Lateral (sideline)	Approach
B-707-100B	108	108	110
B-707-300C	114	108	121
B-727-100	103	105	109
DC-8-61	116	106	112
DC-9-30 (JT8D-7)	97	105	110
B-747	108	97	109
DC-10	99.6	96	105
L-1011	97.1	107	102.3

Sources: First five listings from report on first meeting of the ICAO Committee on Aircraft Noise; last three listings from data supplied by manufacturers--as reported in March 1972 issue of Airline Management.

The widebody jets have demonstrated that the severity of aircraft-generated noise can be reduced substantially by the application of technology at the design stage. Under expected conditions of public pressure, there is little doubt that future jet engine designs will be much quieter, permitting substantial future noise reduction over time.

At most commercial airports, however, the problem of narrowbody jet noise must be resolved before there is significant relief from the overall noise problem in areas within airport noise contour patterns. (A typical noise contour pattern based on NEF calculation methodology is shown in Figure VI-1.) Whether narrowbody noise reductions possible with present technology are worth the required economic cost is a question now being seriously debated in industry and government circles. The outcome cannot be predicted at this time.

Emissions

The following commentary on emissions will deal with the quantities and kinds of emitted pollutants, their harmful effects, the relationships between engine speeds and pollution, and trends in pollution reduction.

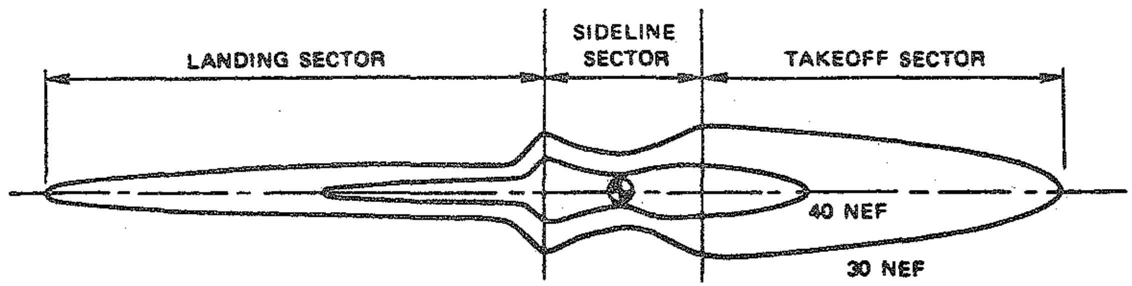
Quantities and Kinds of Emissions

Studies of a number of large metropolitan areas indicate that aircraft generate from one to two percent of the overall pollution in these areas. A Los Angeles study further indicated that, since aviation generated pollution is more concentrated in areas adjacent to airports, it may account for as much as 10 percent of the total pollution in the immediate airport environment.

The relative importance of the major types of pollutants emitted by aircraft engines is shown in Table VI-5.

Harmful Effects of Emissions

Although a considerable amount of research has been done in recent years on air quality, the state of the art in this field is still at a primitive stage. There is sufficient clinical evidence, however, to indicate that the kinds of emissions produced by aircraft engines (which are similar to those produced by other types of internal combustion engines) can produce adverse effects on humans. These effects include eye irritation, respiratory disease, impairment of visual acuity,



- ONEWAY RUNWAY UTILIZATION
- NORMAL CLIMB GRADIENT
- NORMAL 3 GLIDE ANGLE

FIGURE VI-1 NOISE EXPOSURE FORECASTS FOR A TYPICAL LARGE MIDCONTINENT AIRPORT RUNWAY

Table VI-5

AIRCRAFT ENGINE EMISSIONS COMPARED WITH EMISSIONS
FROM OTHER SOURCES
AVERAGE ANNUAL EMISSIONS, 1967
(Thousands of Tons)

Type	(A) All Sources in U.S. Excl. Civil Aircraft	(B) All Civil Aircraft in U.S.	(C) Col. B Percentage of Col. A
Carbon Monoxide	66,125	924	1.2
Hydrocarbons	19,016	152	0.7
Nitrogen Oxides	13,007	16	0.1
Particulates	12,004	11	0.1
Total	110,052	1,103	1.0

Source: 1968 Study by Northern Research and Engineering Corporation for the U.S. Department of Health, Education and Welfare.

and impairment of time interval discriminations. In addition, pollutants from aircraft engines may adversely affect plants, animals, soils, water, and man-made materials.

Relationships Between Engine Speeds and Emissions

The chemistry of jet engine operation is such that the concentrations of carbon monoxide and hydrocarbons are relatively high at idle and taxi power settings of the engines, and are reduced rapidly as the power is increased toward takeoff setting. The patterns for nitrous oxides are the reverse, with quantities increasing as the power setting is increased. Because of the importance of carbon monoxide and hydrocarbons in the total pollution mix, it has been estimated that idle and taxiing emissions may produce in the order of 80 percent of the total aviation generated pollutants. This evidence has very long implications in terms of airport taxiway design and idle/taxiing procedures.

Trends in Pollution Reduction

Advancing technology has made possible a gratifying trend of improvement in emission generation characteristics of aircraft engines during the past 15 years. This trend is related to the introduction of aircraft engine types in Table VI-6.

Table VI-6

EMISSIONS BY ENGINE TYPES DURING TAKEOFF AND LANDING

	Pounds of Emission	
	Per Engine	Per Psgr. Carried*
Piston engines	111.6	14.88
Jet engines (1958)	55.2	3.56
Turbofan engines (1961)	49.1	3.16
JT9D engines (1970)	33.5	.6979

* Assumes 50 percent load factor for each aircraft type.

Notes: Emissions are for the landing-takeoff (LTO) cycle, including all operations below 3,000 feet. Known engine emissions during each phase were multiplied by the average number of minutes during each operation; idle, 13.0 minutes; takeoff, 1.4 minutes; and approach, 5.8 minutes.

Source: Report by G. P. Sallee at SAE/DOT Conference on Aircraft and the Environment, Society of Automotive Engineers, 1971.

Another type of improvement, which may have psychological significance equal to or greater than its physiological significance, is the trend toward the almost complete elimination of visible particulates, with resulting "smoke-free" engines. Retrofit modifications for this purpose are being made on older type jet engines, and it is estimated that by the end of 1972 the smoke trails previously associated with low-flying jet aircraft will have been essentially eliminated.

As a result of the indicated improvements in technology, the aggregate pounds of pollutants emitted by all aircraft in the commercial fleet are estimated to have been reduced by more than 50 percent between the year 1958 (when commercial jets were introduced) and the year 1970. The trend is expected to continue into the future as more widebody aircraft with high-bypass engines are brought into the commercial fleet mix. Further application of technology in subsequent engine designs will probably result in still further increases in aggregate volumes.

Airspace

As with other subtasks reported on in Section VI, the assessments relating to airspace were made prior to the development of any projections of the quantities and characteristics of aircraft movements in and over Michigan in future years. The purpose of the brief review of airspace considerations at this time was to determine whether any already-foreseeable airspace constraints exist that should be considered in the evaluation of specific statewide airport systems alternatives in Task Group 3.

The analysis consisted of a review of current and prospective technology in navigation and air traffic control, an examination of general airspace problem areas, and the development of general conclusions.

Current and Prospective Technology*

Navigation

At present, extensive VOR coverage is provided in Michigan by a combination of federal and state-owned facilities. Coverage is adequate over essentially all the state at reasonable altitudes. Associated DME facilities (VOR/DME or VORTAC) are less extensive but cover the most heavily trafficked air routes in the state. Non-directional beacons (low frequency homers) are provided by state and counties for supplemental navigational coverage.

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* A glossary of air navigation terms used in this section is presented at the end of the report.

As IFR operations increase, in particular areas and on particular route segments, additional DME facilities collocated with VORs will become desirable. These will enable more precise navigation and more flexibility in defining waypoints, and are also necessary for implementation of area navigation capabilities as they are presently developing.

Instrument landing systems are not treated here since they are usually considered to be part of the airport system, but it is well to point out that area navigation capabilities will permit a greater flexibility in the selection of approach paths to airports not served by instrument landing systems.

As for airborne navigational equipment, VOR is the predominant radio navigation system in use by U.S. civil aircraft at this time. Additionally, DME receivers are a part of the avionics of essentially all air carriers and many air taxi and business aircraft, and some general aviation aircraft. Area navigation systems that allow one to navigate with respect to any chosen paths, rather than only on paths from one VOR to another, are coming into being. These airborne equipments range in sophistication from (1) simple devices that provide guidance to and from fictitious or "ghost" VOR facilities (offset by a given amount from an actual VOR), to (2) sophisticated equipment that includes pictorial map displays, time-to-go computation, and so forth.

The trend toward area navigation equipment can be expected to gain momentum as FAA establishes area navigation airways that are more convenient and economical to use than conventional ones. This can be expected to occur post-1975 in the high-altitude airspace and post-1980 elsewhere.

In addition to the operational flexibilities gained from the use of area navigation, a greater flexibility in siting navigation facilities is gained; this flexibility may have substantial implications for better navigational coverage (e.g., more flexibility in developing over-lake routes).

Air Traffic Control

Current air traffic control procedures in most areas in the U.S. rely on the use of surveillance radar. Precise information on radar coverage in the state of Michigan was not available for this survey, but it is readily obtainable. Flight service stations supplement ATC route traffic control centers in the provisional control services in some areas and at many airports where traffic control towers are not installed.

In the future we can expect to see additional air traffic control towers installed where operations warrant, enabling a greater volume of IFR operations into and out of these airports. Radar surveillance systems will be upgraded and supplemented to a greater extent with secondary radar beacon system (ATCRBS). This latter trend requires the use of airborne radar beacon transponders on each aircraft (IFR) and permits a more precise and sure identification and radar surveillance function. All air carrier operators and most taxi and business aircraft operators that conduct IFR operations have radar beacon transponders at present, or will have them within the next few years.

Sophisticated collision avoidance systems (CAS) and less sophisticated proximity warning indicators (PWI) are currently under development. The purpose of these devices would be to reduce collision hazards in the air, principally in the heavy traffic airspace of certain terminal areas. These system concepts are cooperative in nature, in that all aircraft operating in an area of airspace to be protected must be equipped to participate in the CAS or PWI system. A natural time lag between development and wide usage of avionics equipment makes it likely that no such system will be in wide use within 10 years. A possible exception would be the use by airlines of a collision avoidance system among themselves. To be useful, other aircraft would have to be excluded from certain airspace within which the airlines were to use their CAS.

More automated ATC equipment, including better information displays and information processing, is being installed at major terminal areas throughout the country. Automated information processing for the enroute environment is similarly being installed. These automation measures will be installed where warranted over the next few years. They are expected to reduce the load on air traffic controllers and hence increase air safety. Some minor benefits in terms of air traffic control capacity may be attained in certain cases.

General Airspace Problem Areas

Inter-Airport Air Traffic Control Coordination for IFR Operations

Where IFR operations are conducted into and out of airports that are relatively close together, coordination of operations by ATC becomes necessary. The Detroit Metro-Willow Run airport pair is an example. As the numbers of operations increase, more flexibility for approaches and departures is needed. Where airspace is shared by operations into and out of these two airports, coordination becomes increasingly necessary. Depending on the orientation of runways, active coordination needs tend to develop when IFR airports are closer than 6 to 15 miles apart, when more than 10 to 20 operations per hour are conducted into each airport. In all but extreme cases, ATC procedures can be worked out to ensure and maintain compatibility of operations. Whether or not capacity constraints become significant can only be assessed on a case-by-case basis, but this cursory analysis has uncovered no severe existing constraints. A more thorough analysis should investigate existing airspace procedures for various wind conditions for the Detroit Metro-Willow Run area mentioned above, and for the Niles-South Bend (Indiana) pair if IFR operations there are expected to increase substantially in the future.

IFR Approach and Departure Flight Paths Crossing Heavy VFR Operational Areas

Where VFR and IFR airports are closer than approximately 10 miles and the VFR airport underlies an IFR airport approach path, airspace procedures and geometry must be looked at to assess the possibility of a safety hazard. Such hazard would be associated with the possibility of airborne collision between VFR traffic in or near the VFR traffic pattern and IFR operations down the approach path, under condition of high cockpit workload. As mentioned previously, approach procedures were not analyzed, but a first examination of the navigation and airport charts for Michigan indicates that the following airport pairs should be looked at to ensure no IFR/VFR conflicts, should traffic levels there increase substantially in the near future: Iron Mountain (Ford)-Niagara, separated by 7 or 8 miles if IFR operations into Ford are conducted; and Muskegon-Grand Haven, separated by about 12 miles. (There is probably no problem here, since approach paths do not appear to cross.)

A VFR airport within about 5 miles of an IFR airport, under one of its departure paths, presents a similar possibility of conflict. Procedures can in general be developed to alleviate any possibility of conflict where it appears necessary. Operational penalties incurred are generally not substantial. Area navigation capability will further reduce any operational penalties sustained.

Areas of Heavy Mixed VFR and IFR Activity Within Approximately 30 miles of a Reasonably Busy IFR Airport

In the airspace below 8 to 10 thousand feet, the hazard of airborne collision between air carrier aircraft and VFR general aviation aircraft is greatest. The operational effectiveness of the see-and-avoid concept appears to be insufficient in these areas because of cockpit workloads, visibility problems, and other factors. The use of so-called "positive control airspace" has begun to proliferate to minimize this hazard. This concept requires all traffic within a given area to be under the active control of ATC, and in radio communication. The concept has the operational disadvantage of increasing the load on the air traffic control facility substantially. A workable and economically feasible CAS/PWI system would likely reduce the needs for positive control airspace while minimizing the hazard of collision, but full implementation of such a system is at least 10 years away. For the present, one relies on design of airspace procedures, pilot education and training programs, and the use of positive control airspace when necessary, in high density mixed traffic environments. In addition to the Detroit Metropolitan area, the Kalamazoo-Battle Creek area could develop problems of this sort if traffic levels increase substantially.

Further studies of these areas would need to be made to determine at what levels of activity the problem would begin to manifest itself.

Other Potential but Minor Airspace Problem Areas

Flight service stations generally provide additional services to general aviation aircraft while flying over bodies of water. These services consist of maintaining periodic radio communications to facilitate immediate rescue activity if a water ditching becomes necessary. While this sort of activity increases the workload of FAA personnel, no constraints on IFR operations are likely.

Air traffic control procedures associated with traffic crossing the U.S./Canada border were not investigated. A cursory examination of these procedures should reveal whether any significant airspace constraints exist or are prospective.

Military training requirements in some part of the country account for a substantial part of the traffic load on ATC facilities. This does not appear to be the case in Michigan where only in the relatively sparse upper peninsula does there appear to be any substantial military activity (Sawyer Air Force Base, and several low level navigational training routes). This military activity in Michigan does not appear to create any current operational constraints on air traffic control and airspace usage.

Airspace Conclusion

On the basis of this preliminary review, no constraints on the development of airports in Michigan are apparent that cannot readily be alleviated with existing technology or with technology likely to be available within the next 10 years. This conclusion will be further tested and verified as air traffic projections are developed in subsequent stages of the study.

Airports

The basic function of an airport is to serve as a point for the efficient transfer of passengers, baggage, and shipments between ground vehicles (access and egress) and air vehicles. That many of today's airports are not performing this function efficiently is a fact that is well known to air travelers. Points of congestion and delay include access roadways, parking lots, passenger terminals, departure and arrival gates, aircraft runways and taxiways, and air traffic patterns in the airport area. Walking distances up to one mile between auto parking lots and departure gates (and between gates themselves) are not uncommon. Experienced observers are generally agreed that airport development has failed by a wide margin to keep pace with the demand for air travel and with technological development in aircraft design and size.

Numerous concepts for the improvement of airport design and efficiency are being developed, particularly for larger airports. The technology of the major airport complex of the future may include doubledecked aircraft parking ramps, circular runways, advanced "people movers" and drift-off runway egress--coupled with automated navaids, and V/STOL and STOL. The ground link between various urban centers and the airport may be by high-speed tracked air-cushion vehicles, or other advanced surface means. It is possible that by the year 2000, both passengers and their baggage will be "containerized" at a downtown location and loaded into a vehicle that becomes a part of the aircraft fuselage at the airport.

Advanced concepts such as these must of course be recognized in a long range airport systems planning study. However, some very important qualifying factors should also be recognized:

- Many of the concepts now under discussion will reach a stage of practical application only in the latter half of the 30-year time span included in the Michigan airport systems study, if then. Some may be substantially modified.

- The concepts apply largely to a size category that few Michigan airports other than Detroit (and possibly other regional airports) will reach in the next one to two decades. Indeed, design and operational problems affecting most Michigan airports within the foreseeable future will probably be solved more by the judicious use of existing technology than by reliance on "new" technology.

Generally, discussions of state-of-the-art advancements in airport technology are more applicable to master planning and specific project planning at individual airports than to a statewide systems planning study. However, a broader-level commentary on technology can be of benefit at the systems planning stage by providing background that is helpful in the treatment of capacity, cost, and airport/airway interface considerations that arise in the analysis of statewide airport system alternatives (Task Group 3 of the present study).

The commentary in this portion of the report will be presented in three parts that are patterned after the major airport components: airside (runways, taxiways, aprons, and lighting systems); terminal (passenger and baggage handling); and land side (access and parking).

Airside Considerations

The productivity of airside facilities at an airport is indicated by the number and kinds of aircraft that can be accommodated in a given period of time. In the future, progressively greater emphasis will be placed on meeting traffic and schedule growth by improving the productivity of existing airside facilities as opposed to simple expansion of the facilities on a "more of same" basis. This is due to the growing limitations on the availability of adjacent land for airport expansion and, in many cases where land is available, to the greater cost of achieving expansion under a "more of same" approach.

Future productivity increases are expected to result from a combination of the following factors: more efficient lateral separation of parallel runways; computer aided approach systems (CASS); more effective use of dual-lane runways; high-speed runway access and egress; more efficient taxiway use; and microwave landing systems.

It is reasonable to expect that, as a result of advances in technology in these areas, the capacity of some types of runways can be increased significantly during the period included in the Michigan study (possibly 25 to 50 percent), without any lowering of safety standards. A corollary to greater runway productivity will be lower unit airport investment and operating costs per aircraft operation handled. Increased runway capacities will be compatible with increased airspace capacities as discussed in the preceding commentary.

Terminals

The terminals at Michigan air carrier airports (other than Detroit Metro) range from simple terminals with one gate and manual baggage handling, to multiple frontal gates at Lansing with some mechanical baggage handling, to two short fingers and baggage carousels at Grand Rapids. Passenger convenience of parking an automobile immediately adjacent to the airport, and walking no more than a few hundred feet through the terminal to the airport gate is still maintained. In the next few years, however, the larger airports such as Grand Rapids will have to consider the effects of extending fingers versus satellite terminal or remote aircraft parking. Airports such as Lansing will have to consider the limitations of continuing its frontal gate positions. The smaller air carrier airports prior to any expansion must consider whether the expansion will be compatible with the requirements of the 1980s and 1990s.

The decision on the type of terminal appropriate for each airport should come from detailed master planning and economic studies for that airport. For information, some major types of basic terminal configuration are discussed in the following:

(1) Simple Linear Terminal. Additions to this type of facility are achieved merely by a linear addition to the terminal, with corresponding additions to curbspace on the landside. The concept does not lend itself to common-use waiting areas, concessions or hold rooms. The cost of such expansions where gate positions are dependent on terminal size can soon become prohibitive.

(2) Finger Terminal. In this concept, fingers are extended from the central terminal, with gates and holding areas at appropriate intervals. Installations of this kind can become large and complex, as at the Miami International and Atlanta airports. Multiple terminals, each with its own configuration of fingers, are found at Chicago's O'Hare Airport and at the San Francisco International Airport.

(3) Unit Terminal with Boarding Satellites. "People-mover" conveyances for transporting passengers between the central terminal and satellites can contribute greatly to the success of this type of configuration. An example is the use of horizontal elevators at the Tampa International Airport.

(4) Central Terminal with Remote Satellites. The best known application of this concept is at Dulles International Airport, where mobile lounges are used for transportation between central terminal and satellites.

(5) Airline Unit Terminal. Under this concept, each airline has its own terminal building and aircraft loading area. This concept, while appropriate at some very large airports, is not suitable for most of Michigan's air carrier airports. At airports of their planned size, serious diseconomies would result from the inherent duplication of airline facilities.

Figure VI-2 presents a matrix showing the degree to which different terminal configuration concepts meet selected functional requirements.

Trends

The trend toward automation in both passenger and cargo handling is expected to continue. Technology is now available to permit self-service ticketing, self-service check-in, and self-service baggage checking by passengers at terminals--all through automated facilities. Traveler education on the use of automated facilities must proceed at a gradual rather than rapid pace. The extent to which passengers are both willing and qualified to deal with automation at terminals will have to be determined by experimentation.

Another important trend is the trend toward functional and modular terminal design. More widespread adoption of functional and modular design concepts offers about the only hope of offsetting or partially offsetting highly escalated labor and material costs in construction. The economies possible with modular prefabricated units were dramatically brought into focus recently by the experience of one airline in preparing interim terminal facilities. A series of prefabricated mobile homes 16 feet wide and 40 feet long were placed on concrete block foundations alongside a passenger concourse. An opening was prepared between the concourse and each mobile home; and the latter was used temporarily as a passenger holding area for a loading/unloading gate. Within a week,

Terminal Concept	Psgr. Walking Distance - Parking Lot to Aircraft	Psgr. Travel Distance - Connecting Flights	Distance from Aircraft to Baggage Pickup	On-Airport Psgr, Ground Transportation Equipment Costs	Noise Abatement Requirement for Building	Difficulty in Expanding	Apron Area Required for Aircraft Parking	Travel Distance for Aircraft Between Gate and Runway	Difficulty in Catching Flight if Access Transportation Delayed	No. of Stories Required
	Ratings*									
Simple	L	L	L	L	H	H	L	L	L	1
Linear	L†	L†	L	L	H	H	M	M	L	1
Finger	H	H	M	M	H	M	H	H	M	2
Satellite	H	H	H	H	M	L	L	H	H	2
Mobile Lounge	L	H	H	H	L	L	L	L	H	2
Unit	L	H‡	L	H	H	M	H	H	L	1

* H - High
M - Medium
L - Low

† Low with limited gate positions.

‡ Except for intra-line connections.

FIGURE VI-2

FUNCTIONAL CHARACTERISTICS AND RATINGS OF SELECTED TERMINAL CONFIGURATIONS six gate positions were created at about one-sixth of standard building costs. While the mobile home structures did not contain all the facilities and amenities desirable in a holding area, the esthetic and functional quality of these modules was sufficiently high to convince management that greater use of modular concepts at terminals has considerable potential payoff.

In the parametric airport cost estimates to be developed in Task Group 3, the impacts of the above factors on unit cost trends will be recognized.

Landside Considerations

For the foreseeable future, most airports in Michigan will not be large enough to require access systems other than conventional highway/street systems. Since highway/street systems are usually built and operated by governmental jurisdictions other than airport authorities, a coordinated approach will be necessary in new airport construction to see that the airport itself and its access system are properly interfaced. If future airport size levels should be sufficiently high to warrant consideration of rapid transit or other specialized access systems, each case should be analyzed on an individual basis.

The parametric cost estimates to be developed in Task Group 3 will separately identify access costs and include them as an earmarked component of total airport system costs. Cost allocations may be necessary if specific roadways serve airport access and other purposes.

VII INSTITUTIONAL, FINANCIAL, AND ENVIRONMENTAL CONSIDERATIONS

This section reports on Task 2.11, the purpose of which was to identify and describe at an early stage any constraints of an institutional, financial, or environmental nature that might limit the development or successful implementation of a prospective statewide airport system plan. As in other parts of Task Group 2, primary emphasis is on air carrier airports.

Institutional Considerations

The term "institutions" as used in the study refers to all public and private agencies having an interest in the statewide plan. A stated objective of Task 2.11 was to assess "any apparent deficiencies in the authority, organization structure, internal policies, staffing, or communications procedures of agencies at different levels of government that might seriously impair airport development." Another objective was to examine the interaction of governmental agencies "with a variety of non-governmental parties having an interest in the plan, including airlines, general aviation interests, chambers of commerce, property holders associations, the financial community, and conservation and environmental groups." The study team's assessments represent a planning-oriented rather than a legally-oriented analysis of these factors. As indicated later, subsequent legal review of some aspects of the subject may be desirable.

Figure VII-1 shows in matrix form the major agencies and organizations affected by the airport systems study and their principal areas of interest. In a study such as this, where many groups have an interest in one or more aspects of the planning process and where different points of view exist, the coordination and communications processes are highly complex.

As coordinator of the study effort, the Michigan Aeronautics Commission communicates directly with all interested parties. In addition, the Commission has established a formal Advisory Committee consisting of representatives of major organizations having an interest in the study. The Committee's periodic meetings provide a forum for discussion. In

Organizations	Direction and Coordination of State Airport Systems Planning	Direction and Coordination of Regional Area/Local Comprehensive Planning	Airport Ownership	Airport Management	Represent National Interest in Aviation Matters	Financing of Airport Planning and Development	Environmental/ Community Relations Matters	Economic Regulation of Airlines	Airport Access (highway and other)	Business and Commercial Relations	Environmental Community Relations Matters	Land Use/ Zoning	Airline Interests	Aviation Trades	Aviation Manufacturers Interests
	Areas of Interest														
Michigan Aeronautics Commission	✓														
Michigan Interagency Transportation Council	✓														
Federal Aviation Administration					✓	✓									
Environmental Protection Agency							✓								
Civil Aeronautics Board								✓							
Department of Housing and Urban Development							✓								
Michigan Highway Department									✓						
State Department of Commerce										✓					
Regional, Area Metropolitan Planning Agencies*		✓				✓	✓		✓		✓	✓			
Planning and Development Districts*		✓				✓	✓		✓		✓	✓			
County Governments*		✓				✓	✓		✓		✓	✓			
City Governments*		✓				✓	✓		✓		✓	✓			
Airport Authorities			✓												
Michigan Association of Airport Executives				✓											
Air Transport Association													✓		
National Air Transportation Conference													✓		
Michigan Aviation Trades Association														✓	
Michigan State Chamber of Commerce															
General Aviation Manufacturers Association										✓					✓

* Applies to some but not all of indicated organizations.

FIGURE VII-1 RELATIONSHIPS BETWEEN ORGANIZATIONS AND AREAS OF INTEREST addition, committee members may communicate directly with one another on either a formal or informal basis. Organizations not represented on the committee may have a voice in planning either through an existing committee member or through direct communication with the MAC. (The MAC will, if necessary, add to the formal membership of the committee.) The approach taken by the MAC appears to be functioning successfully. (Credit for this goes in part to the sensitivity of the MAC staff to the communications needs that are inherent in a broad, diverse study effort.)

The study team found evidence suggesting that a future need may exist for realignment of responsibilities of some existing agencies and the creation of new agencies having responsibilities in airport planning.

- It would appear appropriate for the MAC to review the question of whether a larger share of responsibility for land use and zoning near airport areas should be assumed at the regional (area) or state level. Visual inspection of air carrier airports in the state reveals instances where local land use and zoning authorities have allowed the encroachment of residential and other urban development into areas too close to airports. Further encroachment by real estate developers may occur. Furthermore, the frequency of exposure to aircraft noise will increase with traffic and schedule growth (see Section VI). Thus, although new policies at the federal level will provide help,* the noise problem will probably become more serious in Michigan unless corrective action is taken. (As background, Exhibit VII-1 presents comments by a well known legal authority on institutional problems associated with airport-related zoning and land use. It will be noted that this commentator is pessimistic about the prospect of achieving effective control through local sources.)
- The need for certain regional (area) agencies will be parallel to any need that exists for regional airports.

  Areawide Planning Agencies. The areawide planning agency concept is strongly endorsed by the federal government.

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* As an example, the U.S. Department of Housing and Urban Development has adopted a policy of withholding financial assistance and guarantees for proposed housing developments where airport noise levels will be excessive.

Exhibit VII-1

EXCERPT FROM "LEGAL ASPECTS OF AIRCRAFT NOISE AND SONIC BOOM IN THE UNITED STATES"*

Where a new airport is being built in a relatively undeveloped area or where property under an approach pattern at an existing airport is undeveloped, it would seem the part of common sense to ensure that such property remains in uses compatible with airport operations. This is especially true where, as is frequently the case, the compatible use of the land would be beneficial (preservation of a "green" area) or profitable (i.e., airport-related industrial and commercial activities).

Nevertheless, compatible land use has not been accomplished very often. The reasons for this include: (1) deep-seated local disagreements as to whether practical steps to limit the use of the land are locally desirable; (2) confusion of projections as to where, and how great, the noise will be; (3) fragmented local government units in the near vicinity of airports; (4) the lack of overriding state power to achieve desirable planning; and (5) questions as to the extent of the local government's power to zone or acquire property for noise abatement purposes.

The need for overriding state power arises because, in many cases, two, or even many, local government units have jurisdiction over the airport and surrounding areas. Since a local government's jurisdiction is usually limited to its own territory, the city that owns and operates an airport may not have power to condemn, purchase or zone property in a neighboring community even if the latter touches the border of the airport. Neighboring local government units, even though each has adequate powers to act within its own boundaries, may refuse to cooperate with the airport or with each other even to the extent of having coordinate laws.

Such legal complexities when added to, or used as excuses by, competing local political, social and business interests, may doom any effort to achieve effective land use planning--unless help is received from above (i.e., from the State). While a few states have finally begun to address themselves to this problem, such vital efforts are only beginning.

* A paper presented by Warren Christopher of the firm of O'Melveny and Myers before the SAE-DOT Conference on Aircraft and the Environment, February 8-10, 1971.

Such an agency "should be able to speak for the many political jurisdictions insofar as all areawide planning is concerned. This agency should be able to serve as an effective forum for discussion of airport related issues, presenting an acceptable majority position ...."*

Regional (Area) Airport Authorities. A pending bill before the Michigan legislature (House Bill No. 5708) contains enabling legislation permitting two or more counties to create a regional airport authority having full power to own and operate an airport, including the power to borrow money for self-liquidating capital improvements. Although some of the bill's specific provisions may be questioned in some quarters, the broad need for enabling authority of this kind appears obvious. The study team has been informally advised that the chances for the passage of the bill appear good.

Financial Considerations

To establish background for the financial assessments called for in the study, a review was made of airport cash flow channels, historical sources of funds for airport capital outlays and current outlays, and the historical capability of airports for financial self sufficiency. Examination was made of factors affecting need and availability of capital funds and also of possible "new" sources of funds. The general financial outlook for Michigan airports was assessed.

Airport Cash Flow Channels

In general, airports require funds for two broad purposes: capital outlays and current outlays. Capital outlays are defined as all outlays for the acquisition of land; for the construction or improvement of runways, taxiways, buildings, and other long term additions; and the acquisition of vehicles and other capital equipment. Current outlays are made up

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* From a paper given in February 1971 by Robert F. Bacon of the FAA. Further description of the role of the areawide planning agency is contained in two federal publications: the Office of Management and Budget Circular No. 95; and the FAA's Planning Grant Handbook. Extensive additional literature on the subject is available.

of two components: operating outlays, as required for salaries, maintenance, utility services received, and the like; and debt-service outlays, as required to meet principal and interest payments on previously incurred long term debt.

Funds for capital outlays are typically obtained from two primary sources: grants from federal, state, regional, and local governmental units; and long term borrowing, usually requiring repayment in annual installments covering principal and interest under an amortization schedule. Funds required for current outlays are typically derived from current airport revenues, consisting of landing fees and other user charges, together with revenues derived from concession- and service-related activities. Sometimes, deficiency appropriations or operational grants are made by parental governmental units, such as counties or cities, to meet current deficits of airports. Sometimes a parental government unit, particularly in the case of smaller airports, will provide assistance not shown in the airport's financial records. This assistance is in the form of "free" or "reduced rate" services such as police protection, fire protection, snow removal, and ground maintenance. Practices vary according to local policy.

The practice of financing airport improvement through the issuing of general obligation bonds by the parental governmental unit has been greatly reduced in the past two decades, as has the related practice of supporting airport operations partly through local taxation. Future use of these approaches in the financing of Michigan airports is expected to be limited.

Federal, state, and regional airport development grants are made under the following guidelines.

- The FAA may make grants under the Airport Development Aid Program, subject to availability of funds, equal to one-half the cost of land acquisition and "airside" (e.g., runway, taxiway, ramp) development. The Agency may also fund a higher percentage of certain expenditures for lighting and navigation aids. It has no authority to make grants for the financing of terminal and other buildings (except those required for safety purposes). At larger airports, where terminal and related costs are heavy, FAA grants account for less than 25 percent of funds required for many capital improvement programs. At smaller air carrier airports, the ratio of federal funding to total need may be closer to 50 percent.
- In Michigan, state airport development grants are typically awarded to local governments on a matching (50-50) basis,

subject to the availability of state monies and compliance with state requirements. Funds used by the state for this purpose historically have been derived from the aviation fuel tax and aircraft registration fees.

- In some cases, regional commissions such as the Upper Great Lakes Regional Commission will underwrite portions of the cost of airport development when such development is deemed essential to the region's economic development.

The remaining funds to be provided by local agencies (through borrowing or other sources) may range from substantially more than half of total requirements in the case of larger airports to a considerably lower ratio in the case of smaller airports.

Airport Capability for Financial Self-Sufficiency

Numerous studies have indicated that larger airports tend to have an inherently greater capability for financial self-sufficiency than do smaller airports. The larger airports have a much stronger revenue base in the form of airline user charges and concession- and service-related revenues derived directly or indirectly from airline passengers and shippers. The stronger revenue base strengthens not only the larger airport's ability to meet current operating expenses but also its ability to borrow by issuing revenue bonds. Its financial strength thus tends to be self-reinforcing.

As a correlary, smaller airports tend to be more subsidy-dependent than larger ones. This factor is recognized by the MAC in the formulation of state airport development assistance policies.

Need and Availability of Capital Funds

The total capital funds required to implement the prospective statewide airport systems plan will be estimated in a later stage of the current study. Therefore, expected needs cannot be compared with expected sources of funds at the present time. In a study by the Michigan Aeronautics Commission in 1970, forecast need for airport development funds exceeded forecast funds available under existing policies by a significant margin. This margin may be substantially lessened in the new estimates from the present study as the result of liberalization of federal grant policies and/or the emergence of new sources of funds.

Possible Sources of Additional Funds

A recent court decision upheld the legality of a local "head tax," (sometimes called "ticket tax," or "service charge") on airline passengers, and some airports are now imposing this charge. The question of whether such a charge ought to be collected and, if so, by whom is currently the subject of vigorous debate among federal, state, and local governmental units and the airlines.* It is argued in some quarters that a tax of this kind, if imposed, ought to be collected and administered at the state or federal level to ensure greater uniformity in its impact on air passengers. However, this concept is opposed by some local airport authorities. The Michigan Aeronautics Commission is prepared to collect and administer revenues from this type of tax, if responsibility for its collection and administration falls to the Commission. If the new source of funds materializes, it could lead to a substantial increase in state money available for airport development.

In addition, there is some indication that federal policy may be changed to permit FAA funding of a portion of airport terminal development costs under the Airport Development Aid Program. Proponents of this change maintain that it would be in keeping with the amounts intended by Congress to be spent under the Airport and Airways Act of 1970. The proposed change is endorsed by the Air Transport Association among others. If it is effected, state and local airport authorities in Michigan--as well as in other states--will be relieved of some of the burden of financing terminal development.

General Financial Outlook

When the known sources of airport development funds are considered on the basis of the ratio of each to total need, the prospects appear good that a substantial portion of the total development to be called for in the forthcoming Michigan airport systems plan can be successfully funded. If new sources of funds materialize, a still larger share of total need can be funded.

During the analyses of airport system alternatives in Task Group 3, an assessment will be made of two financial factors associated with each alternative. The first is the extent to which development funds probably

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* The legality of this type of tax may be subject to further court tests.

will be available to meet foreseen system need (this will be an order-of-magnitude comparison). The other factor is the extent to which financial hardships might be imposed on existing airports because of the reduction or cessation of airline operations. Means of dealing with any financial problems discovered in the analysis will be examined, and appropriate recommendations will be made.

Environmental Considerations

Until a few years ago, airport development was planned and accomplished largely on the basis of technical and economic criteria, with little regard to possible environmental consequences. Today, in contrast, both federal and state policy recognize environmental criteria as being highly important in airport planning in Michigan. Indeed, it is virtually certain that all major future analyses relating to airport development in the state will include some version of the critical question, "What environmental costs, as well as economic costs, are required to provide the indicated benefits to travelers, shippers and others?". It is also highly likely that both federal and state funds will be withheld from any airport development projects that are in clear violation of environmental and related social goals.*

Environmental/Community Relations Impacts

Table VII-1 shows the major adverse environmental and community relations impacts of airport related activity. The two most serious impacts are noise and atmospheric pollution attributable to aircraft. (See technical discussion in Section VI.) The ground pollution problem at airports is similar in a number of respects to that of other large plant complexes having pollution-generating facilities and equipment. Expected future trends in the kinds and quantities of noise and pollution generated are highlighted below.

(1) Aircraft Noise--As discussed in Section VI, the widebody jets now being introduced generate substantially less noise than do their predecessors--a factor that should result in some relief at very large airports as the newer

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* Aviation generated noise, often viewed in a medical or community relations context, is included under "environmental" considerations for the sake of convenience.

Table VII-1

MAJOR ENVIRONMENTAL AND COMMUNITY RELATIONS IMPACTS

Source	Noise	Impacts: Atmospheric Pollution (exhaust emissions)	Ground and/ or Water Pollution	Solid Waste
Aircraft in flight	x	x	x*	
Ground sources				
Aircraft (taxiing and idling)	x	x		
Airport service vehicles	x	x	x	
Auto traffic (access and parking areas)	x	x	x	
Mass transit (where applicable)	x	x	x	
Aircraft service and maintenance areas	x	x	x	x
Passenger and cargo terminals			x	x
Fuel storage and transfer areas		x†	x	

* Operating procedures for earlier jet engines called for dumping up to one quart of raw fuel from each engine during climb out for the purpose of reducing fire risk and maintenance problems. This practice is not necessary with newer jet engines, and it is being eliminated.

† Atmospheric pollution in fuel storage and transfer areas results from venting requirements.

aircraft become more important in the schedule mix. As a practical matter, however, noise-reduction benefits of wide body aircraft are not likely to be realized at any Michigan airports except Detroit for at least another five to ten years; aircraft of this size cannot be supported by traffic volumes at other airports during that period.*

Heavy offenders in noise generation include the four-engine, three-engine, and twin-engine airline transports of prewide body design, some of which are likely to remain in service for one or two decades. It is possible to install sound-reduction retrofit modifications to the engines of these aircraft, but the cost of doing so appears high in relation to expected reduction in noise levels. It is also possible to redesign nacelles and to design and install quieter engines in the aircraft. However, the costs in some cases, would probably exceed the present value of the aircraft. The question of what to do about the noise problems of the aircraft is now being vigorously debated in government and industry. The outcome cannot be predicted at the present time.

Unless noise reduction modifications of some kind are made in present and future aircraft of these types, the noise problem at Michigan airports will become progressively worse during the next decade because of increased schedules and accompanying exposure to noise.

Some alleviation may be possible in the form of a change in flight approach procedures (as distinct from changes in airport or aircraft design). The prospective procedures require a steeper approach to the runway, which reduces ground noise by keeping aircraft higher longer. The procedures are being tried experimentally at a number of locations. It is too early to determine whether they will prove workable on a large scale.

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* Minor exceptions to this generalization may occur particularly in the latter part of the period. If new regional airports are built, they are likely to support schedules in wide body aircraft.

(2) Aircraft Emissions--Widebody jets are also an improvement over their predecessors in pollution generation characteristics (as evidenced by lower pounds-per-passenger emission rates per landing/taxi/takeoff cycle). As in the case of noise, these benefits will not be significantly felt at airports other than Detroit for the next decade.

As indicated in Section VI, pre-widebody jets are undergoing a program of retrofit modification that will greatly reduce particulate emissions, with the result that "smoke-free" operation of virtually all these types will be an accomplished fact by the beginning of 1973. (Widebody jet engines were initially designed to be "smoke-free.")

There is considerable promise that "narrowbody" jets to be manufactured in the future can have the benefits of improved engine design that will reduce the output of carbon monoxide and hydrocarbons at taxi and idle speeds. (These are the speeds at which a large portion of the two pollutants are emitted.) It appears likely that the resulting unit reductions in emissions will more than offset additions to schedule frequency and will therefore result in a lower aggregate volume of the emissions.

The emissions can be further reduced through any changes in airport design and taxi/idling operating procedures that will encourage the minimizing of engine operation at taxi and idle speeds.

(3) Airport Ground Facilities--The goal of minimizing noise and pollution by airport ground facilities and equipment is an important one, but it can be more appropriately dealt with through channels other than the present statewide systems planning study. A considerable share of responsibility should fall on area and local authorities at the time when area plans, individual airport master plans, and specific project plans are subsequently developed. At the latter stages, environmental impact statements satisfactory to federal and state authorities will be a prerequisite to federal and state funding assistance.

Relationship to Airport Size

There is an obvious relationship between an airport's size and the magnitude of its environmental/community relations problems. At larger airports, higher volumes of aviation-produced atmospheric pollution are mixed with higher volumes produced by other urban sources to result in a compounded effect. Also, the frequency of noise exposure is much greater than at smaller airports.

In-depth analyses of noise and pollution factors at specific airports were not planned as a part of the systems study. In the absence of specific analyses, the study team has adopted an important tentative planning assumption: outside the Greater Detroit area, serious aviation-generated atmospheric pollution problems will exist in the foreseeable future at few if any Michigan air carrier airports. The atmosphere in the vicinity of the smaller airports is cleaner to begin with, and not enough aviation activity is foreseen to cause a serious problem. (See technical discussions in Section VI.) This tentative assumption should be reviewed by Advisory Committee membership representing environmental interests.

The airport noise problem, which will be escalated by further schedules resulting from traffic growth, may be serious at a number of airports. The problem, which is closely associated with land use and zoning practices, was discussed earlier in the report.*

STOL Aircraft

Recent experience at Eastern seaboard locations indicates that any STOL aircraft design that fails to meet rigid standards relating to noise, pollution and operational factors will not be allowed to operate on a scheduled basis into highly populated areas. It appears that the burden of responsibility will rest primarily with aircraft designers and manufacturers: if they can produce aircraft meeting the standards, the aircraft will be allowed to operate; if they cannot, no STOL types will operate from short runways in the areas.

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* See Section VI and commentary on "Institutions" earlier in Section VII.

Governmental Agencies Concerned

The responsibility of federal and state agencies in developing and enforcing airport-related environmental standards stems from a number of legislative acts. Among the most important of these acts at the federal level are the Environmental Policy Act of 1969, the Airport and Airway Development Act of 1970, the Clean Air Amendments Act of 1970,* and Section 4(f) of the Department of Transportation Organic Act. The state has separate water pollution control and air pollution control statutes; in addition, the "Anderson-Sachs" Bill (P.L. 127) gives private citizens the right to sue polluters without showing personal injury, so long as significant potential harm to the environment is at issue.

The principal federal agencies concerned are:

- The Environmental Protection Agency, which provides direction and coordination of environmental activity under the Environmental Policy Act of 1969.

- The Department of Housing and Urban Development, which has limited responsibility under the 1969 Act for enforcement of noise criteria.

- The Federal Aviation Administration, which now has a significantly broadened environmental responsibility in addition to its responsibility in the areas of aeronautics and cost/benefit applications.

The state agencies primarily concerned with environmental matters are the Water Pollution Commission, the Air Pollution Commission, and the Advisory Council for Environmental Quality. The latter organization performs a number of functions, including serving in an advisory capacity to the Governor on environmental matters, conducting study of new concepts and methods for improving environmental quality, and conducting review of environmental statements associated with prospective major construction and related undertakings that could have significant environmental impacts.

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* The Clear Air Amendments Act of 1970 gave the Environmental Protection Agency the authority to set emission standards for aircraft engines. The Air Transport Association and the Airport Operators Council International have asked the Senate Public Works Committee on Air and Water to allow the FAA to retain authority over aircraft noise regulation.

State Level Actions

It would appear appropriate for the Michigan Aeronautics Commission to delineate environmental actions to be associated with the present statewide airport planning effort, as distinct from those to be associated with subsequent stages of airport planning and development. Much of the responsibility for the latter should rest with those who perform area airport planning and master and specific project planning at individual airports.

By contrast, actions of the types indicated below appear appropriate to Task Group 3 of the statewide systems planning study.

- Identify environmental problems of a major nature as statewide systems alternatives are analyzed.*
  - If nonenvironmental considerations favor creating a new airport in any area where none now exists, screen the area to determine whether environmentally suited subareas are available from which a specific site can later be selected.
  - If nonenvironmental considerations favor creating any regional airport by expansion of an existing airport, screen to learn whether environmental constraints may cause serious problems.
  - If forecast long range growth will require substantial expansion of some existing airports, screen to learn whether environmental constraints may cause problems when the expansion occurs.
- Maintain a sensitivity to the environmental public relations aspects of the current study program.
- Consider whether responsibility for development and enforcement of land use and zoning regulations should be shared at the state level. (See also commentary in "Institutions" portion of this section.)

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* As previously indicated, noise is expected to constitute the most serious environmental problem at airports, except in a few areas characterized by high levels of atmospheric pollution.

VIII THE ECONOMIC IMPACT MODEL

Two principal objectives must be met in the development and application of the economic impact model. One objective is the projection of population and economic data for use in predictions of air passenger and air cargo demand. The other objective is making the economic projections sensitive to changes in air service levels so that projections of the Michigan economy will reflect appropriately the economic impact of alternative airport development programs.

The air passenger demand model requires projection of population data for zones within and without the state of Michigan for the years 1975, 1980, 1990, and 2000. The manner in which these data are used in the model for projecting air passenger travel is described in Section IV of this report. The method to be used for air cargo predictions necessitates the enumeration of regional income, particularly for the manufacturing sectors, for the various planning regions within the state of Michigan for 1970 and projection of these levels for the years 1975, 1980, 1990, and 2000. The use of these income figures to factor air cargo demand projections is discussed in Section V.

These population and economic projections used for projecting air passenger and air cargo demand are called "normative" projections. They are sometimes called "trends continue" projections and, as such, assume that neither an active airport development program is adopted to improve Michigan's competitive position vis-à-vis the rest of the United States nor is airport development completely discarded so that Michigan's competitive position is worsened. In other words, it is assumed that airport development programs continue in a manner similar to the past so that Michigan's competitive economic position remains stable over time.

On the other hand, it is to be expected that a change in airport development from this normative position would have an impact on the economic growth patterns of Michigan. If a strong airport development program is adopted and implemented, the various economic regions within the state will be more accessible to their markets, thus providing an inducement for more people and more industry to locate in these regions. Conversely, a weak or nonexistent airport development program would reduce accessibility and discourage economic development.

The measurement of regional accessibility is defined by a generalized cost or utility function that includes both direct travel cost and travel time costs. Its form is described in the formulation of the passenger demand model (the w value for air). Its effect for any two cities, say Flint and St. Louis, is to describe how a reduction in generalized travel cost between these two cities, brought about by airport development at Flint, will increase travel between the two cities. For passenger travel, this is likely to make Flint a more desirable place for the businessman to locate (or visit). Hence, Flint's relative competitive position for attracting new industries (and "doing more business") is improved.

The economic impact model meets its objectives in the following manner. First, both the state of Michigan and the rest of the United States is divided into a set of zones. Outside Michigan the zones correspond to the travel zones described in Section II. Inside Michigan, two different sizes of zones are used. For population data the 27 travel zones are used. However, the 13 state planning regions are used to describe the level and structure of the economy. The state planning regions are used because they provide a more reliable basis for detailed description and analysis of the various industrial sectors constituting the Michigan economy.

Next, the Michigan economy is accurately described for the base year 1970 according to well-defined accounting rules. This description provides the basis from which projections of population and the level and structure of the economy can be made. It also provides much of the necessary data input for the development and calibration of the economic impact model itself.

Finally, the impact model, which is of the econometric type, uses these data and accessibility measures in developing a set of equations relating economic and population growth to population and economic levels already existing and to the effects that transport accessibility have had in determining these existing levels. These equations are then used to provide the necessary projections.

Description of the Michigan Economy

For this study, the 1970 Michigan economy is divided into 30 industrial sectors. The initial description for each sector includes figures on employment, payroll, and value added. It should be remembered that value added represents the regional component of national income. Summary figures for the entire state are shown in Table VIII-1.

Table VIII-1

THE MICHIGAN ECONOMY, 1970

Industrial Sector	Employment (thousands)	Payroll (millions of dollars)	Value Added (millions of dollars)
1. Agriculture, forestry, and fisheries	10.1	$ 39.0	$ 43.6
2. Mining	10.5	86.0	118.2
3. Contract construction	107.5	1,044.0	1,434.9
Manufacturing industries			
4. Food and kindred products	50.2	387.2	1,047.0
5. Textile mill products	3.5	26.8	48.9
6. Apparel and other textile products	20.6	153.6	286.6
7. Lumber and wood products	12.2	69.2	138.4
8. Furniture and fixtures	21.0	162.8	320.9
9. Paper and allied products	29.3	244.0	436.5
10. Printing and publishing	32.8	256.0	493.6
11. Chemicals and allied products	40.8	406.4	1,362.3
12. Petroleum and coal products	2.4	25.6	114.2
13. Rubber and plastics products, N.E.C.	24.9	188.0	362.3
14. Leather and leather products	4.0	22.0	55.2
15. Stone, glass and clay products	20.2	174.4	447.0
16. Primary metal industries	96.1	904.0	1,681.4
17. Fabricated metal products	118.9	1,022.8	1,954.6
18. Machinery, except electrical	176.7	1,784.0	3,357.5
19. Electrical equipment and supplies	46.3	400.8	698.6
20. Transportation equipment	195.8	2,160.9	4,930.4
21. Motor vehicle parts and accessories	181.1	1,851.9	3,749.3
22. Instruments and related products	8.3	70.8	120.9
23. Miscellaneous manufacture	11.1	84.0	151.8
24. Ordnance and accessories	7.7	94.4	191.4
Total Manufacturing	1,103.8	$10,489.6	$21,948.8
25. Transportation, Communication and Public Utilities	128.5	1,113.2	1,827.7
26. Wholesale Trade	149.9	1,372.8	1,901.1
27. Retail Trade	462.3	2,042.8	3,641.4
28. Finance, Insurance and Real Estate	119.2	840.8	3,005.8
29. Other Services	410.7	2,229.6	3,693.7
30. Government	477.6	3,625.1	4,513.7
Total	2,980.1*	$22,882.9	$42,128.9

* Total labor force is 3,234.1 thousand, including unemployed of 254.0 thousand.

Table VIII-1 (Concluded)

Notes to Table VIII-1:

(1) The payroll for agriculture, forestry and fisheries sector includes that for both farm employees and proprietors. It is comparatively low considering the level of employment in that sector, because no estimates of income in kind are included nor do employees or proprietors in this sector receive as many monetary fringe benefits as those in other sectors.

(2) No split was made in the mining sector between liquid and gas mining and solid ore mining, because the size of the sector was too small to permit reliability in allocating the two different types of mining activities among the various regions within the state of Michigan.

(3) Tobacco manufacturing (SIC code 21) is included in the food and kindred products manufacturing sector.

(4) Motor vehicle parts and accessories is the only sector not compatible with two-digit SIC codes. To reestablish comparability, it is necessary only to add the figures given to those of the prior sector, transportation equipment, to obtain total figures for the two-digit sector titled "transportation equipment."

(5) The government sector includes members of the armed forces, as well as civilian employees of the federal and local governments.

Data from several sources were used in developing this description. These include:

(1) The Censi of Manufacturing, Retail Trade, Wholesale Trade, and Selected Services for 1967 to provide basic relationships between employment, payroll, and value added.

(2) County Business Patterns to provide a basis for 1970 employment and payroll from which the relationships developed can be used for verification and provide estimates of 1970 value added.

(3) National income statistics, including both the supplement to the Survey of Current Business and more recent issues of the Survey of Current Business to (a) verify estimates in changes in worker productivity, (b) verify relationships between value added and gross output or sales so that value added can be reported for all sectors, and (c) provide a basis for which Michigan's share of the national economy may be determined.

(4) Price indices from Bureau of Labor Statistics publications to ensure that the transformation from 1967 to 1970 is measured accurately in constant dollars rather than current dollars.

These data provide the control totals for allocation of economic activity levels by sector among the state planning regions within Michigan. The initial estimates for allocation are obtained from the Censi of Manufacturing, Retail Trade, Wholesale Trade and Selected Services and County Business Patterns described above. Since these data are incomplete on a regional level, primarily because of disclosure problems, an iterative procedure is used to ensure compatibility within the various regions and the state control totals. A similar procedure is used for the zones outside the state of Michigan.

Finally, additional data are generated for each region to describe consumption demand, investment demand, and government demand by industry source within the region. These relationships have been developed using data from the National Planning Association and the Input-Output Structure of the American Economy developed by the Department of Commerce. Net trade figures for each region are then defined by simple comparison of the demand for products within the region and its value added.

Economic Impact Model Structure

The impact model uses many of the accounting features and relationships developed in preparing the description of the economy. In equation form, the model takes the following structure for each industry sector:

Value Added = Consumption Demand + Investment Demand

+ Government Demand + Net Trade.

All values are positive with the possible exception of net trade. If net trade is positive for some sector, the region exports the goods of that sector; if negative, the region is an importer.

Sum (all sectors) Net Trade = Zero.

This holds for each region, and it states that, in total, for any outflow (inflow) of goods there is a corresponding inflow (outflow) of either goods or capital. Thus, over all sectors, if a region is a net importer of goods, for example, there must be a corresponding outflow of capital.

Consumption demand is estimated in a two-step process. First, total consumption is estimated on a per capita basis as follows:

Total consumption = a proportion of value added per capita

which accounts for the long term stability of consumption as a proportion of total income. Consumption by industry source is then estimated from a set of equations as follows:

$$\text{Consumption}_i = a_i \text{ total consumption } b_i$$

where: a and b are parameters; the subscript i denotes the i^{th} industry.

To keep the model purely linear for computational efficiency, two things are done in estimating consumption. First, the consumption by industry source equations is substituted in the total consumption equation so that:

Consumption = a function of value added

Second, a scalar increase in per capita consumption is precomputed for each forecast year, and these constants, which change from forecast year to forecast year, are coded in matrix format and substituted as required when making projections.

Both government and investment demand are estimated as a constant proportion of value added. Thus:

Government demand = A * value added

Investment demand = B * value added,

where A and B are parameters that vary from sector to sector so that, for the i^{th} industrial sector, by simple addition, we have:

$$\text{Government demand} + \text{investment demand} = (A_i + B_i)\ \text{value added}_i$$

Given these relations, net trade is readily determined by adding the various demand components (consumption, investment, and government) and subtracting that total from the value added for the sector.

Net trade becomes the primary measure of a region's competitive position. If the sector is an exporting industry, i.e., net trade is positive, that region has a favorable competitive position for that industry. If the sector is an importing industry, the region has an unfavorable competitive position. Several factors determine this competitive position as follows:

- The presence of other industries supplying the industry being analyzed
- The cost of labor
- The accessibility of markets to the industry.

For this analysis, cost of capital is not considered because (1) data are insufficient or not sufficiently accurate to permit this variable to be included on a regional basis for each of the sectors analyzed and (2) it is assumed that capital is sufficiently mobile that its effect on locational decisions, particularly for larger companies, that its effect on locational choices will be small. Thus, for each sector, an estimating equation is developed and parameters estimated so that net trade may be predicted as a function of the three variables cited above. The quantitative measure of the presence of industrial suppliers is measured by the value added of these suppliers in the region itself. Cost of labor is measured by dividing total payroll by total employment in a class of industries. For each manufacturing industry, for example, total manufacturing payroll is divided by total manufacturing employment and, similarly, for the trade and service industries. Market accessibility is measured using the travel conductance (w_m) values described elsewhere in this report with population in a destination zone being a surrogate measure of market size in that zone.

Given these sets of individual estimating equations for different sectors and different components of value added, what remains is to tie them together. This is accomplished by sets of equations describing the following:

(1) Value added per employee rises over time as productivity increases in the various sectors constituting the regional economy. Hence, for each sector an equation describes the change in real income per employee over time. A weighted average of these equations describes the change in real income for regional residents over time. We note in actual application that sometimes a small statistical discrepancy exists in applying this procedure that tends to increase the further one projects into the future.

(2) A preliminary population estimate is made and provides a basis for an initial estimate labor force participation and employment for each region.

(3) The employment estimates so derived are multiplied by the value added per employee to obtain an initial estimate of regional income.

(4) The consumption, government demand, and investment demand equations are then applied for each sector of the regional economy and the corresponding net trade estimates added to determine the level and structure of the economy corresponding to the preliminary population estimate.

(5) The sum of total value added for the region obtained from step (4) may not agree with the initial estimate implied in step (3). If it is larger, the region will grow more than implied by the population estimates; if smaller the region will grow less. Thus, an iterative procedure is implied to bring the two estimates into balance.

(6) In balancing the two estimates, a "reduced-form" set of equations is developed to obviate the need for an iterative solution. What this "reduced-form" set of equations does, in simple if imprecise terminology, is to treat the entire system of equations as an interdependent set of equations and, by substitution of terms among the various equations, derive a new set of equations providing the same type of results but doing this in one step rather than iterating.

Model Application

Application of the model will entail use of a computer program that has as inputs the various population and economic data described above. The initial application develops the "normative" forecasts described to provide a benchmark from which economic impacts may be compared. Subsequent applications require the description of a proposed airport development plan, the calculation of new accessibility measures determined by this plan in context of the national airport development, insertion of these accessibility measures into the model data set, and processing the model.

Economic impact is appraised by comparing certain economic measures with those obtained from the normative forecast. These include:

- Population change in each region and statewide
- Income or value added change for each region and statewide
- Net trade change by sector for each region and statewide.

Alternatively, these same comparisons could be made between some postulated airport improvement program and one where nothing is done to improve airport accessibility in Michigan. Such a comparison could identify the economic loss if a do-nothing program were implemented.

IX ANALYSIS AND EVALUATION OF ALTERNATIVES

The methodology to be used in Task Group 3 for identifying, modeling, and evaluating alternative airport systems is discussed in this section. This includes consideration of (1) the variables that need to be specified to define each airport system alternative, (2) the modeling procedure used in the analysis of an alternative, and (3) the evaluation procedures to be followed and associated evaluation measures to be obtained for each alternative.

Analysis of Alternatives

A number of variables serve to identify alternative airport systems for Michigan. These include:

- Airport locations
- Service levels (type and number of flights) between airport pairs
- Surface and air access characteristics between each airport and the zones it serves.

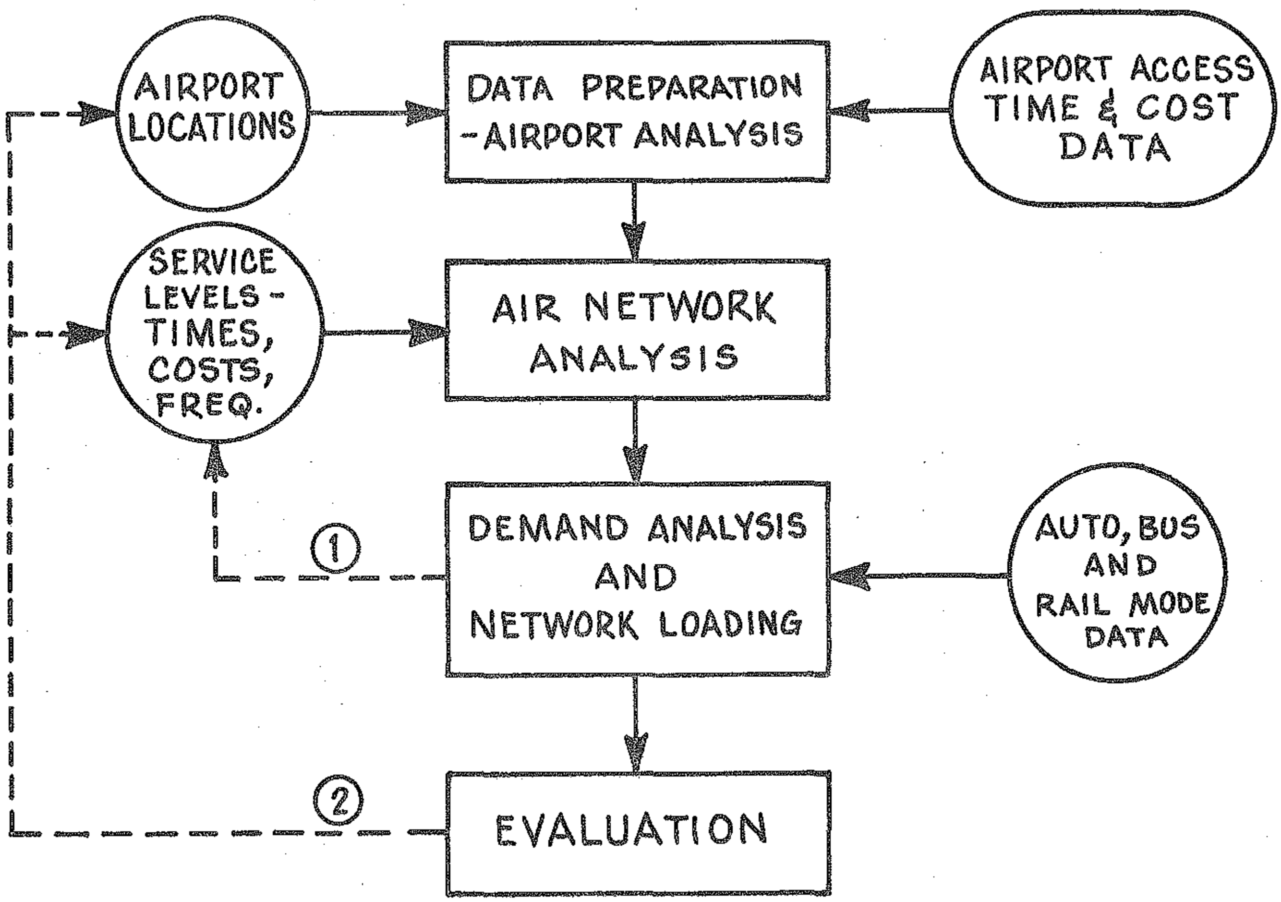
Because of this large number of variables, a systematic procedure is necessary to analyze a given alternative and use the results of the analysis to suggest new alternatives.

The steps to be followed in analysis of alternatives are outlined in Figure IX-1. As indicated by the rectangles in the figure, the analysis will consist of four basic components:

- Data preparation--airport analysis
- Air network analysis
- Demand analysis and network loading
- Evaluation.

Figure IX-1

ANALYSIS STEPS*



* *Inputs To Process Shown In Circles; Process Components Shown In Rectangles; And Feedback Loops Shown In Dashed Lines.*

The points at which input variables enter the analysis are indicated by the connections of the circles in the figure to the basic analysis components.

The dashed lines in Figure IX-1 illustrate the "feedback" or iterative nature of the analysis, wherein the analysis results are used to modify the input variables. Moreover, an "improved" alternative will be specified, based on evaluation measures and other relevant considerations. Although this procedure relies quite heavily on the analysts' direct participation in translating evaluation measures for each alternative into improvements in those alternatives, it is felt that this procedure will provide the most thorough understanding of the decision variables and, hence, result in a more comprehensive final airport system plan.

The analysis of an alternative begins by specification of a set of airport locations within Michigan. This selection is limited to combinations of the 31 airport sites identified during Task Group 2. (Airport location alternatives are described in Section III.)

Closely related to the selection of airport locations is the specification of zone to airport access (times and costs). For most alternatives these times and costs will be generated by the procedures outlined in Section IV. (Namely, access times will be based on automobile travel, and access costs will be based on the assumption of a fixed percentage of access trips by auto, taxi, and other surface modes.) In a few specific alternatives, new modes of access (e.g., high-speed rail service) will also be considered.

The "air network analysis" step combines the zone-to-airport access data with airport-to-airport service measures (time, cost, and frequency) to arrive at zone-to-zone air service measures. The specification of airport-to-airport service is a critical step in the analysis because it influences subsequent predictions of demand. As indicated by Figure IX-1, the specification is arrived at in an iterative manner (feedback loop (1)). At the outset, time and cost of travel for each of three flight categories are catalogued for each airport pair. (The flight categories are non-stop, direct, and connecting.) From this master list, a single flight category and frequency of service are initially chosen for each airport pair in a subjective manner so as to anticipate the optimal service frequency. Later, after demand predictions are made, the choice of flight level service is reexamined. Frequency, or flight category, or both are then modified in successive steps until demand and flight service are compatible.

Results of the "air network analysis" are used in the "demand analysis and network loading" step. The methods for predicting passenger and cargo demands are as described in Sections IV and V. Once a final set of air service measures has been determined, the "network loading" portion of this step yields activity levels for each Michigan airport:

- Passenger traffic levels
- Air cargo volumes
- Flight operations.

These activity levels serve as the primary measures for determining the facility requirements at each airport.* Directly related to this determination are estimates of airport capital costs. The activity levels also serve as the basis for estimates of airport operating costs and revenues.†

In the "evaluation" step of the analysis, discussed in detail below, it is noted that the evaluation results for one alternative will be used to:

(1) Modify input data for that alternative

(2) Select the next alternative for examination.

This iterative process is indicated in Figure IX-1 by the branches of the feedback loop labeled (2). The use of this systematic analysis procedure will lead to identification of a limited set of alternatives for detailed and comprehensive examination during Task Group 4 of this study.

Evaluation Procedure

The purpose of the evaluation procedure is to provide useful information to the Advisory Committee and MAC staff for comparison of alternative airport systems. As a guide to the kinds of information that might be most useful, the recent statement of Michigan's overall aviation goals and objectives‡ was carefully reviewed. This review suggested the

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* The method for translating activity levels to facility requirements is now being developed by HNTB.

† This method, employing parametric estimating techniques, is also under development by HNTB.

‡ National Transportation Planning Study: Phase One--Aviation Goals for the State of Michigan, prepared by Michigan Department of Commerce, Aviation Commission, February 1971.

following five categories of evaluation criteria:

(1) Traveler and shipper impacts

(2) Air carrier impacts

(3) Airport operator impacts

(4) Economic impacts

(5) Institutional, financial, and environmental impacts.

During Task Group 2, work has focused on the types of quantitative data and qualitative information that can be generated in the analysis for these criteria.

Traveler Impacts

As the airport system is improved, the following benefits to air travelers can be expected:

- Some travelers who currently travel by air (or, more precisely, who are predicted to travel by air under the case case alternative) will benefit by using an airport that provides better service.

- Some travelers who travel by other modes of transportation will switch to air travel because of the improved service.

- Some persons who do not travel (or who make fewer trips) will travel rather than spend their time and money on something else and thereby benefit because of the improved air service.

The number of travelers in each of the three groups will be determined in the analysis and the following benefits will be developed: travel cost benefits, including reductions in access cost and airline fare costs; travel time benefits, including reductions in airport access times and city-to-city travel times; and frequency of service benefits. The travel time benefits will be measured in minutes and in dollar equivalent values; and the frequency of service benefits will be measured in terms of dollar equivalent values.

The mathematics of obtaining the dollar equivalent values is described in the Appendix. As indicated there, the dollar equivalent values will be derived directly from the model that will be used to estimate traveler demand and modal choice. Since the model represents the best estimates of travelers' behavior and values, it should provide reasonably accurate assessments of the benefits.

The benefits to air travelers in the first group, i.e., those currently traveling by air, are calculated directly from the time, cost, and frequency improvements and are equal to the time and dollar equivalent values of the improvements. Benefits to air travelers transferring from other modes of travel and to those induced to travel under the improved alternative are calculated according to the economic theory of consumer surplus. An estimate of these benefits can be obtained from the simplified equation:

$$\text{Benefits} = 1/2(C_0 - C_1)(D_1 - D_0) \quad ,$$

where C_0 and C_1 are the total dollar equivalent costs of the base case and improvement alternatives, respectively, and D_0 and D_1 are the demands under the two alternatives.

Benefits are calculated for each of the three air traveler groups for every zone pair and then summed to obtain an estimate of total air traveler benefits under the improved alternative.

Shipper and Receiver Benefits

As explained in Section V, the study method for air cargo will not explicitly consider the causes for diversion of shipments between air and surface line-haul modes.* This approach limits consideration of potential cargo benefits to cases where shipments are routed through a different airport (than the base case) and the shippers or receivers profit thereby. As further explained in Section V, data collected during the study indicate that (1) differences in total shipment time via alternate Michigan airports are very small and (2) differences in total shipment cost depend on factors that the study is not equipped to measure (i.e., potential for shipment consolidation). Consequently, there is no basis for calculation of quantitative shipper and receiver benefits.

* Instead, reliance will be placed on national projections of the percentage of such diversion.

For some alternatives, effects on shippers and receivers will be assessed qualitatively. For example, in the alternatives that call for discontinuance of air carrier service at an existing Michigan airport (and no air feeder service is provided), extra costs of pickup and delivery drayage to the next closest airport(s) will be weighted against the likelihood of better cargo service there.

Air Carrier Impacts

Changes in the Michigan airport system may impact on air carriers in a number of ways, affecting both revenues and expenses. As airport locations, air carrier service, and airport access are improved, more traffic will be drawn to the air carriers and their revenues will increase. To handle increased traffic and to meet the assumptions of routing, technology, and frequencies of service specified by each airport system alternative, changes in operations will be required, and as a result, aircraft operations costs will change. Finally, if substantial increases in traffic volumes at existing airports are forecast or if new airports are postulated for an airport system alternative, the air carriers may have to rent more space at airports or make additional capital investments in terminal facilities.

To assess these impacts, work during Task Group 2 was directed to methods for estimating the following comprehensive measures of air carrier impact:

- Air carrier revenues
- Aircraft operating costs
- Air carrier terminal costs.

As discussed below, the work indicates that these comprehensive measures cannot be quantified with sufficient accuracy to justify their calculation in the study. Instead, assessment of air carrier impacts will rest primarily with the judgments of the Advisory Committee members representing air carrier interests. For example, in the comparison of two alternatives, the study team will rely on such judgments in assessing which alternative is "more attractive" from an air carrier viewpoint. Some data will be developed in the analysis to assist in such judgments.

With regard to the first desired measure, "air carrier revenues," passenger revenues can and will be obtained by summing traveler fare expenditures. (These fares are calculated as a part of the traveler benefit analysis.) However, cargo will not be examined on an origin-destination basis in the study--and this is a necessary prerequisite for determining cargo revenues. Predictions of cargo amounts at each Michigan airport will be determined in the study and may serve as a basis for estimating future cargo revenues from current cargo revenues and amounts.

The difficulties encountered in fashioning a method for accurately estimating aircraft operating costs are related to the scope of the air traffic considered in the study. The study appropriately focuses on air traffic to, from, and within Michigan. However, aircraft costs are related to their operation on a systemwide basis--including service between points that are outside Michigan. For example, increasing the frequency of service between a Michigan airport and an external zone airport by one flight per day may have a wide range in variation of effects on aircraft operating costs. Aircraft utilization might increase or decrease, depending on whether the carrier, in effect, had to purchase another aircraft to provide the assumed service. Systemwide routing changes might have to be made. Flight crews might or might not be used more efficiently. Thus, the problem of accurately determining aircraft operating cost for each airport system alternative, in terms of actual practice, is extremely complex and impractical within the scope of the current study efforts.

Since aircraft operating cost data are ultimately directed toward the issue of whether postulated air carrier service is "reasonable" in view of predicted traffic levels, less direct methods will be used to aid in such assessments: For each alternative that survives other screening procedures, a table will be prepared listing the predominant type of service, frequency of service, and passenger traffic volume by airport pair. (The format will roughly correspond to that of Figure II-5 in Section II.) Advisory Committee members will be asked to comment on the reasonableness of the service levels postulated.

For air feeder service*--a small but important segment of total air service--the treatment will be more detailed. Here the air service is assumed to be a point-to-point operation, and estimates of aircraft operating costs will be compared with revenues to assess feasibility.

With regard to the last of the comprehensive measures, "air carrier terminal costs," estimates will be developed as a part of method for assessing airport operator impacts (as discussed below). These will be

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* As defined in Section III, this term is applied to a service between existing Michigan airports and postulated regional airport sites, Detroit, and Chicago.

generalized estimates and are likely to vary from observed costs at specific airports.* Because these costs represent transfers between two parties to the study (carriers and airport operators), the generalized approach appears adequate.

Airport Operator Impacts

Costs and revenues for each airport system will be prepared by individual airports. The cost and revenue data will not necessarily agree in detail with actual cost and revenue experience at specific airports, since the method used will not be airport-specific.

To enable cost and revenue estimates to be prepared quickly for a large number of alternatives, an approach called parametric estimating will be used. This approach uses cost data collected from a number of airports and relates those costs to significant factors that affect costs. Trend or regression lines are prepared in graphical form to relate cost to one or more of the factors. For example, passenger terminal building capital costs might be related to number of annual passengers, number of aircraft operations, or both.

A number of relationships will be used to estimate components of

- Airport capital costs
- Airport operating costs
- Airport revenues.

The estimating method is currently under development by HNTB. As planned, it is an early stage component of Task Group 3.

It should be noted that the estimating method is not intended for application to Detroit Metropolitan Airport. As indicated in Section II, the present activities and facilities at this airport are of vastly different scale than those of other Michigan air carrier airports. Also, while it is appropriately within the scope of the statewide study to estimate Michigan-related activity levels (e.g., passenger and cargo volumes) at Detroit Metropolitan and study its interaction with other airports in the state, Detroit Metro's present and future role in serving

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* Air carrier terminal costs at a specific airport depend on the terminal configuration, carrier and airport operator negotiations, and other factors. Such detail (and speculation) is beyond the scope of this study.

national air travel patterns must be considered in its facilities planning (e.g., as a transfer point for traffic whose origin and destination is outside Michigan). Thus, the MAC staff will make separate estimates of costs and revenues at Detroit Metropolitan, with heavy reliance placed on data provided by Detroit Metro's planners.

Economic Impact

The economic impact model that will be used in the study is discussed in Section VIII. That portion of the model that provides an assessment of the degree to which changes in air carrier services affect economic and demographic growth is used in the evaluation phase of the study. Specifically, the following projections will be compared between alternatives to assess economic impact by state planning region:

- Employment
- Value added
- Net trade by industrial sector.

Institutional, Financial, and Environmental Impacts

This assessment will be largely qualitative and is discussed in greater detail in Section VII. Institutional impacts on existing governmental units will be considered for each alternative. Institutional problems that impede formation of regional airports, as well as institutional actions that might be taken to facilitate such formation, will be considered. Possible state legislation, taxing powers or organizational authority, will be suggested if appropriate.

With regard to financial impacts, it will not be possible to conduct financial feasibility studies such as might be done at the airport master planning level. Instead, this task will entail comparison of airport costs and revenues, evaluation of airport funding requirements and constraints, and preliminary analysis of the financial problems associated with each airport system alternative.

Studies regarding environmental impacts will be addressed principally toward aircraft noise and air pollution effects.

Overall Evaluation

At the conclusion of Task Group 3, evaluation data and descriptive material will be assembled into a condensed summary form and supporting text for the better alternatives identified during the analysis. Searches will have been made to find alternatives that are clearly dominated by others, i.e., that are inferior in all respects, and to find other alternatives that are nearly dominated by others, so that MAC staff and the Advisory Committee can proceed to eliminate alternatives on the basis of comparisons by pairs.

Evaluation results will be summarized in tabular form, tentatively employing the evaluation measures shown in Table IX-1. Such measures allow for the direct comparison of alternative airport systems. They will be presented in the most meaningful units--which in many instances will be dollars. However, some measures--particularly those associated with institutional and environmental impacts--will be presented qualitatively rather than quantitatively.

In some instances, the evaluation measures will be further stratified to reflect the impacts on individual subgroups, such as specific groupings of zones or airports. For example, passenger traffic might be stratified into two categories:

- Trips between Michigan zones,
- Trips between Michigan and external zones.

After the report on the evaluation results is published and distributed, a meeting between MAC staff, the Advisory Committee, and contractor staff will be held to discuss study results and to take appropriate steps toward choosing the most attractive alternatives for detailed investigation--including general aviation impacts--during Task Group 4.

EVALUATION MEASURES

Air Traveler Impacts

- Access times and costs
- Line-haul times and costs
- Number of transfers and transfer delay times
- Total estimated benefits

Shipper and Receiver Impacts

- Qualitative assessment of major service changes

Air Carrier Impacts

- Passenger revenues, cargo volumes
- Service level and traffic by airport pair
- Revenues and operating costs for air feeder service
- Air carrier terminal costs (estimated)

Airport Operator Impacts

- Airport capital costs
- Airport operating costs
- Airport revenues

Economic Impacts

- Employment
- Economic value added
- Net trade by industrial sector

Institutional, Financial, and Environmental Impacts (largely qualitative)

- Institutional impacts on government units, legislative requirements
- Airport funding requirements
- Aircraft noise and air pollution effects

X GENERAL AVIATION ANALYSIS

The MAC has undertaken responsibility for planning general aviation airport development in the current statewide study.* This development is to be planned for the years 1975, 1980, and 1990.

For each study year, a four-step approach will be used as follows:

(1) Define and describe existing airports

(2) Forecast number of based aircraft

(3) Forecast number of aircraft operations

(4) Identify deficiencies of existing airport facilities and plan improvements.

In applying the planning method, emphasis will be placed on refining and expanding the plan for general aviation facility improvements that was developed in the 1970-75 Michigan State Airport Plan. Central to the method is the concept of treating the Michigan study zones in the statewide study as planning units. The steps of the planning method are discussed below.

Step 1. Define and Describe Existing Airports

The principal purpose of this step is to document the basis for planning. For the 1975 planning year, the existing airports will be those of 1970. Similarly, the "existing" airports for 1980 will be those of 1970 plus those for which development is justified by 1975.

Descriptions of existing airports for 1970 will be based on information maintained by the MAC. This includes facilities information, data on aircraft operations from the Traffic Counter Program, and data from past surveys (e.g., the Michigan Aviation Fact Finder). The airport descriptions will be updated for 1975, 1980, and 1990 by incorporating results of the planning for prior periods.

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* As MAC's contractor, SRI has provided consulting assistance on the planning method.

Step 2. Forecast Number of Based Aircraft

The method to be used for forecasting the number of based general aviation aircraft at the zone level is relatively simple; namely, based aircraft will be treated as a function of zone population.

For forecasting purposes, the state has been divided into four regions as shown in Figure X-1. For each region, 1970 per capita aircraft factors have been calculated. These factors are displayed in Table X-1. The table also displays factors for 1975, 1980, and 1990. The growth in per capita ownership reflected by these data is a consensus of several predicted growth rates (net of population effects) for the United States. This approach has been adopted because the past growth in Michigan's general aviation aircraft fleet parallels that of the United States.

Table X-1

PLANNING FACTORS FOR FORECASTING BASED GENERAL AVIATION AIRCRAFT

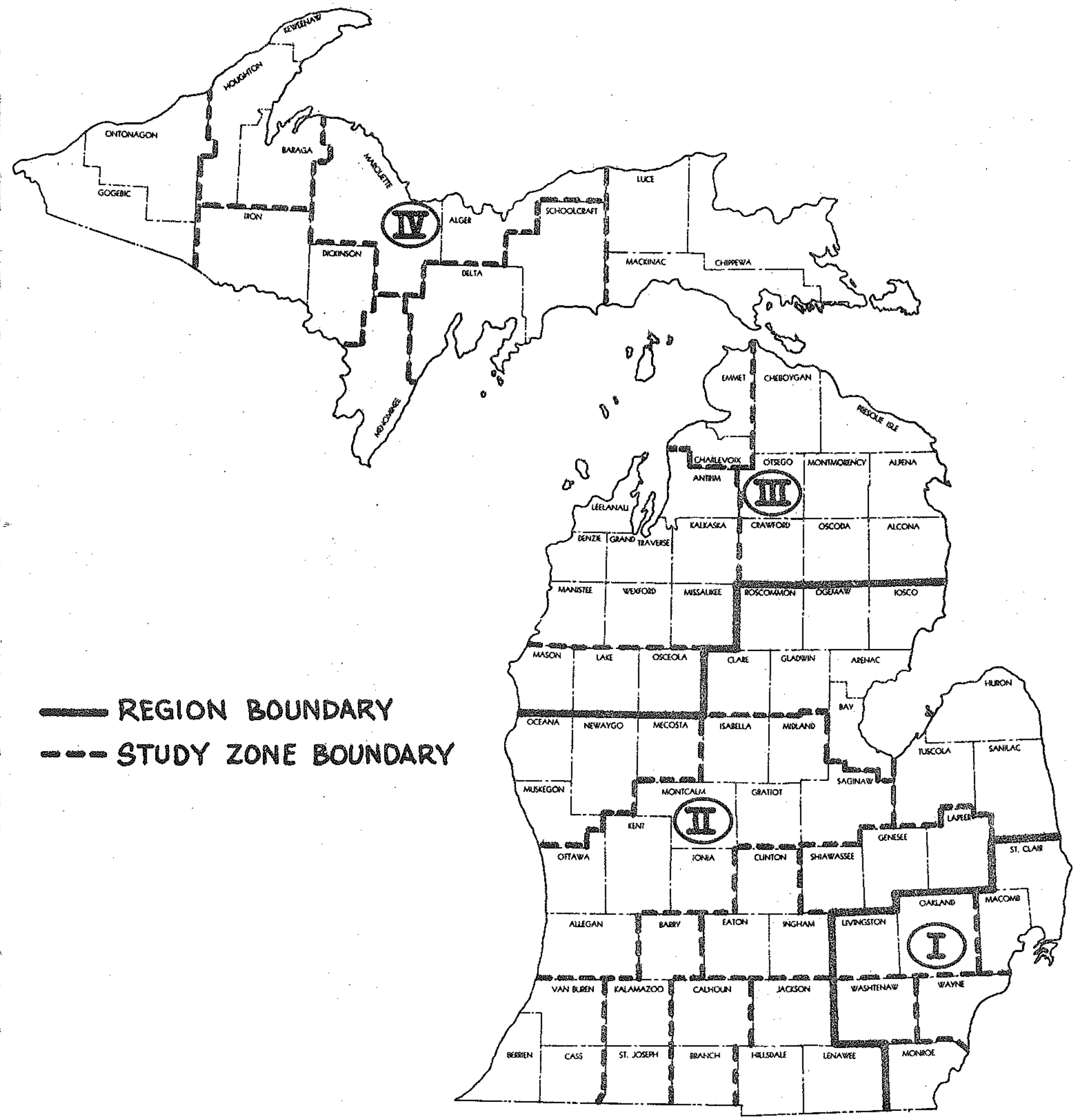
State Region	Study Zones	Based Aircraft Factor (to be multiplied by zone population in thousands)			
		1970	1975	1980	1990
I	1, 15, 16, 17, 18	0.47	0.59	0.70	0.94
II	2, 3, 4, 5, 6, 7, 8, 19, 20, 21, 22	0.77	0.96	1.16	1.54
III	9, 10, 23, 24	0.88	1.10	1.32	1.76
IV	11, 12, 13, 14, 25, 26, 27	0.60	0.75	0.90	1.20

As an example of the use of the Table X-1 factors, the Lansing zone (Zone 6) population in 1970 was 378,000. On this basis, predicted aircraft would be:

(378) (0.77) = 291 based aircraft.

Figure X-1

GENERAL AVIATION REGIONS



This compares with an actual number of 1970 based aircraft of 328, according to MAC records. Clearly, the method is imprecise* but is judged of sufficient accuracy for planning purposes.

The next task of Step 2 is to calculate the mix of aircraft types for each zone. As a guide, the projections of Table X-2 will be used. These trends (e.g., a reduction in the proportion of small, single engine aircraft in the fleet) will be applied to each zone's 1970 mix of aircraft types.

Table X-2

A NATIONAL PROJECTION OF GENERAL AVIATION FLEET MIX

Type of Aircraft	Percentage of General Aviation Fleet 1970	1975	1980	1990
Single engine, reciprocating 1 - 3 Place	34%	29%	24%	19%
Single engine, reciprocating 4+ Places	48	51	55	59
Multiengine, reciprocating	13	13	12	12
Single and multiengine, turboprop	1	2	3	3
Multiengine, turbojet	1	1	2	2
Other (e.g., Rotorcraft)	3	4	4	5
Total	100%	100%	100%	100%

Source: R. Dixon Speas Associates. Extrapolated to 1990 by Stanford Research Institute.

* It happens that the statistical "fit" for Lansing is among the worst cases.

The final task of Step 2 is to allocate the predicted based aircraft for a zone among the zone's existing airports (as established in Step 1). Past experience of the MAC staff indicates that it will be necessary to exercise subjective judgment in accomplishing the task, guided by:

- The present distribution of aircraft among airports in the zone
- The present and projected distributions of population within the zone
- The size mix of projected aircraft additions.

Step 3. Forecast Number of Aircraft Operations

Forecasts of general aviation aircraft operations* are required in analyses of the adequacy of airport facilities and are also of value in analyses in airport access trips by general aviation users (as described in Step 4, below). Numerous approaches to forecasting aircraft operations are suggested in aviation literature.

One broad approach is to forecast operations on the basis of total based aircraft, with different planning factors used depending on type of airport (e.g., whether the airport is in a metropolitan area, whether the airport serves air carriers). Examples of this "airport features" method include:

- The FAA planning approach--as described in "Formulation of the 1972 National Airport System Plan"
- The approach described in "Transportation Predictive Procedures, Technical Report 9A" by the MAC.

An analysis has been conducted to develop revised factors for this approach in Michigan. Source data on airport operations included those from the Michigan Traffic Counter Program, FAA 5010-1 forms (for air carrier airports) and FAA control tower counts for 1970. The planning factors resulting from the analysis are displayed in Table X-3. As shown in the table, the state is again divided into four regions and two types of airports are distinguished.

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* An aircraft operation is a takeoff or landing.

Table X-3

PLANNING FACTORS FOR GENERAL AVIATION OPERATIONS

State Region*	Airport Type	Annual Operations per Based Aircraft Itinerant	Local	Total
I	Air carrier and/or tower	350	350	700
	General aviation only, no tower	275	550	825
II	Air carrier and/or tower	450	450	900
	General aviation only, no tower	250	500	750
III	Air carrier and/or tower	450	550	1,100
	General aviation only, no tower	500	500	1,000
IV	Air carrier and/or tower	300	475	775
	General aviation only, no tower	450	900	1,350

* See Figure X-1.

When the planning factors of Table X-3 are applied to individual airports, in an attempt to replicate 1970 operations, rather poor results are often obtained. The Kalamazoo Airport (in Zone 3, Region II) is an example of one of the worst cases as shown below.

	Actual General Aviation Operations (1970 Tower Count)	Predicted Operations (195 based General Aviation Aircraft)
Local	63,000	88,000 (450 X 195)
Itinerant	63,000	88,000 (450 X 195)
Total	126,000	176,000

Although predictions of general aviation operations need not be extremely accurate for planning necessary airfield capacity (because capacity is added in large increments relative to aircraft operations), errors of this magnitude suggested that other forecasting approaches be examined. However, the examination suggested no alternative to the "airport features" approach that yielded consistently better results in replicating 1970 operations. The discrepancies appear to arise because of unique airport operating patterns--patterns that can be expected to continue in the future. Therefore, forecasts of operations will be made on an incremental basis for airports whose 1970 operations are known. The Michigan Traffic Counter Program is a primary source of this information for general aviation airports.

In the incremental approach, the input is the increase (decrease) in based general aviation aircraft calculated in Step 2 of the planning method. The appropriate "airport features" planning factor will then be applied to determine the increase (decrease) in operations. This calculated number of operations is added to (or subtracted from) 1970 operations. As a hypothetical example, consider a general aviation non-tower airport (Zone 6, Region II) for which 1970 operations are known:

Predicted 1975 aircraft	100
Less actual 1970 aircraft	-50
Increase in based aircraft	50

Predicted increase in total annual operations: 50 aircraft times 750 operations per aircraft* = 37,500.

Actual 1970 operations	55,500
Plus predicted increase	+37,500
Predicted 1975 operations	93,000

For airports where 1970 operations are not known, future operations will be predicted by applying the planning factors to the total predicted based aircraft. Thus, in the hypothetical example posed above, predicted operations would be calculated as:

Predicted 1975 aircraft	100
At 750 operations per aircraft*	x750
Predicted 1975 operations	75,000

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* From Table X-3.

The second task within Step 3 is to estimate the "critical aircraft" --that is, the type of aircraft most demanding in terms of runway requirements. For some airports, this assessment can be made directly from the airport's based aircraft mix. However, it will be necessary to consider the nature of transient (nonbased) aircraft operations for many Michigan airports, particularly those in the proximity of recreational areas.

Step 4. Identify Deficiencies of Existing Airport Facilities and Plan Improvements

In this step, the aviation demands placed on each airport--as calculated in Steps 2 and 3--are compared with the airport's capability. A likely result of this examination is that demand will exceed capability at some airports. In this instance, the question is whether to improve the existing facility or plan for a new airport. Even if the comparison of future demand and existing capabilities suggest that existing airports would be adequate, the potential benefits of new airport facilities may outweigh their costs.

The wide range of potential improvements to the existing general aviation system was developed by the MAC in preparation of the 1970-75 State Airport Plan. Similarly, estimates of capital costs for these airport improvements have been made. There remains the need to assess the benefits of such improvements relative to the existing system.

The research organization MATHEMATICA has developed a methodology for estimating general aviation airport user benefits, published in its report "Public Investment in General Aviation Airports: An Application of Cost Benefit Economics." The approach is referred to as the "map method." It derives the public benefit for a new airport* on the basis of several key assumptions.

- The principal source of public benefit that can be quantified† is the savings in ground access to the new facility. This time savings is valued at the median wage rate of the airport user.
- Airport users patronize the closest airport that offers the services in which they are interested.

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* Or expanded capabilities of an existing airport.

† Nonquantifiable benefits include potential increases in community employment, and an ability to obtain supplies quickly in an emergency.

- Airport users are distributed geographically in exactly the same way as population is distributed.

By means of these assumptions, estimates can be developed on the amount of general aviation activity (based aircraft, operations) that would be transferred from an existing airport to a proposed new facility. Moreover, a dollar value is obtained for the resulting public benefit. This amount can then be compared with costs of the proposed development as a partial test of its worthiness.

The map method will be used selectively in the present study to assess the feasibility and timing of general aviation airport developments that were proposed in the 1970-75 State Airport Plan. Other means of justification, such as those described in the 1970 MAC report "Aviation and Economic Development," will also be used (e.g., effects on a community's industries).

Appendix

PASSENGER DEMAND MODEL EQUIVALENCE MEASURES

Appendix

PASSENGER DEMAND MODEL EQUIVALENCE MEASURES

Equivalent Types of Service

Consider the following general formulation of the demand model for a specific zone pair (i,j) and mode m:

$$w_m = a_m t_m^{\alpha_m(1)} c_m^{\alpha_m(2)} \left[1 - e^{-0.12 f_m}\right]^{\alpha_m(3)}$$

$$W = \sum_{\substack{\text{all} \\ m}} w_m$$

$$D = \beta_i \beta_j (P_i P_j) W^{0.9}$$

$$D_m = \left(\frac{w_m}{W}\right) D$$

where

t_m = total (i→j) travel time,

c_m = total (i→j) travel cost (dollars),

f_m = frequency of (i→j) service (trips per day),

P_i = total population of zone i.

The a_m, α, and β values are calibration parameters, D_m and D are daily one-way (i→j) modal demand and total demand, respectively.

Assume now that the conductance values for the auto, bus, and rail modes are not affected by variations in air service and let (t_1, c_1, f_1) and (t_2, c_2, f_2) represent two different categories of air service (e.g., (1) nonstop service and (2) direct flight service consisting of one intermediate stopover) for a specific airport pair. These levels of service will be "equivalent" to one another if they produce the same demand between the airports, which is the same as requiring that $w_1 = w_2$, or

$$t_1^{\alpha(1)}\ c_1^{\alpha(2)}\ (1-e^{-0.12f_1})^{\alpha(3)} = t_2^{\alpha(1)}\ c_2^{\alpha(2)}(1-e^{-0.12f_2})^{\alpha(3)} \qquad (1)$$

where $w_i = w_{air}(t_i, c_i, f_i)$.

This result defines the equivalence relationships between two equivalent levels of service. It indicates how changes in one variable can be offset by changes in another variable, e.g., how an increase in frequency of service is equivalent to (i.e., yields equivalent air demand) a specific reduction in travel time or cost.

Equation 1 can be used to convert any service level (t,c,f) into an equivalent service level $(t^*, c^*\ f^*)$, where the "equivalent time and cost" variables t^* and c^*, respectively, are specified. The resulting "equivalent frequency," f^*, is then determined by solving

$$w(t,c,f) = w(t^*,c^*,f^*)$$

yielding

$$f^* = \left(\frac{-1}{0.12}\right) \ln \left[1 - \left(\frac{t^*}{t}\right)^{\alpha(1)/\alpha(3)} \left(\frac{c^*}{c}\right)^{\alpha(2)/\alpha(3)} \left(1-e^{-0.12f}\right)\right] \qquad (2)$$

where "ln" is the natural logarithm function. Thus, several different types of service (nonstop, direct, connect) for a specific airport pair can be converted to their equivalent times, costs, and frequencies. Furthermore, if the equivalent times and costs are all chosen equal to one another, then the equivalent frequencies can be added directly to obtain the desired single service level (t_e^*, c_e^*, f_e^*) for the specified airport pair. That is:

if

$t_i^* = t_e^*$ and $c_i^* = c_e^*$, for all service levels i.

then

$f_e^* = \sum_i f_i^*$ is the equivalent total frequency of service,

and

(t_e^*, c_e^*, f_e^*) defines the single service level that is equivalent to the totality of service levels between the specified airports.

The basis for equivalent times and costs has been chosen as the minimum airport-to-airport time and cost (e.g., nonstop basis if one such flight available, direct flight basis if available and no nonstops available). This basis avoids some potential computational problems associated with the solution of equation (2) and provides a consistent approach to the analysis. A modification made to this analysis procedure, also to ensure added consistency, was to convert each individual flight (frequency of 1) to an equivalent frequency rather than lumping flights together and converting the total lumped frequency to an equivalent value.

The decision to use airport-to-airport rather than zone-to-zone times and costs in equivalence calculations was made for purposes of computational efficiency. Otherwise, a vast number of zone-pair service levels would have to be calculated for each airport pair considered. The result of such is to produce a small error in the equivalent frequencies for trips consisting of high access times and costs and relatively low flight times and costs.*

Dollar Equivalent Values for Travel Time and Frequency

The procedure to be employed in finding equivalent values is described above. Applying it directly to the solution of the equation

$$w(t,c,f) = w(t^*,c^*,f^*),$$

as was done to obtain equation 2 above, yields the following expression for converting travel times and frequencies of service to equivalent dollar values:

$$c^* = c\left(\frac{t}{t^*}\right)^{\alpha(1)/\alpha(2)}\left(\frac{1-\exp(-0.12f)}{1-\exp(-0.12f^*)}\right)^{\alpha(3)/\alpha(2)} \qquad (3)$$

where the variables t, c, and f are the observed time, cost, and frequency, respectively, and the variables t^*, c^*, and f^* are the equivalent values of time, cost, and frequency, respectively.

Equation 3 is used to obtain the total dollar equivalent cost of a particular service level (t,c,f) with respect to preselected equivalent time (t^*) and frequency (f^*) variables that represent a basis for comparison. (In most instances it will be desirable to select these equivalent time and frequency variables to be the minimum values found in the alternatives being compared.) By subtracting out the total (direct) travel costs, c, the total dollar equivalent time and frequency value becomes

$$c^* - c = c\left[\left(\frac{t}{t^*}\right)^{\alpha(1)/\alpha(2)}\left(\frac{1-\exp(-0.12f)}{1-\exp(-0.12f^*)}\right)^{\alpha(3)/\alpha(2)} - 1\right].$$

A positive value indicates a net time-frequency benefit to be realized over the service level provided by t^* and f^*, whereas a negative value for $c^* - c$ indicates a net time-frequency disbenefit.

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* It can be argued that air travelers make their tradeoffs between flights providing different levels of service based solely on the air portion of the trip, i.e., that the tradeoffs between different service levels is independent of the access and egress portion of the trip.

GLOSSARY OF AIR NAVIGATION TERMS

VFR (Visual Flight Rules) - Rules for flight when collision avoidance is possible by visual reference to other aircraft on a "see and be seen" basis.

IFR (Instrument Flight Rules) - Rules for flight when weather conditions are below the minimums prescribed for VFR rules.

ATC (Air Traffic Control) - A service operated by appropriate authority to promote the safe, orderly and expeditious flow of air traffic.

PWI (Proximity Warning Indicator) - Equipment which indicates to the aircraft pilot the direction and distance of other aircraft in the proximity.

CAS (Collision Avoidance System) - A system for avoiding aircraft collision by use of PWI or related equipment.

VOR (Very High Frequency Radio Range) - As in a VOR transmitter, used to send signals for directional air navigation.

DME (Distance Measuring Equipment) - Airborne equipment for measuring the distance between an aircraft in flight and a designated land point.

VOR/DME - Combination VOR and DME for providing indications of both bearing and distance.

TACAN - Military version of VOR/DME.

VORTAC - Commercial VOR and military TACAN co-located at a given point.