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## Travel Simulation and Traffic Analysis

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TECHNICAL MEMORANDUM NO.2

# TRAFFIC SIMULATION AND TRAVEL ANALYSIS

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Prepared for

THE INTERSTATE DIVISION FOR BALTIMORE CITY

By

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2807

March 1974

# PREFACE

This memorandum, the second of a series of seven technical memoranda on the Baltimore Regional Environmental Impact Study (BREIS) prepared for the Interstate Division for Baltimore City (IDBC), describes the assumptions, methodology, and findings for travel simulation and traffic analysis.

The other technical memoranda are:

- 1 -- Socioeconomic and Land Use Analysis
- 3 -- Air Quality Analysis
- 4 -- Water Resource and Solid Waste Analysis
- 5 -- Noise Analysis
- 6 -- Analysis of Environmentally Sensitive Areas
- 7 -- Summary Analysis and Evaluation

In addition to IDBC, the Baltimore Regional Planning Council and the Maryland Department of Transportation, including the Mass Transit Administration, have been active participants in the study. Other agencies which have assisted in the project include:

- Maryland Department of Health and Mental Hygiene, Bureau of Air Quality Control
- Maryland Department of Natural Resources
- Maryland Department of State Planning
- Baltimore City, Department of Planning
- Baltimore City, Department of Transit and Traffic
- Baltimore City, Department of Health
- U.S. Federal Highway Administration
- U.S. Environmental Protection Agency

Undertaking the effort was a multidisciplinary team consisting of Alan M. Voorhees & Associates, Inc., with overall responsibility for the study, in conjunction with:

- ESL, Inc. -- Noise Analysis
- Jason M. Cortell and Associates, Inc. -- Environmentally Sensitive Areas
- Economics Research Associates -- Economic Analysis
- Dr. David Marks, Resource Analysis, Inc. -- Water Resources & Solid Waste
- Dr. Gerhard Israel, University of Maryland -- Meteorology

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# I. BACKGROUND

This study, initiated in the spring of 1973, was the culmination of a series of events related to transportation systems planning and highway construction that had occurred over a number of years in the Baltimore region. The following brief statement outlines the events leading up to the study to provide a context within which the results of the study should be reviewed.

The highway system which is the subject of this study was defined in a previous comprehensive study of the Interstate plan in Baltimore by Urban Design Concepts Associates, (1) as well as in several other planning studies that preceded it. (2) This system, shown in Figure I-1, is known as the 3-A system. It was adopted in 1969 by the Baltimore Planning Commission and subsequently approved by the Regional Planning Council (RPC) for inclusion in the General Development Plan. The 3-A system consists of several segments of I-70N, I-83, I-95, the I-395 and I-170 spurs, and City Boulevard, an arterial link not on the Federal Interstate System. In the spring of 1973, the following portions of the system were complete:

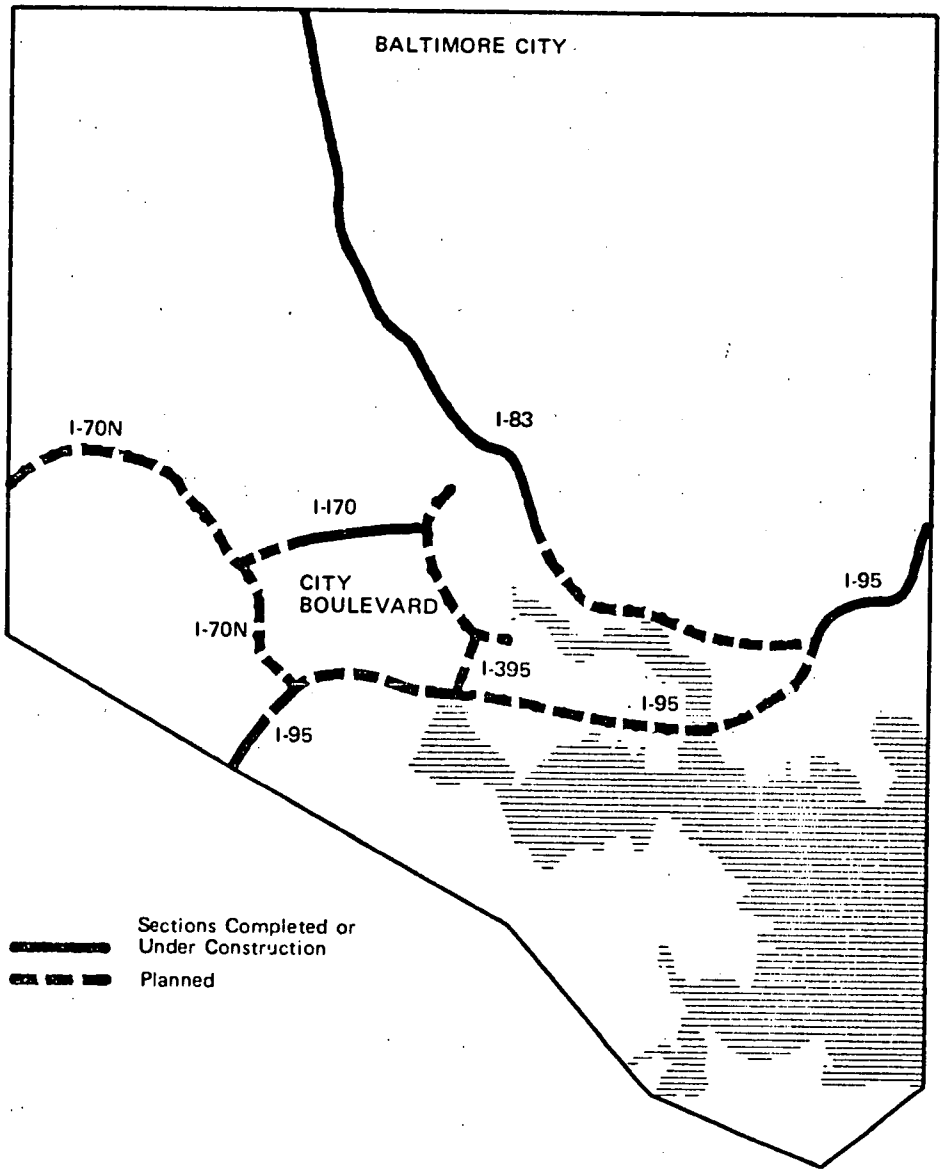
- I-70N was constructed to the City line
- I-95 was constructed to Caton Avenue just inside the City line on the south and was under construction on the east side in the vicinity of the Harbor Tunnel Thruway to O'Donnell Street
- I-83 (Jones Falls Expressway) was constructed on the north to a point near Eager Street.

In addition, several other segments had received design approval.

With the passage of the National Environmental Policy Act of 1969 (NEPA), many of the environmental concerns which had been expressed by various groups in the Baltimore region received official recognition. Section 102(2)(C) of this act requires a detailed statement for any proposed federal action affecting the environment, including:

- The environmental impact of the proposed action
- Any adverse environmental effects which cannot be avoided should the proposal be implemented

Figure I-1. Baltimore 3A System



- The relationships between the local short-term uses of man's environment and the maintenance of long-term productivity

- Any irreversible and irretrievable commitments of resources that would be involved in the proposed action should it be implemented

For federal highway construction, these requirements were reinforced by provisions of the Federal-aid Highway Act of 1970 (Section 136), the Department of Transportation Act as amended (Section 4(f)), the Clean Air Act Amendments of 1970, and the Historic Preservation Act of 1966. The Federal Highway Administration (FHWA), in its Policy and Procedures Memorandum 90-1, has directed that these provisions be fulfilled by highway agencies for each highway construction project.

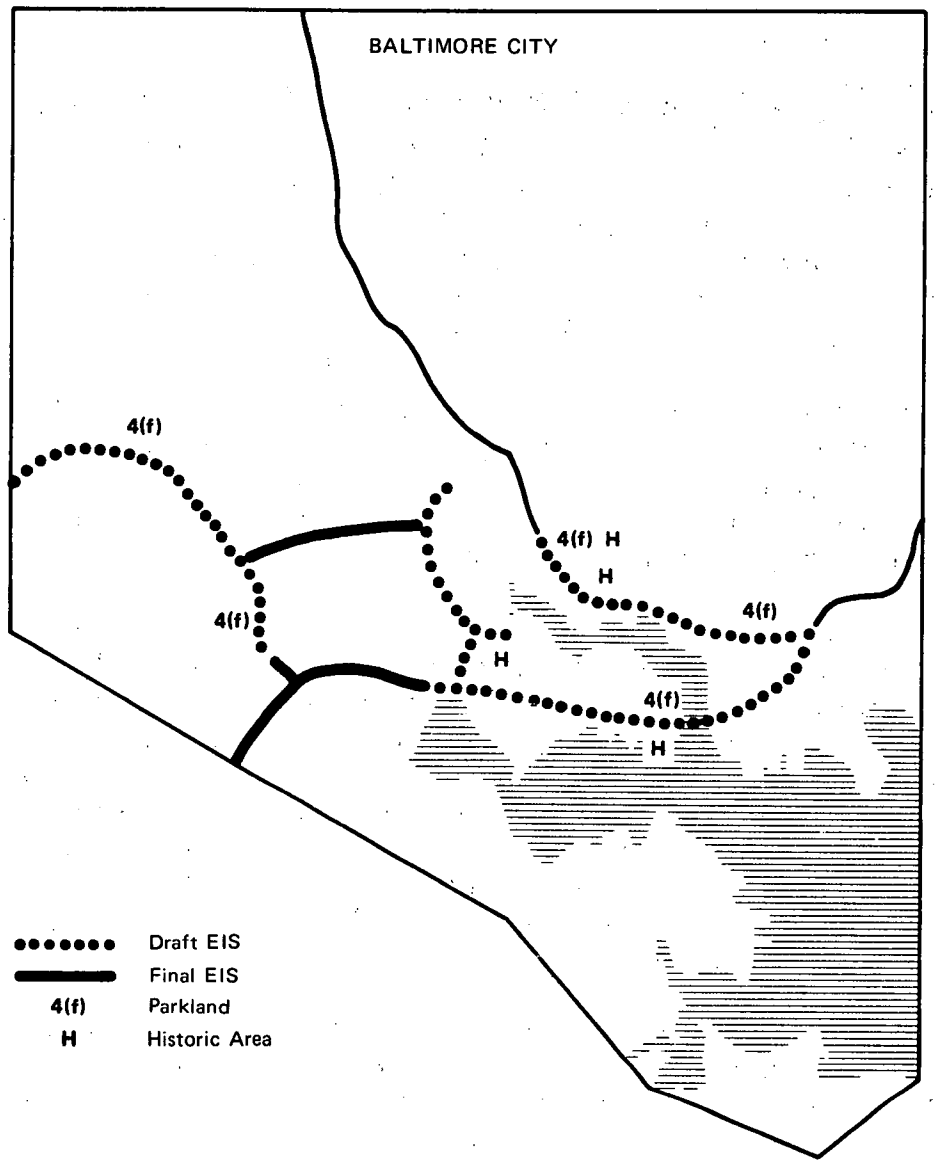
In response to these new requirements, the Maryland Department of Transportation (MDOT) has submitted a draft environmental impact statement (EIS) for each segment of the 3-A system as it reached the location and design approval stage. The segments of the 3-A system for which environmental impact statements have been prepared are shown in Figure I-2.

However, a citizen suit was filed in 1972 against the U.S. Department of Transportation (Movement Against Destruction (MAD) vs. Volpe) charging that the 3-A system as a whole represented a significant federal action and that a regional environmental impact statement should be filed in addition to separate statements for each facility. Another question, relating to the Franklin-Mulberry Corridor (I-170) asserted that the EIS process had not been sufficient to meet NEPA and other federal requirements. Rights-of-way had been purchased in this corridor, and the City would be required to return over $5 million to FHWA if construction on this segment did not begin by June 30, 1973.

Two other cases (Sierra Club, Inc. vs. Volpe and Lukowski vs. Volpe), also questioning the adequacy of the EIS process, were then pending in the courts. It was agreed that the relevant portions of all these cases would be heard concurrently on April 16, 1973.

As a result of this hearing, the court found on June 22, 1973 that "the applicable law does not require that an environmental impact statement be prepared for the 3-A system as such." Further, "components of the 3-A system are not necessarily so interdependent as to require the construction of all the 3-A system or none of it." The court continued that:

Figure I-2. Environmental Impact Statements (EIS) on 3A System



> It may be wise for the city, state and federal authorities to prepare in the near future a statement which considers those environmental impacts that should be determined with respect to the entire configuration, or major portions thereof. Such a statement would be included in one or more of the EISs which will have to be prepared in the future for other sections of the highways in the 3-A system and which will, of course, also include and consider those environmental impacts that should properly be determined section by section or road by road. (3)

As a result of this decision, construction began in the disputed section of the Franklin-Mulberry Corridor on June 22, 1973.

Concurrent with the legal contest, the U.S. Environmental Protection Agency (EPA) was stressing the need for a regional environmental analysis for the 3-A system. In September 1972, based on a series of discussions, a consensus agreement between EPA and FHWA was reached. This agreement provided in part:

- For all remaining segments of the 3-A system under environmental review neither PS&E (plans, specifications and estimates) approval nor further right-of-way approval would be granted by FHWA until a regional impact consideration statement was prepared and circulated to FHWA, EPA, the U.S. Department of Transportation, and the Maryland Department of Health and Mental Hygiene, Bureau of Air Quality Control (BAQC).

- That the regional impact consideration statement will address those regional issues, identified by EPA in its various reviews, that cannot be addressed on a project basis and will include as a minimum:

  1. Cumulative (regional) air pollution impact of the various stages of completion of the currently envisioned 3-A system (including the MTA system) in the years 1978, 1980, 1985, and 1990.

  2. A detailed discussion of possible modifications to the proposed system to mitigate air pollution problems. The effect of these changes on land use and local traffic patterns should be discussed. These modifications should include the options of:

- Increased highway access to the MTA system
- Impact of elimination of various segments of the 3-A system
- Optimization of construction scheduling to minimize saturation of local street systems
- Impact of the no-build-alternative

It is in response to these actions and the desire of regional and local agencies to understand the socioeconomic, traffic, and environmental implications of the 3-A plan that the study presented in this series of reports is directed.

STUDY ORGANIZATION AND PLAN

The study was programmed for completion in approximately six months. The conduct of the study, under the direction of the Interstate Division for Baltimore City (IDBC), was a joint effort by the consultant team and other regional and local agencies. Some of the work for this study was accomplished by RPC and MDOT, with assistance from AMV, as part of the "3-C" (cooperative, comprehensive, and continuing) planning process element of the Unified Transportation Planning Program in the Baltimore region.

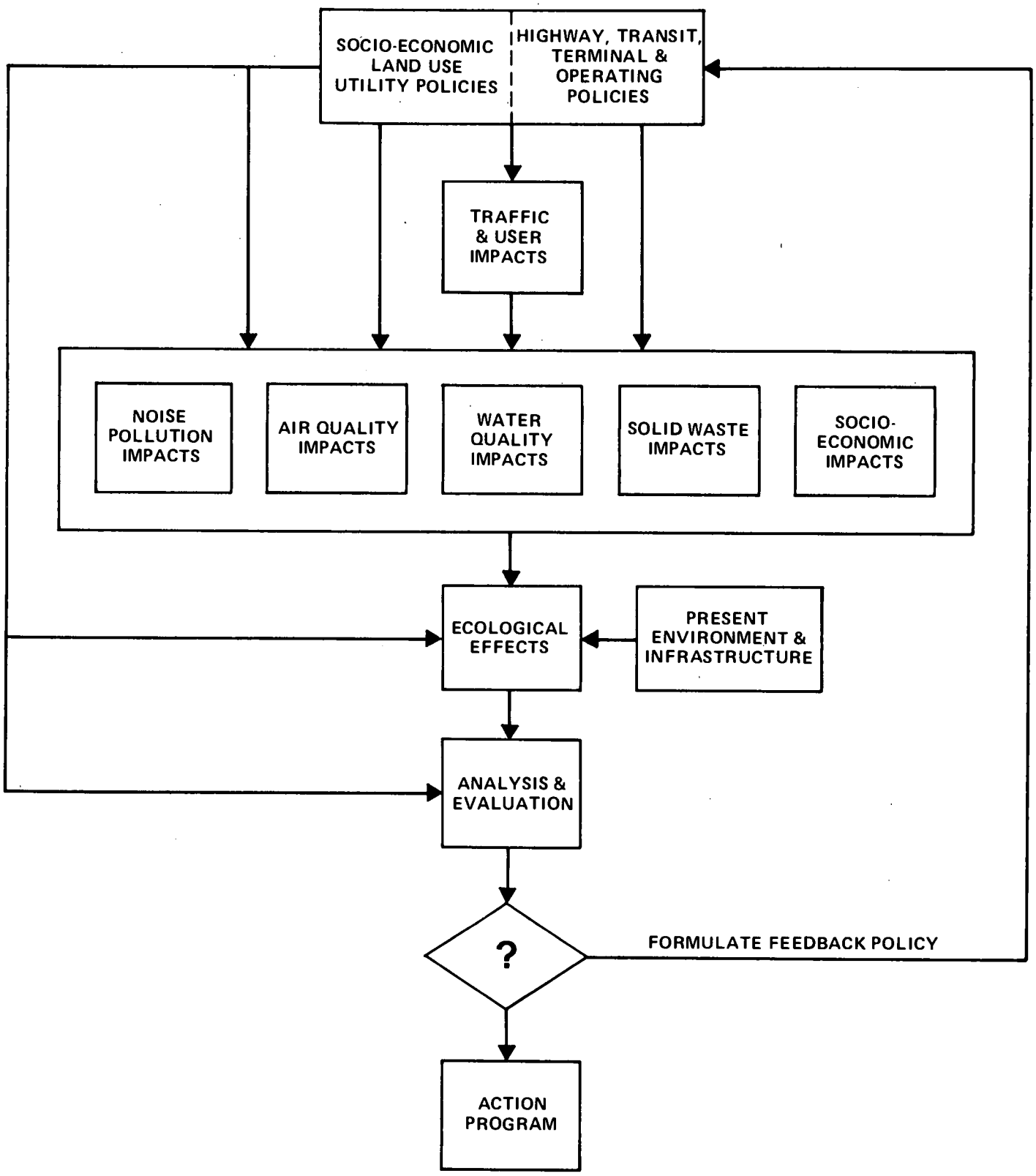
The study process outlined in Figure I-3 was directed toward the measurement of several regional environmental features through which the examination of the estimated future impacts that the 3-A system would have on:

- Socioeconomic and land use factors
- Traffic and travel demand
- Air quality
- Noise pollution
- Water resources and solid waste
- Ecologically sensitive areas

To provide a basis for determining the extent to which future environmental conditions were related to the 3-A system as opposed to other factors, such as growth in population, the environmental consequences of several alternative transportation systems, including a "no-build" option, were also studied. These alternatives were devised jointly by the various agencies associated with the study, both as alternatives to the 3-A system and as a basis for determining the regional environmental consequences of major

Figure I-3.

## BREIS-PROCESS FOR EVALUATION OF ALTERNATIVES



components of that system. These alternatives were selected to isolate various conditions and assess their impact on the region. One of the significant features of this procedure is that land use and socioeconomic activity policies were varied separately for each transportation alternative studied. This permitted an assessment of the predicted effects of changes in urbanization due to transportation policy on the region and demonstrates the interrelationships between transportation and land use.

The study area includes the jurisdictions represented in the RPC -- Baltimore City, and Baltimore, Anne Arundel, Carroll, Harford, and Howard Counties, as shown in Figure I-4. A comprehensive General Development Plan (GDP), which includes a land use pattern element, was adopted for the region in December 1972. It includes the full 3-A system, numerous freeways and other highways outside the City of Baltimore, and a regional rapid transit system comprised of six major lines. This plan serves as one alternative and is the basis for the examination of alternative transportation and land use assumptions for future years.

## DESCRIPTION OF ALTERNATIVES

The transportation and land-use alternatives studied consist of three systems for 1980 and four systems for 1995. A detailed description of the alternatives can be found in Section IV of this technical memorandum. Table I-1 shows a brief summary of the alternative systems. A tear-out copy of Table I-1, which can be used as a reference while reading this report, can be found at the end of Chapter I.

## GENERAL ASSUMPTIONS AND DEFINITIONS

A number of assumptions have been made jointly by IDBC and the study team throughout the conduct of this study. Those which relate to specific areas are stated and described in the appropriate technical memorandum. One general assumption is that no special transportation control strategies to reduce air pollution, except Federal Motor Vehicle Controls, are represented in any of the alternatives. At the time of the study no State Implementation Plan to reduce mobile source emissions in the Baltimore region had been formally adopted.

For purposes of analysis the region was divided into 94 Regional Planning Districts (RPDs) and the urbanized area was further divided into 498 transportation zones. The transportation analysis is concentrated within the area comprising the 1964 Baltimore Metropolitan Area Transportation Study (BMATS) as shown in Figure I-5.

Figure I-4. Study Area—Baltimore Regional Environmental Impact Study

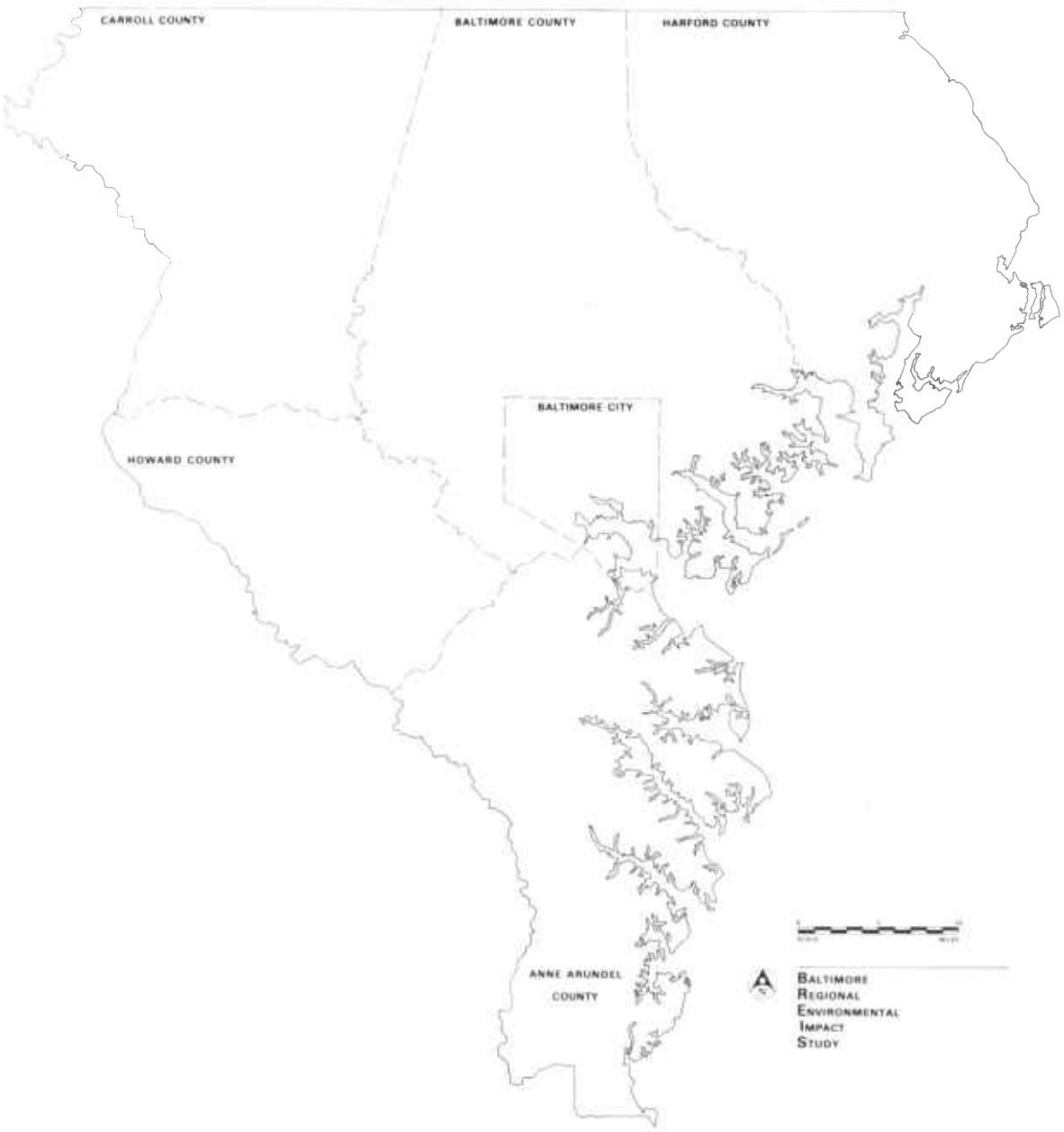


Table I-1.

## TRANSPORTATION ALTERNATIVES FOR BALTIMORE REGIONAL ENVIRONMENTAL IMPACT STUDY

| ALTERNATIVE | YEAR | HIGHWAY ASSUMPTION | | RAPID TRANSIT ASSUMPTION |
|---|---|---|---|---|
| | | 3-A INTERSTATE | OTHER HIGHWAYS | |
| 1 | 1970 | Existing | Existing | None |
| *2 | 1978 | Existing and Programmed | Existing and Programmed | Phase I |
| 3 | 1980 | Complete | Existing and Programmed | Phase I |
| 4 | 1980 | Partial | Existing and Programmed | Phase I |
| 5 | 1980 | Existing and under construction | Existing and Programmed | Phase I |
| 6 | 1995 | Complete | GDP | GDP |
| 7 | 1995 | Existing and under construction | GDP | GDP |
| 8 | 1995 | Complete | Existing and under construction | GDP |
| 9 | 1995 | Existing and under construction | Existing and under construction | GDP |

*Eliminated in favor of Alternative 9.

Figure I-5. BMATS Study Area

## STUDY RESULTS

The purpose for the Baltimore Regional Environmental Impact Study has been outlined in the preceding discussion. The role of the study in the region has been stated in the U.S. District Court decision of June 22, 1973 (3):

> The study has developed into a future planning tool for RPC and Maryland DOT. Many state agencies, such as State Planning, State Health, City Planning and City Health, in addition to RPC and Maryland DOT, will have a use for the study when completed. It will be a data base and data resource document that can be used for possibly setting future transportation policies and other policies within the Baltimore Metropolitan region.

The study results will be framed to answer the following broad questions:

- What were the regional environmental problems in 1970?
- Will there be regional environmental problems in the short-term (1980) with the 3-A system? Without the 3-A system?
- Will there be regional environmental problems in the long-term (1995) with the 3-A system? Without the 3-A system? With the GDP highway plan?
- What are the regional differences between alternatives?
- What regional effects can be attributed to the 3-A system?
- Is there a need for further study?

## LIST OF REFERENCES -- CHAPTER I


1. Urban Design Concept Associates, "Transportation, Environmental, and Cost Summary -- An Evaluation of Three Concepts for Expressway Routes in Baltimore City," 1968. (Supported by a series of reports on route segments).

2. Wilbur Smith and Associates, "Baltimore Metropolitan Area Transportation Study," 1964.

   Alan M. Voorhees & Associates, Inc., "Travel Forecasting and Patronage Estimates for Baltimore Region Rapid Transit System," July, 1968.

   Alan M. Voorhees & Associates, Inc., "Update of Patronage, Revenue, and Operating Costs for Phase I, Baltimore Rapid Transit System," January, 1971.

3. Movement Against Destruction v. Volpe, Civil N. 72-1041-M (D. Md., filed June 22, 1973).

## TRANSPORTATION ALTERNATIVES FOR BALTIMORE REGIONAL ENVIRONMENTAL IMPACT STUDY

| ALTERNATIVE | YEAR | HIGHWAY ASSUMPTION | | RAPID TRANSIT ASSUMPTION |
|---|---|---|---|---|
| | | 3-A INTERSTATE | OTHER HIGHWAYS | |
| 1 | 1970 | Existing | Existing | None |
| *2 | 1978 | Existing and Programmed | Existing and Programmed | Phase I |
| 3 | 1980 | Complete | Existing and Programmed | Phase I |
| 4 | 1980 | Partial | Existing and Programmed | Phase I |
| 5 | 1980 | Existing and under construction | Existing and Programmed | Phase I |
| 6 | 1995 | Complete | GDP | GDP |
| 7 | 1995 | Existing and under construction | GDP | GDP |
| 8 | 1995 | Complete | Existing and under construction | GDP |
| 9 | 1995 | Existing and under construction | Existing and under construction | GDP |

*Eliminated in favor of Alternative 9.

# II. OVERVIEW

This report briefly describes the technical procedures utilized in travel simulation for each of 8 combinations of alternative transportation systems and target years, the results of the travel simulation in terms of regional and subregional travel by the several modes, and pertinent evaluation measures of system performance.

## TRAVEL SIMULATION

All travel simulation utilized the procedures previously developed for the Maryland Department of Transportation and the Regional Planning Council as part of the Continuing, Comprehensive, and Cooperative Transportation Planning Process. These techniques are in general compliance with the methodology in current use for transportation planning and analysis. Section IV of this memorandum discusses the various analytical techniques used, the sequence of application, and summaries of the results. Detailed discussion of the models, the manner in which they were developed, and the results of their application to this project are contained in various reports, technical memoranda and computer tabulations which are referred to in this memorandum and are on file at the Maryland Department of Transportation and the Regional Planning Council.

## SHORT-TERM EFFECTS

Between 1970 and 1980, it is forecast that total trips in the metropolitan study area will increase by a factor of approximately 1.28, from 3.6 to 4.6 million, regardless of the highway plan implemented. In this same period, vehicle-miles of travel will increase by a factor of approximately 1.46, from 17.8 to approximately 26 million per day, while transit travel decreases from 10.6 percent of all trips to 9.5 percent of all trips while increasing in absolute numbers.

The result of these changes will be a slight decrease in the overall level of highway services, even with implementation of the 3-A and GDP segments (Alternative 3) in the 1980 system. Average door-to-door travel time will increase from 19 minutes in 1970 to 20 minutes in 1980. The percentage of peak period highway trips experiencing congestion where travel time delays exceed 25 percent of a traveler's travel time will increase from 19 to 25 percent. Accessibility to places of work, however, will be improved

slightly in the peak period if the highway construction program is implemented, with mean travel time dropping from 29 to 28 minutes.

LONG-TERM EFFECTS

By 1995, the various alternative highway systems result in significant differences in regional growth and, hence, in regional travel demand. Total daily trips, regardless of mode, would reach 6.04 million in 1995, given the GDP systems, including the 3-A system, a growth of 168 percent from 1970. For either of the systems considered having only partial improvements, total trips reach 5.8 million, while the no-build option results in only 5.5 million trips; thus, tripmaking varies by almost 10 percent between alternatives.

Vehicle miles of travel (VMT), a measure of road usage, influencing pollutant generation and energy consumption, exhibits a wider variation, ranging from 34.1 million daily miles given the full system--a growth of 191 percent from 1970--to 32.8 million without the 3-A system, 30.2 with only the 3-A system, and 28.6 million for the no-build alternative. Thus, the no-build would result in 16 percent less vehicular travel than the full system.

The variation in freeway mileage among the 1995 alternatives is even greater than the VMT variation, ranging from 296 miles for the full system to 171 miles for the no-build, a variation of 42 percent. The net result is that mean trip speed varies significantly. In the full system, on a 24-hour basis, the mean speed is 25.1 mph; eliminating the 3-A routes drops the mean speed to 23.9 mph; inclusion of the 3-A without the other improvements would result in mean speeds of 18.0 mph; while the no-build is the slowest at 17.3 mph. Overall speeds for the peak period are slower, from 21.4 mph for the full system to 14.9 mph for the no-build option in 1995.

Transit travel is a function of both the highway system and the general distribution of residential and employment opportunities. Thus, while the full highway system would result in 657,000 daily transit trips, the no-build highway alternative would yield fewer patrons, only 653,000, primarily due to fewer people and jobs in the transit-competitive area. Construction of mainly suburban roads (Alternative 7) reduces downtown travel so that only 615,000 transit trips would be handled, while the emphasis on the 3-A system (Alternative 8) focuses travel downtown so that 690,000 daily transit trips are forecast.

Variations in the 1995 services provided by the highway system arise both from the scope of the system and the resulting distribution of population and employment.

By 1995, with the full system (Alternative 6), mean highway peak-period travel time will reach the 1970 level of 19 minutes even though trips will be over a mile longer on the average. Without the 3-A highway system, the mean time will be slightly greater at 20 minutes while the no-build alternative would result in a mean highway trip time of 23 minutes. More significantly, the percentage of highway trips experiencing congestion delays of 25 percent or more of a traveler's travel time would drop from the 1970 value of 19 percent to 17 percent for Alternative 6, while with the no-build alternative 46 percent of peak trips would experience this level of congestion.

In spite of the more compact development resulting from the no-build option, peak travel times to jobs are increased to congestion. In 1970, the mean time to a job opportunity was 29 minutes in the peak period. With the full system, this would hold almost constant at 28 minutes, while it would increase to 36 minutes with the no-build alternative. Similar trends are evident for the individual jurisdictions.

In general, it may be said that travel conditions will hold nearly constant or deteriorate slightly by 1980, depending on the alternative. By 1995, with the construction of the entire 3-A system, highway travel conditions will be somewhat better than in 1970, while the no-build option would result in much higher levels of congestion than presently found.

Implementation of the full rail system will greatly increase the attractiveness of transit over current transit. The decision on the highway system will have little impact on transit patronage.

Figure II-1 illustrates these areas in the region which experienced congestion in 1970. Figures II-2 and II-3 illustrate 1995 areas of congestion given the full 3-A and GDP plan and the no-build alternative, respectively. The impact of no construction in terms of areawide traffic congestion is clear.

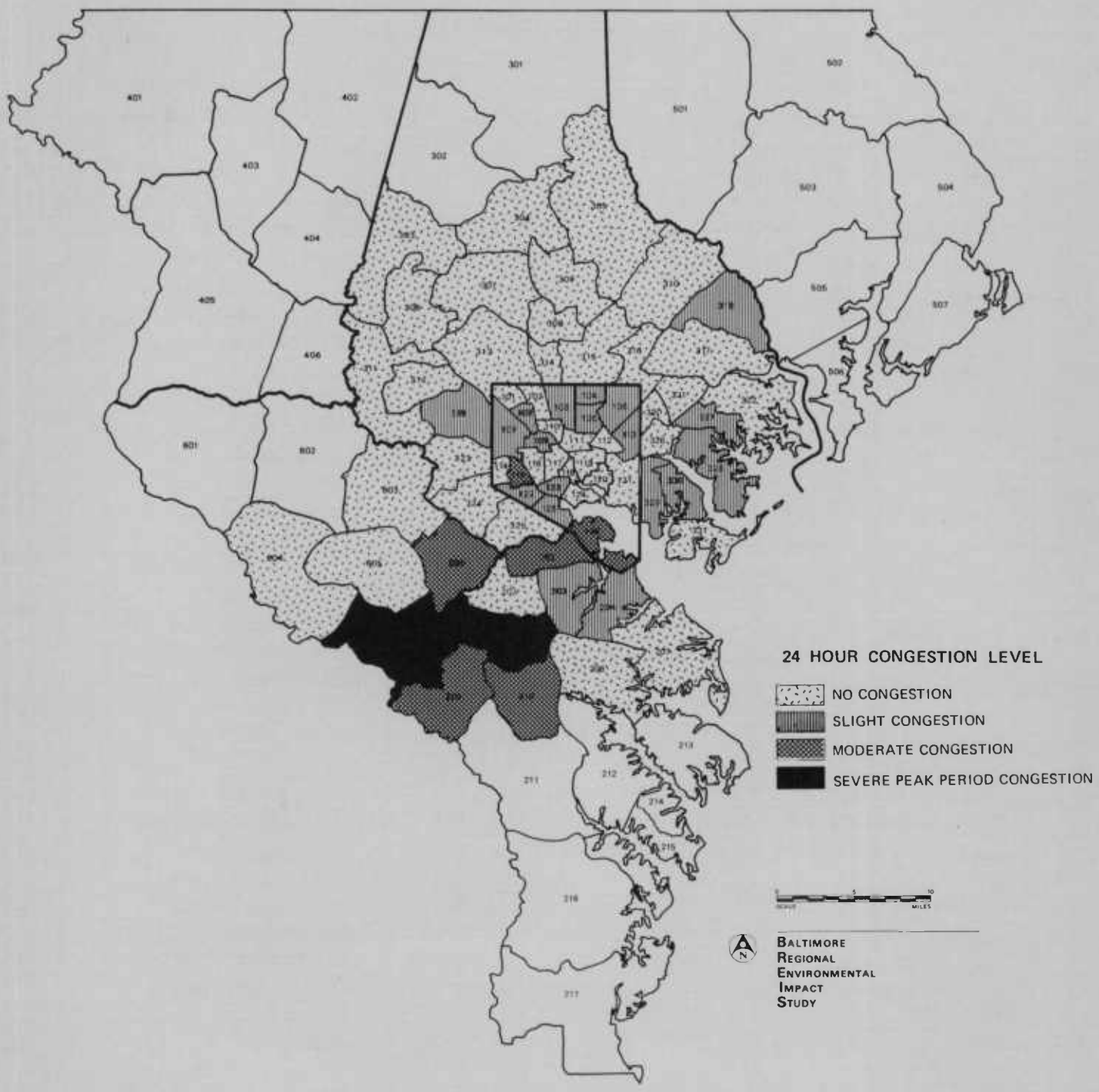



FIGURE II–1
1970 ALTERNATIVE 1
TRAFFIC CONGESTION LEVELS

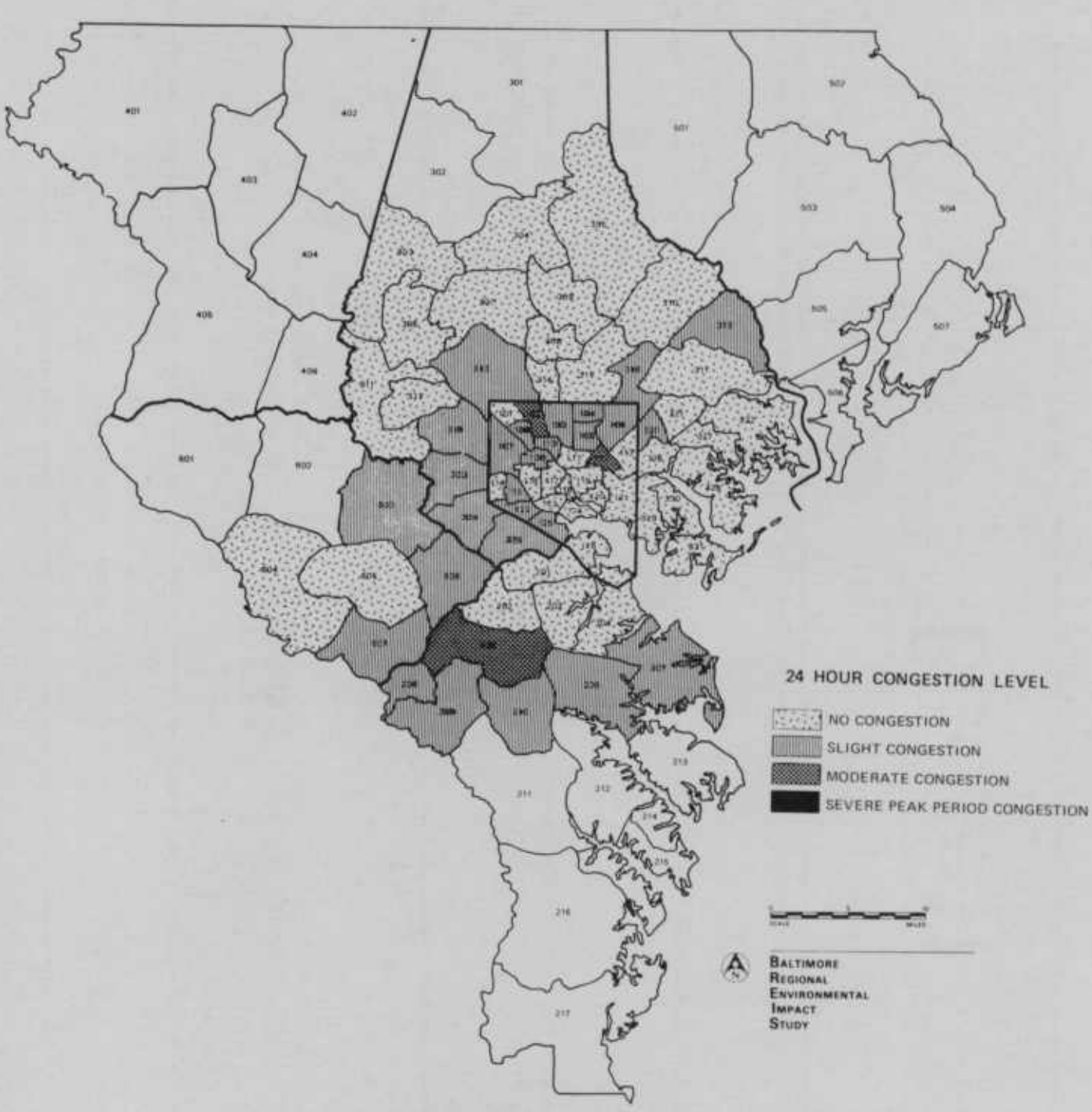



FIGURE II–2
1995 ALTERNATIVE 6
TRAFFIC CONGESTION LEVELS

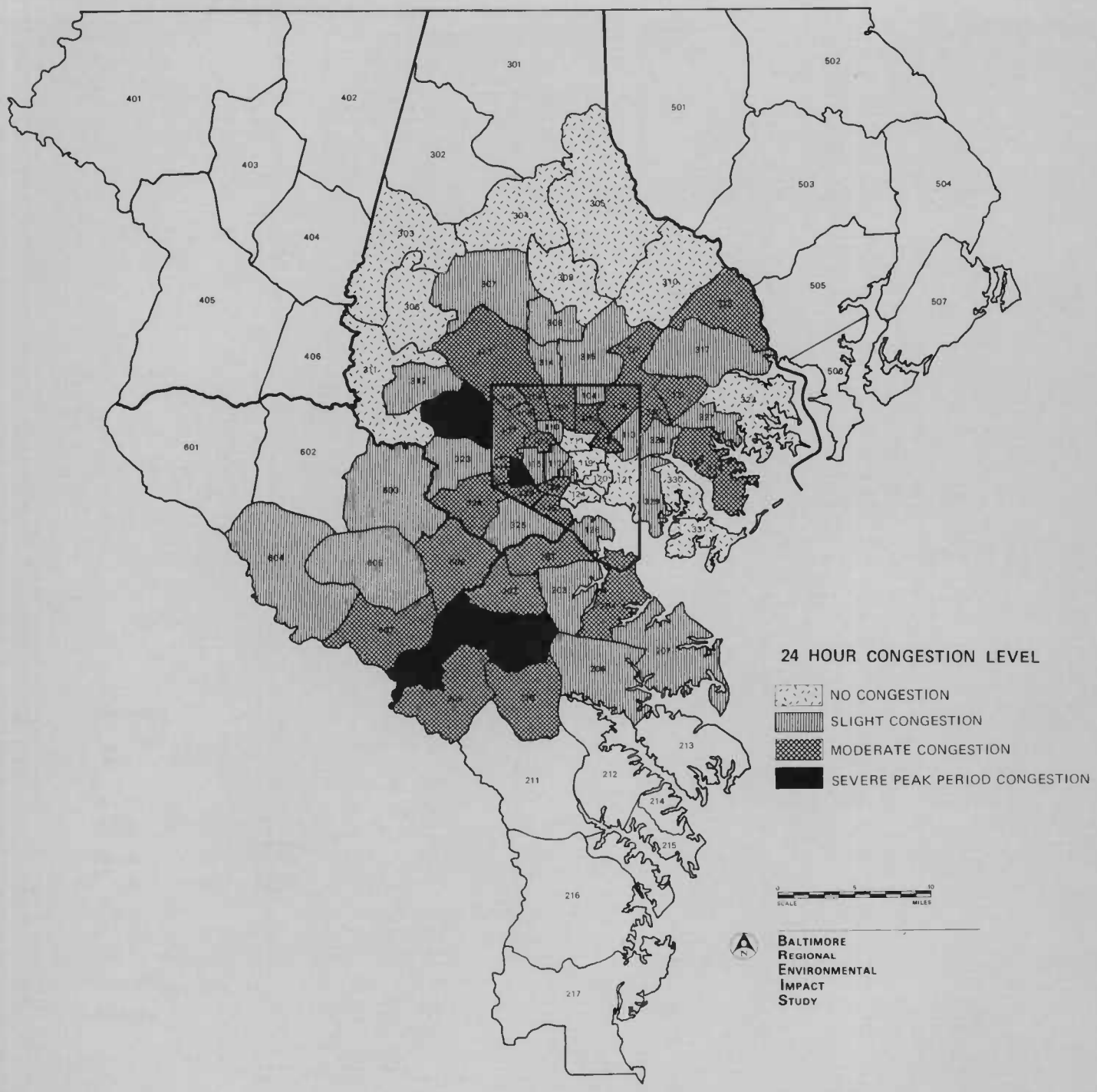



FIGURE II–3
1995 ALTERNATIVE 9
TRAFFIC CONGESTION LEVELS

# III. INTRODUCTION TO TRAVEL FORECASTING

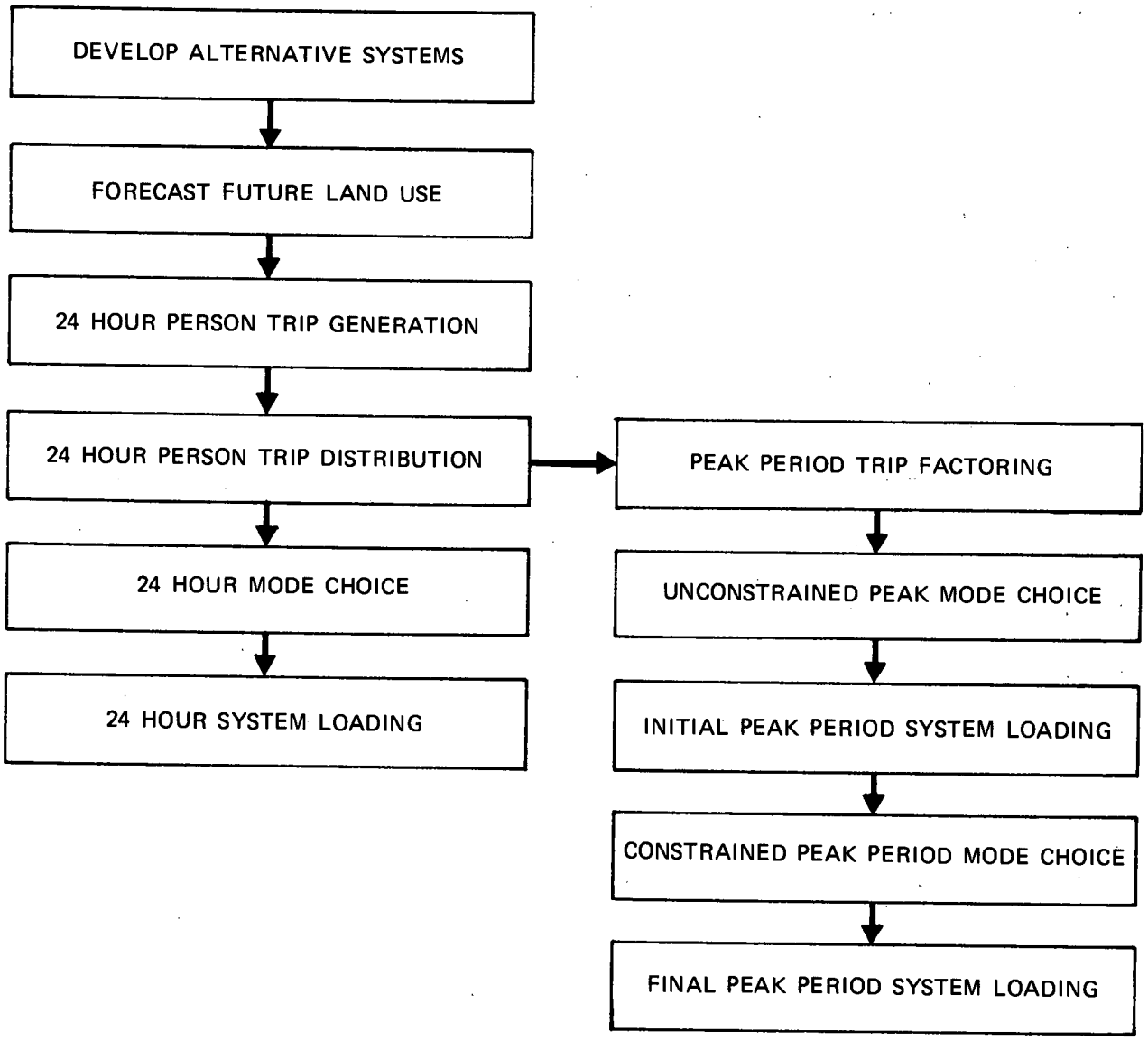
The purpose of this technical memorandum is to describe the simulation of travel on eight alternative transportation systems for the Baltimore region. These simulations were undertaken to enable an evaluation of transportation system performance and to provide important inputs to the determination of the environmental impacts described in other technical memoranda. This memorandum presents the techniques used in these simulations and the systemwide results concerned with system performance and level of service.

Section I contains a description of the eight alternative highway systems which were devised jointly by the agencies involved. Each of the highway systems was assumed to have a transit system as part of the alternative. For 1970, this was the then existing bus lines run by the MTA and five private operators. For the three 1980 alternatives, a unified transit system under MTA operation with radial rail rapid transit in two corridors (Phase I Rapid Transit) was assumed. The four 1995 alternatives contained a much expanded transit system with a 6-legged rapid transit system providing most of the line-haul service.

The simulation techniques were developed by the 3-C process as part of the UTPP over the course of the last seven years. The basic steps in simulating each alternative are shown in Figure III-1. The trip generation phase requires as input the land use and population distributions from an urban development model (USM). The trip generation output consists of an estimate of the number of trips by purpose which are to begin and end in each traffic zone during the typical 24-hour weekday. The trip distribution, also done on a 24-hour basis, links up the beginning and ending of all trips for each purpose. The next step in the 24-hour simulations is to determine the choice of mode of these travelers (i.e., auto driver, auto passenger, or transit passenger), and finally, all the vehicle trips are assigned to the highway system to determine the estimated flows on the road network. For five of these systems, transit assignments were performed on a 24-hour basis to determine ridership on the bus and rapid transit lines.

An important aspect of the travel simulations was the special attention given to rush hour traffic. After the trip distribution, a technique developed by the 3-C Process was used to determine the origins and destinations of all trips in the peak 2-hour period of the afternoon rush. A separate

FIGURE III–1
TRAVEL SIMULATION APPROACH



mode choice technique sensitive to peak travel conditions was used. A "capacity restraint" technique was used to estimate the flows on all roads of the highway system, as well as the true travel times under the degree of congestion exhibited by the simulations. These "constrained" highway travel times were used in a second iteration of the peak mode choice determinations prior to a final assignment of vehicles to the highway system. Each of the techniques just mentioned is described in detail in Section IV, along with an evaluation of the forecasts provided by each step of the process.

Section V is devoted to further, more detailed evaluation of the eight alternatives. Critical areas within the region are analyzed, and areas of future congestion are pinpointed. The final portion of Section V contains an evaluation of the highway and transit service to the residents of each jurisdiction for selected alternatives. An important aspect of these evaluations is the focus on the individual tripmaker and his complete trip, door to door.

# IV. GENERAL APPROACH AND SYSTEM SUMMARIES

Detailed simulations of travel on present and future highway systems were necessary to determine the extent to which future environmental conditions were related to changes in the highway system. Alternative systems, including a no-build option, were devised jointly by the agencies involved. The simulations and succeeding evaluations were directed toward analyzing the regional environmental consequences of the alternative systems and their various components.

Full scale simulations were carried out on eight alternative highway systems (one for 1970, three for 1980, and four for 1995), using travel models previously developed for the Baltimore region. The 1970 simulation served to estimate base year environmental conditions and as a check on the validity of the simulation models. Various technical reports dealing with the development and use of these models are available from the Maryland Department of Transportation and the Regional Planning Council. (1) The sequence application of these models is illustrated in Figure III-1. This section describes these models and the systemwide results achieved for each of the eight alternatives.

## ASSUMPTIONS

Several basic assumptions relating to the supply of transport services and user response to the costs of obtaining service underlie the travel simulation and analysis carried out in this project. Among the more critical assumptions are:

- Total travel demand is invariant with system supply. The total number of person trips is a function of social and economic characteristics which vary by alternative only and does not vary either with the amount of highway or transit system available or with the cost of travel.

- The relative costs of using transit as compared to highway travel will be approximately stable.

- No restrictions, such as gasoline rationing or limitation of parking supply, will be imposed.

- Traveler response to such factors as travel time and travel cost will remain constant over the 25-year forecasting period.

- By 1980, 28 miles of the Phase I rapid transit system with a coordinated bus system will be in operation.

- By 1995, the full six-corridor rapid transit system with a coordinated bus system will be in operation.

Less critical assumptions reflected in the travel models and network simulation are:

- Highway travel costs, in 1970 constant dollars, will be perceived at about 5 cents a mile.

- Basic transit fares will be 30 cents in 1980 and 1995.

- Parking cost will be a function of demand measured in employees per gross acre.

- The 60 cent toll will be continued on the harbor tunnel, and similar tolls will be imposed on any new harbor crossings.

- The standard 40-hour, 5-day work week will be maintained.

NETWORK DEVELOPMENT

Figures IV-1 through IV-8 illustrate the eight highway systems assumed for this analysis. The system alternatives are numbered 1 through 9. Number 2, which was to represent 1978 conditions, was deleted early in the study. The three parts of each alternative are: the 3-A Interstate System, other highways, and transit. Each element will be discussed in turn for each alternative. Highways will be described in terms of their functional class as well as whether they are new or improved. Summary statistics are presented in Table IV-1, and the systems are described briefly below.

Transportation Network Preparation

Alternative 1 -- Existing System, 1970

This alternative provides the base year information for the analysis of the seven future year alternatives being evaluated. Although the study is being done in 1973, the base year selected was 1970; hence, all maps reflect the roads that existed as of that year.

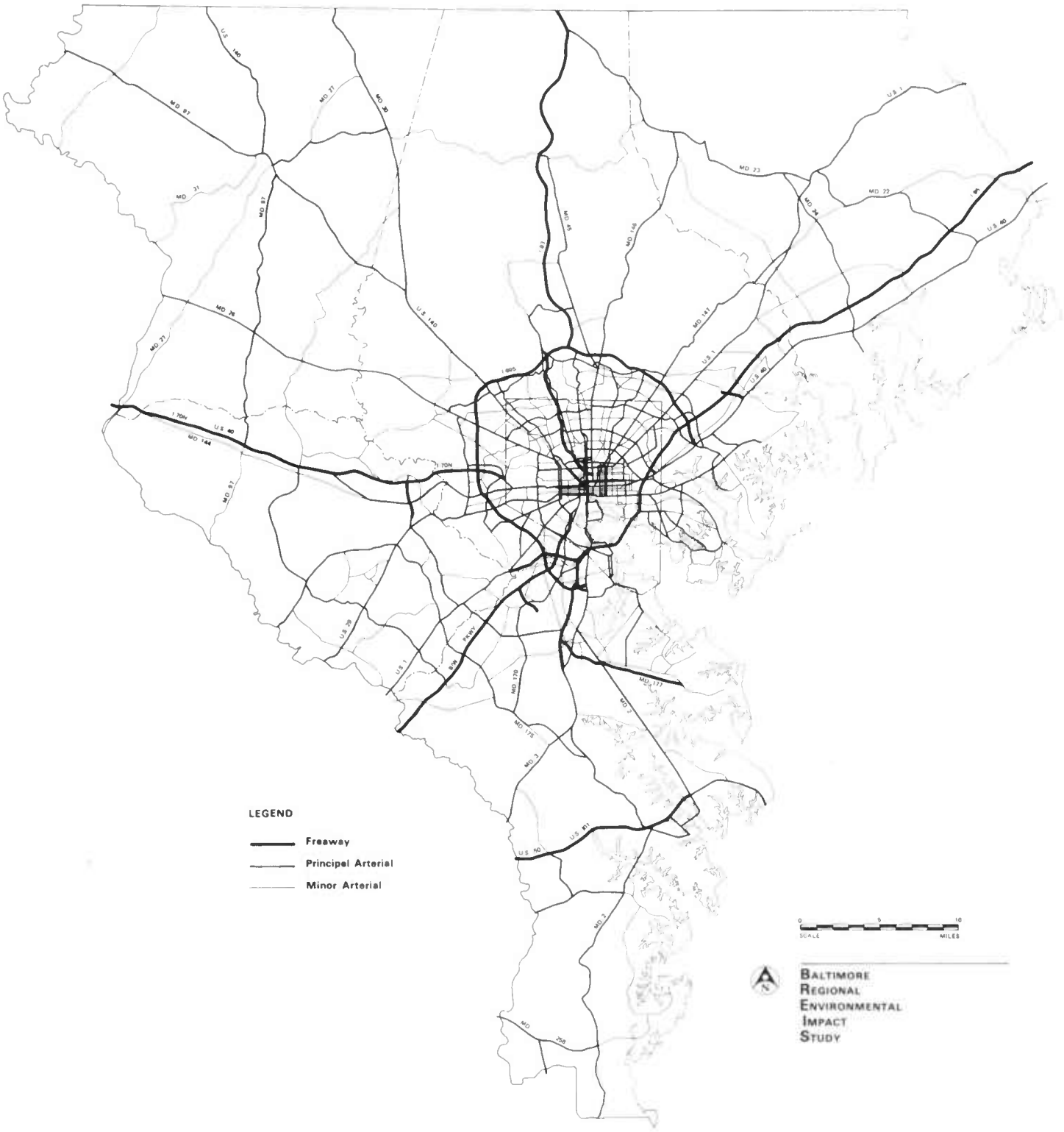



FIGURE IV–1
1970 FUNCTIONAL CLASSIFICATION OF HIGHWAYS

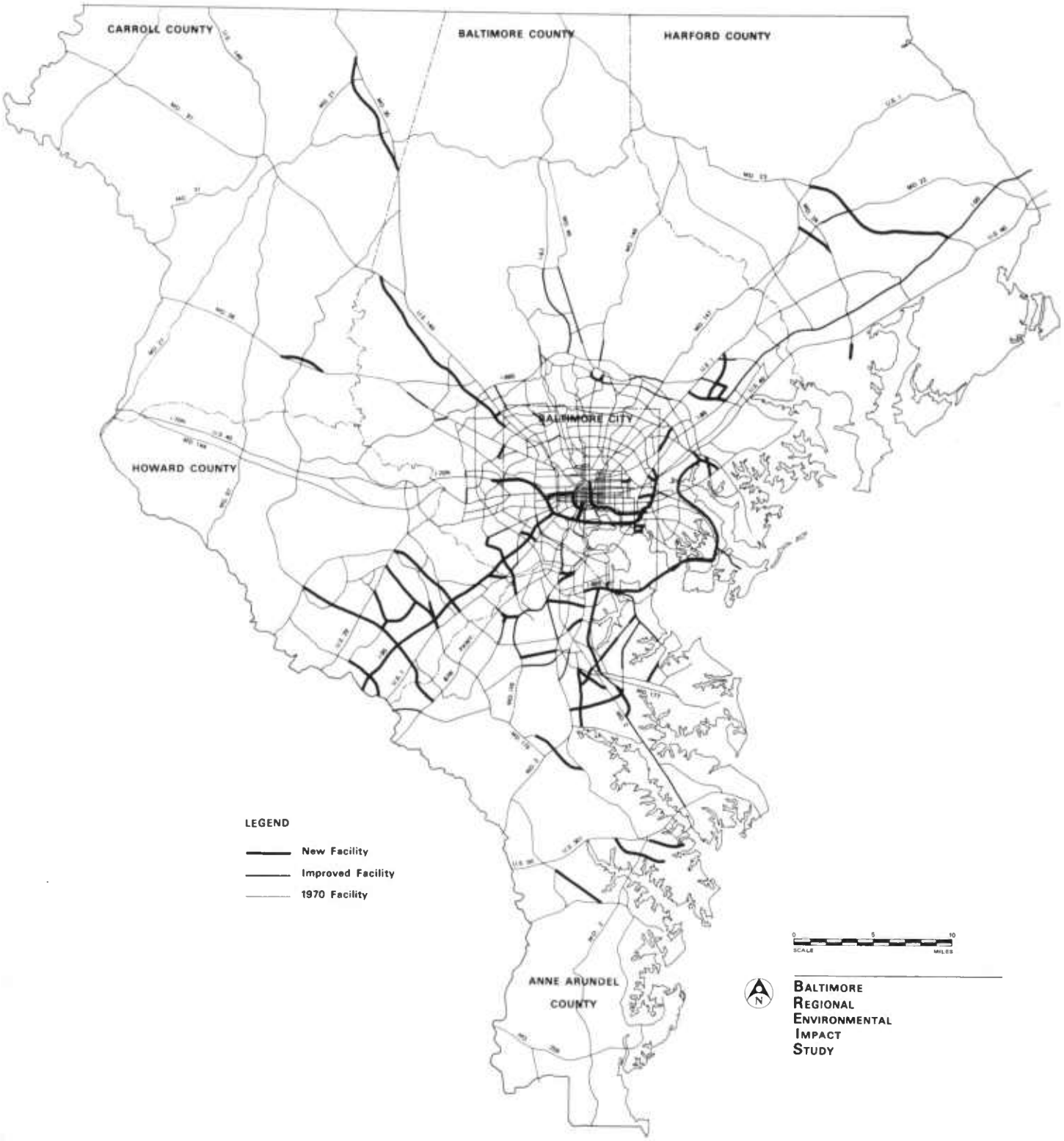
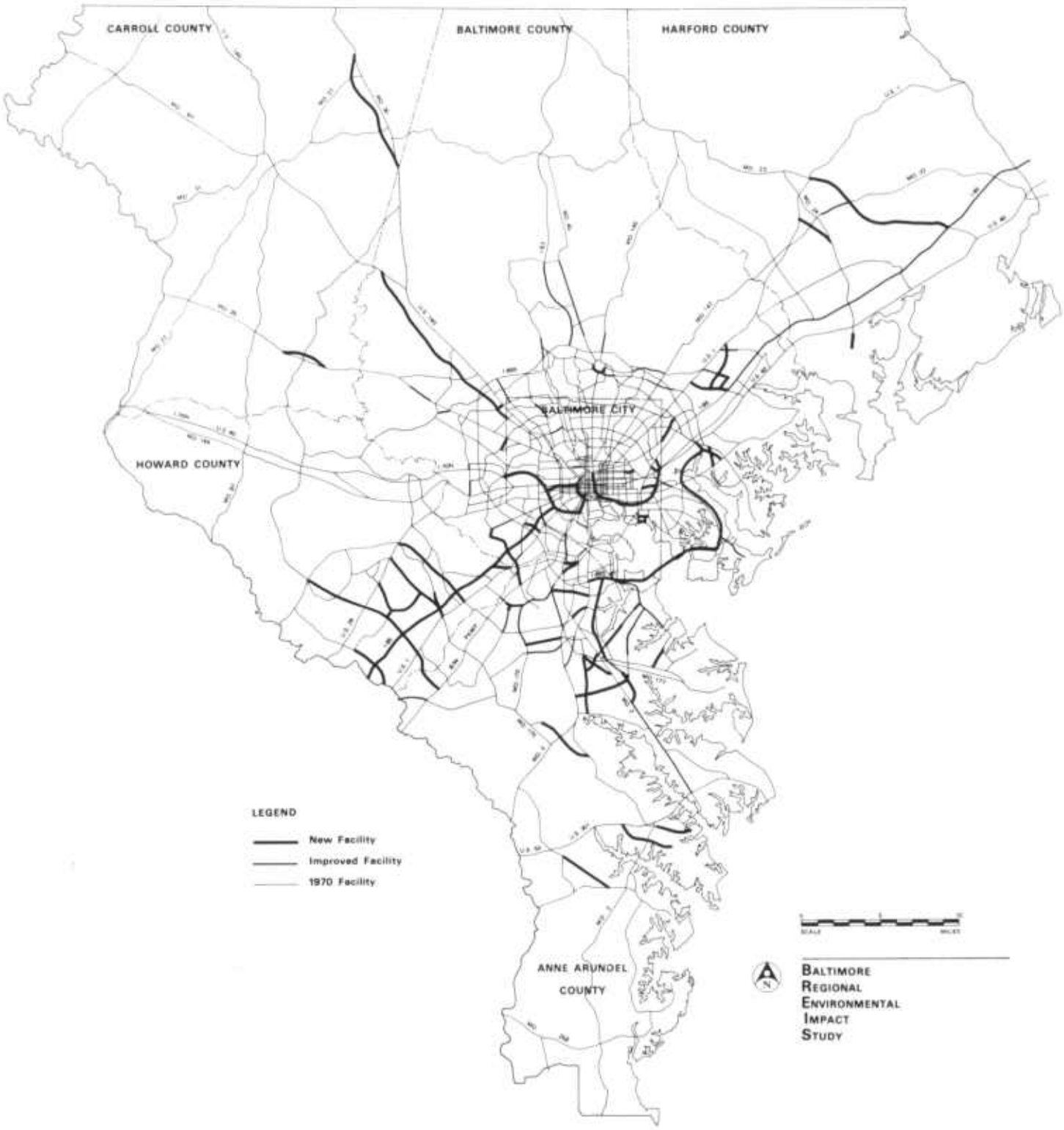



FIGURE IV–2
1980–ALTERNATIVE 3
FUNCTIONAL CLASSIFICATION OF HIGHWAYS

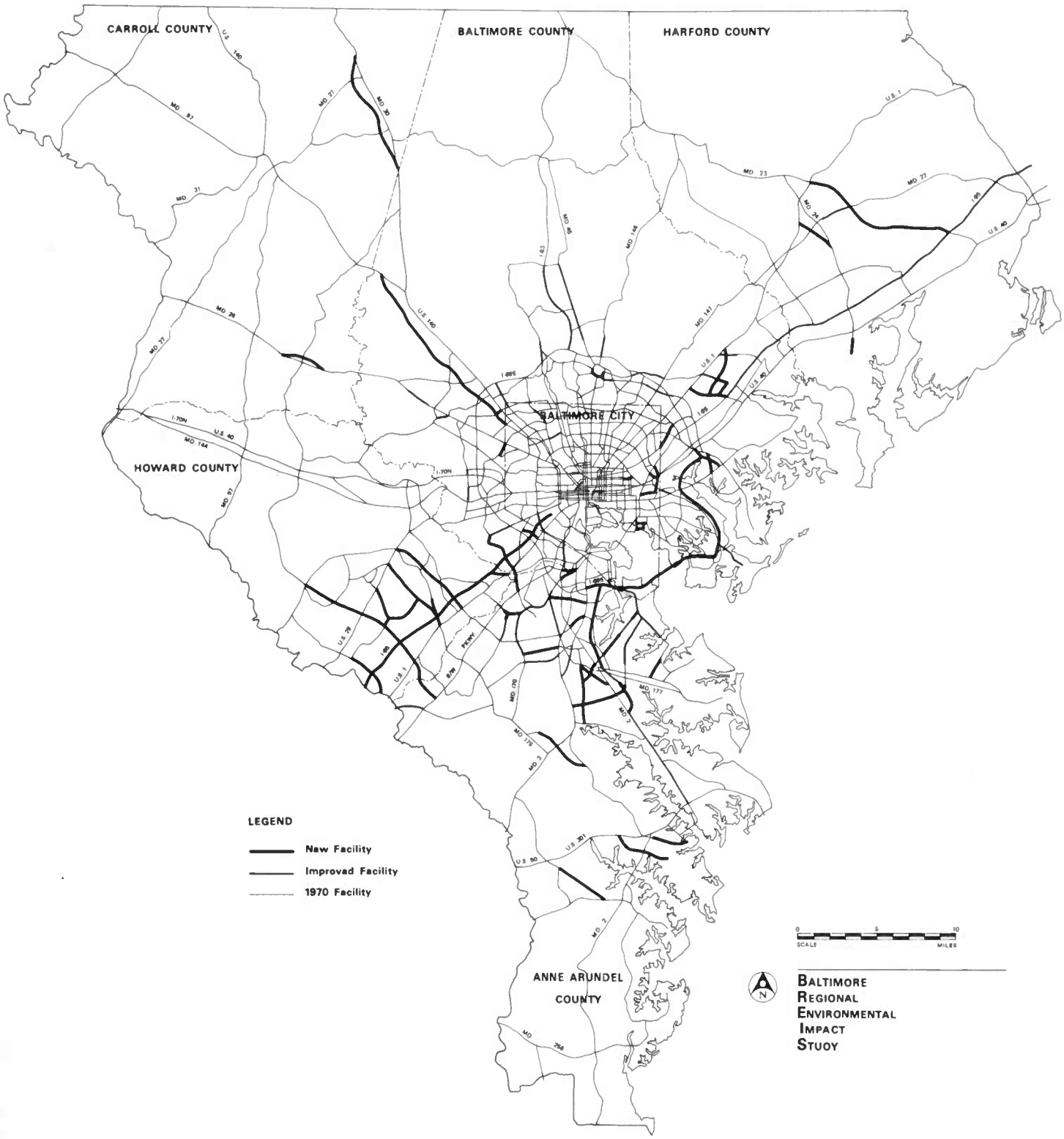
(Complete 3–A System, All Other
Existing And Programmed Highways)




This map does not include the Phase I Rapid Transit System

FIGURE IV–3
1980 ALTERNATIVE–4
FUNCTIONAL CLASSIFICATION OF HIGHWAYS

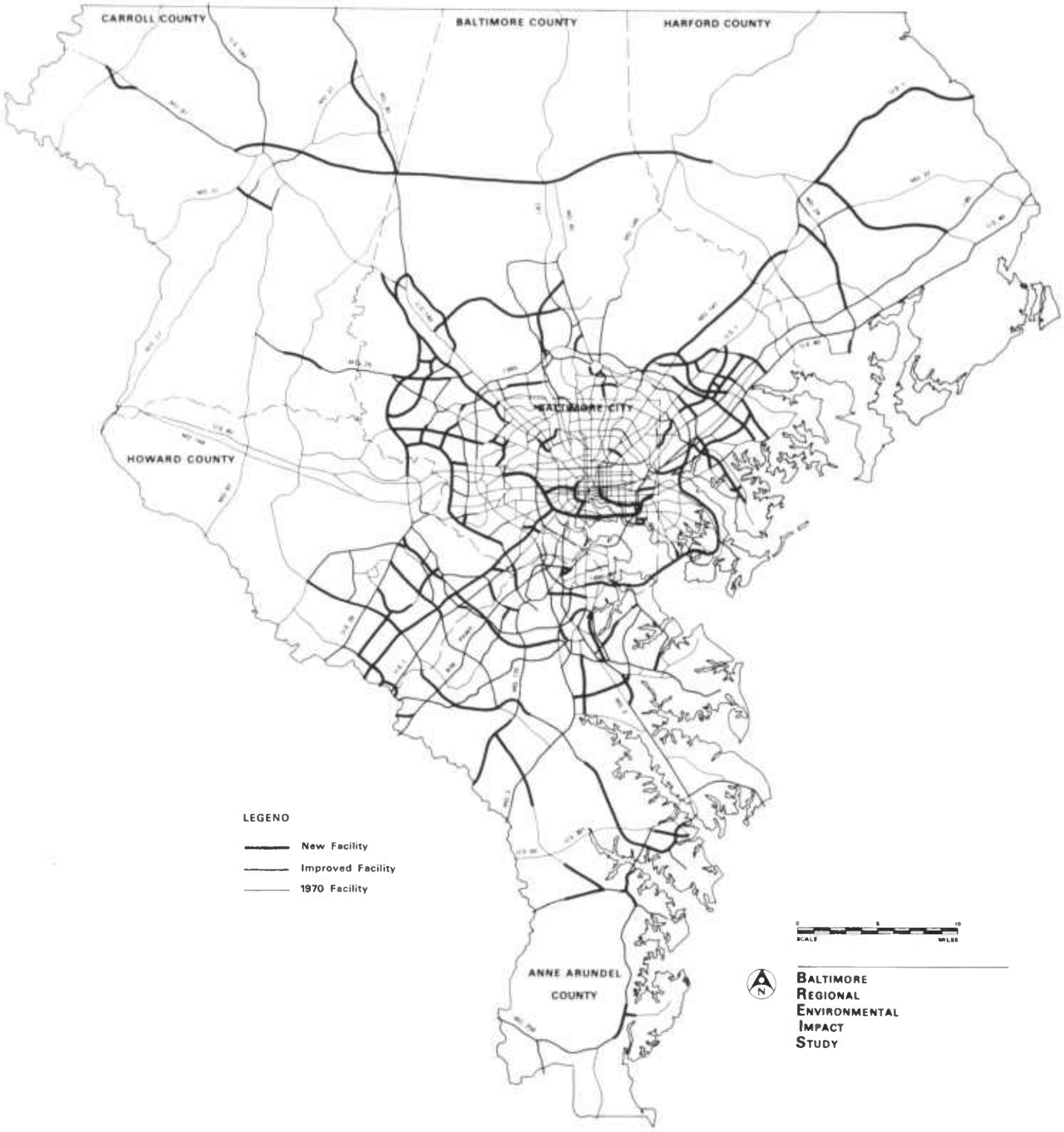
(3–A System Less Ft. McHenry Crossing; All Other Existing And Programmed Highways)




This map does not include the Phase I Rapid Transit System

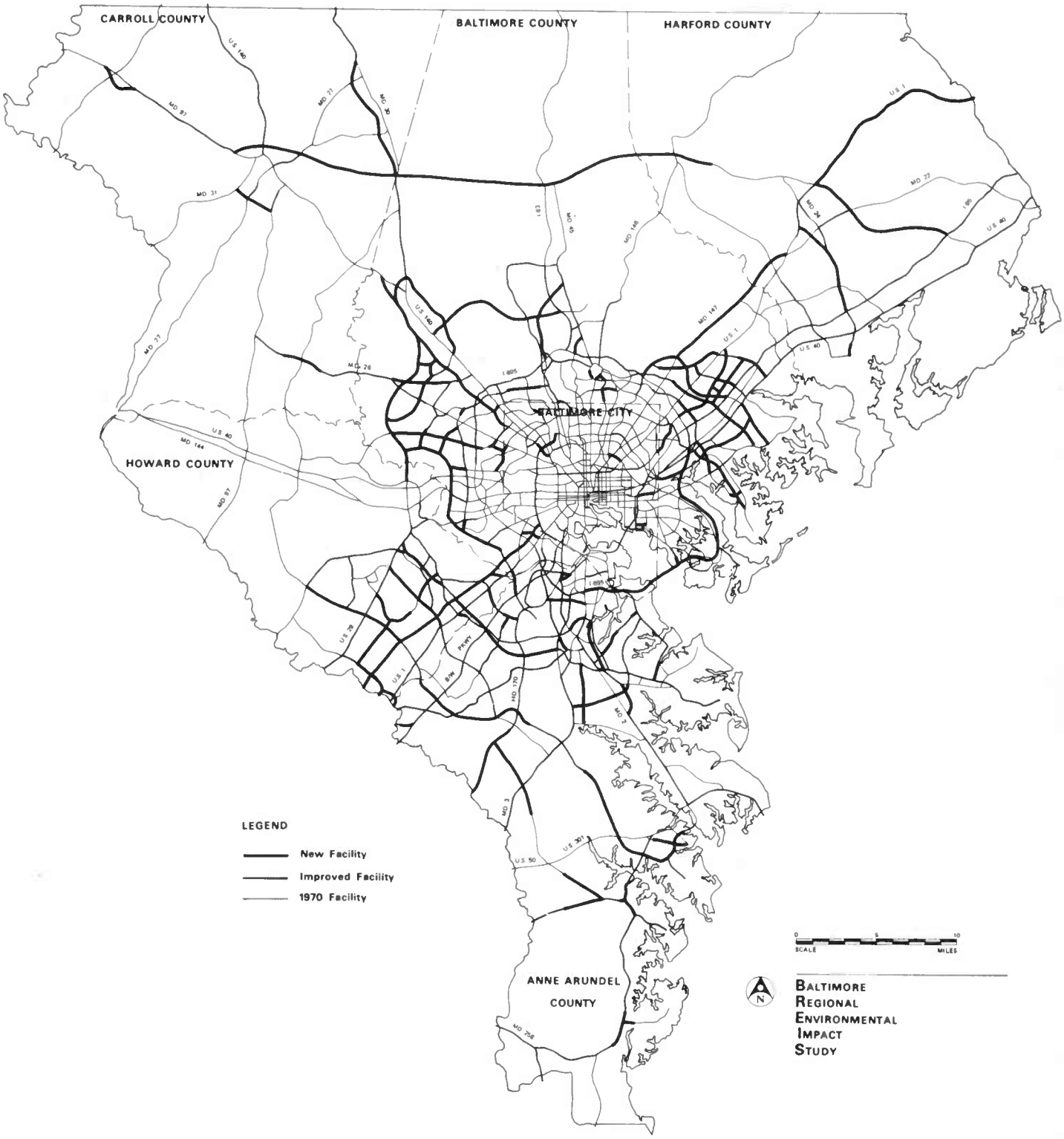
**FIGURE IV–4**
**1980–ALTERNATIVE 5**
**FUNCTIONAL CLASSIFICATION OF HIGHWAYS**

**(No 3–A System; All Other Existing And Programmed Highways)**




This map does not include the GDP Rapid Transit System

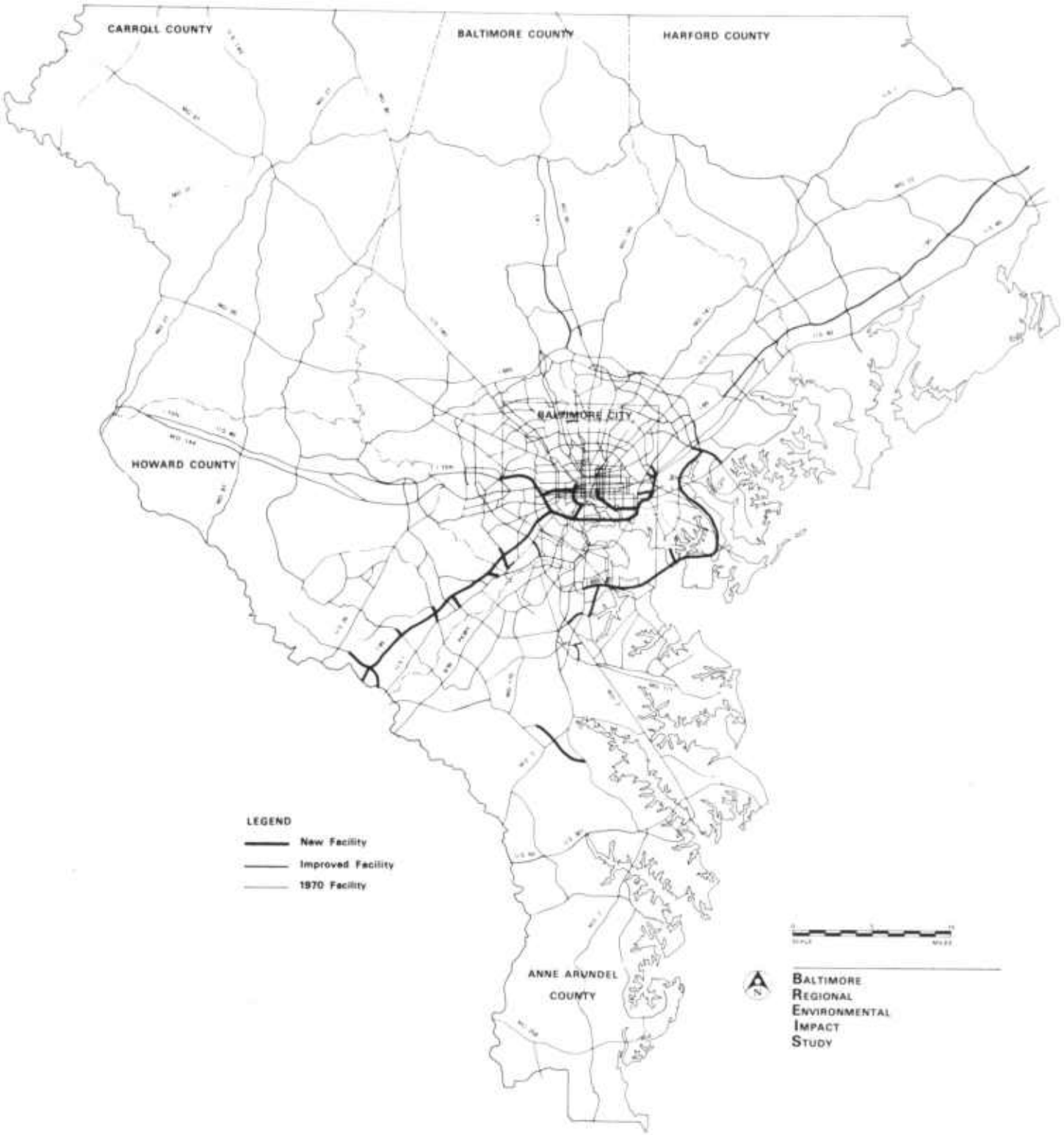
FIGURE IV–5
1995–ALTERNATIVE 6
FUNCTIONAL CLASSIFICATION OF HIGHWAYS
(Complete 3–A System; All GDP Highways)




This map does not include the GDP Rapid Transit System

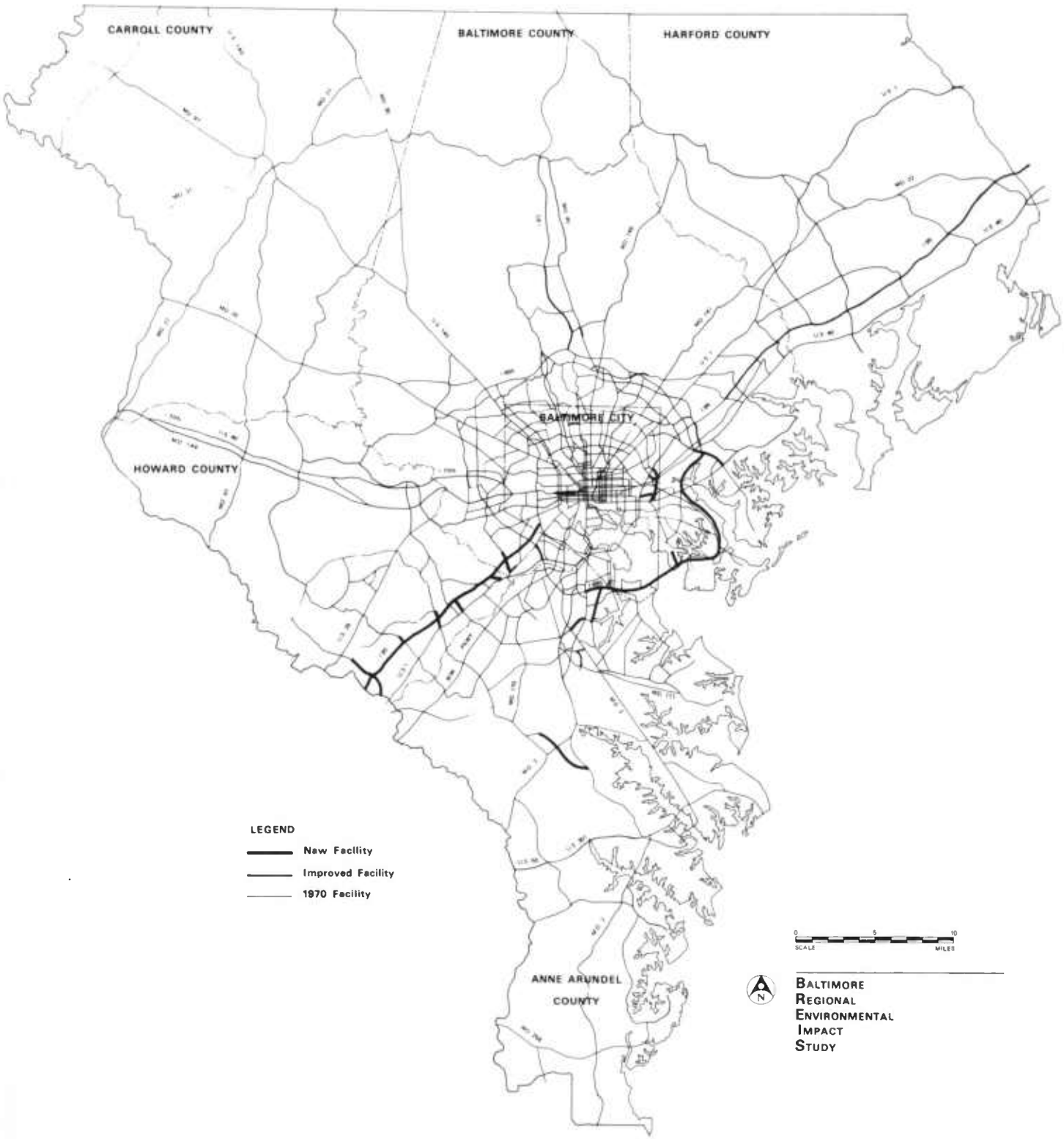
**FIGURE IV–6**
**1995–ALTERNATIVE 7**
**FUNCTIONAL CLASSIFICATION OF HIGHWAYS**

**(No 3–A System; All Other GDP Highways)**




This map does not include the GDP Rapid Transit System

**FIGURE IV–7**
**1995–ALTERNATIVE 8**
**FUNCTIONAL CLASSIFICATION OF HIGHWAYS**
**(Complete 3–A System; Other Highways Existing And Under Construction)**




This map does not include the GDP Rapid Transit System

**FIGURE IV–8**
**1995–ALTERNATIVE 9**
**FUNCTIONAL CLASSIFICATION OF HIGHWAYS**
**(No 3–A System; Other Highways Existing And Under Construction)**

Table IV-1

TRANSPORT SYSTEM SUMMARY STATISTICS

| Year | Transportation Alternative | Center-Line Miles/Highway Miles | | | |
|---|---|---|---|---|---|
| | | Freeway | Arterial | Other | Total |
| 1970 | 1 | 129 | 842 | 363 | 1,334 |
| 1980 | 2 | 233 | 860 | 425 | 1,518 |
| 1980 | 3 | 230 | 860 | 421 | 1,511 |
| 1980 | 4 | 214 | 858 | 412 | 1,484 |
| 1995 | 5 | 296 | 911 | 473 | 1,680 |
| 1995 | 6 | 276 | 908 | 459 | 1,643 |
| 1995 | 7 | 191 | 849 | 388 | 1,428 |
| 1995 | 8 | 171 | 846 | 372 | 1,389 |

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P.M. PEAK 2-HOUR TRANSIT VEHICLE-MILES

| | Bus | Rail | Total | Rail Route Miles |
|---|---|---|---|---|
| 1970 Transit | 15,920 | 0 | 15,920 | 0 |
| 1980 | 18,824 | 3,240 | 22,064 | 27.6 |
| 1995 | 23,803 | 8,370 | 32,173 | 74.7 |

In 1970, the only part of the proposed 3-A system that had been built was that part of I-83 (freeway) that began at the northern boundary of the city and continued to Eager Street in the CBD. Four other important freeways in the region run outward from Route I-695, (the Baltimore Beltway), I-95, I-83, I-70N, and the Baltimore-Washington Parkway. Additionally, the Harbor Tunnel Freeway connects I-95 on the north with I-695 on the south. A notable link missing in the 1970 freeway system is the southern extension of I-95. This was completed in 1972 and is included on other alternatives. The bus system in existence in 1970 was assumed in this alternative.

Alternative 3 -- Complete 3-A

The 1980 system is composed of the completed 3-A system, other existing and programmed highways, and Phase I of the rapid transit system. The 3-A system is composed of 16 segments that form a loop around the inner city that connects I-70N, I-95, and I-83. All segments are functionally classified as freeways except the Boulevard, which is a principal arterial.

A schematic description of the route taken by 3-A would read as follows: I-70N enters the City on the west, traverses Leakin Park and splits into two branches at Baltimore Street, the northern branch (I-170) following Franklin Street until it reaches the boulevard and the southern branch (I-70N) linking up with I-95 as it crosses the southern part of the City and the Patapsco River. I-95 joins I-83, which has entered the City from the north, around the area of Ponca Street.

The remaining part of the area's highway network is assumed to have a fair amount of new construction and upgrading between 1970 and 1980 as proposed in Capital Improvement Program of agencies in the region. The southern portion of I-95 is completed, as is the final segment of the Md. 695 (Baltimore Beltway) the Outer Bridge Crossing. The Northwest Freeway, which runs parallel to existing U.S 140, was also assumed to be operational. Widening improvements will occur on the JFK Expressway (I-95) which runs parallel to U.S.40 north of Baltimore.

Alternative 4 -- 3-A Without Fort McHenry Crossing, 1980

This alternative is similar to Alternative 3, except that the proposed system does not include the Fort McHenry crossing. This part of

the system is composed of four segments that link I-95 on the south with I-95 on the east. The total segment extends from Charles Street to Holabird Avenue.

Alternative 5 -- Existing Plus Committed Facilities Only, 1980

This is the null alternative for the 1980 series of systems tests. It differs from the previous alternative in that it does not include any elements of the 3-A system except construction of a segment in the Franklin-Mulberry Corridor from Pulaski to Pine Street (under construction). As in Alternatives 3 and 4, all other existing and programmed highways are assumed, as well as the Phase I rapid transit system.

Alternative 6 -- Complete 3-A and GDP Improvements, 1995

Alternative 6 represents the full system as described in the General Development Plan (GDP). It is composed of the complete 3-A system, as described in Alternative 3, plus improvements on other highways as recommended in the GDP as well as Phases I and II of the rapid transit system.

As the 3-A system has already been described in detail, the major differences in Alternative 6 are found in the other regional highways and the expanded transit system. Major highway improvements include widening the JFK Expressway, U.S.40, I-83 north of the Beltway, and a segment of the Beltway between Maryland 3 and U.S.1. Within the city limits, Hilton Street has been assumed to be widened for a major part of its length. By 1995, improvements are assumed to have taken place on most of the major roads that link into the Beltway. This includes U.S.29, U.S.1, the Baltimore-Washington Expressway, Md. 3, the Arundel Freeway, and parts of Liberty Road. The segment of road leading to the Harbor Tunnel from Windlass will also be widened.

New facilities are included: the Perring Freeway, which is north of and parallel to the JFK Expressway; the Northwest Freeway; and the Outer Harbor Crossing that links into the beltway. The four 1995 alternatives contain the complete 6-legged rail rapid transit system described below.

Alternative 7 -- GDP Improvements Without the 3-A System, 1995

The components of this alternative closely resemble those of Alternative 6 and include all GDP improvements for highways in the region, with the exception of the 3-A system. Alternative 7 contains only the Franklin-Mulberry Corridor segment of the 3-A. The Phase II GDP regional rapid transit system is assumed.

Alternative 8 -- Complete 3-A System, No Other Facilities, 1995

This alternative assumes construction of the complete 3-A system as described, as well as the complete GDP regional rapid transit. It differs from the other 1995 alternatives in that the remaining highways in the region are assumed to consist only of highways already in existence in 1970 plus those that were already under construction.

Alternative 9 -- Existing Plus Committed Facilities Only, 1995

This is the null for the group of alternatives being tested for 1995. It assumes that none of the 3-A system, except the Franklin-Mulberry Corridor, will be built. It also assumes that the regional highway system will include only that which existed at the time of the study (1973) as well as that which is presently under construction. The transit element for this alternative is the same as for all the other 1995 alternatives; that is, both Phase I and Phase II of the system have been assumed.

Basic descriptions of each network were prepared by the staff of the 3-C Process of the Unified Transportation Planning Process (UTPP). Each network was then coded for computer simulation and checked with the 3-C staff for accuracy and reasonableness of travel paths.

Initial travel speeds and road capacities were based on the type of facility (freeway, arterial, etc.), the area type (CBD, outlying, rural, etc.) and adjacent land use (commercial, residential, etc.). Travel speeds were modified during traffic assignment based upon the number of vehicles desiring to use each link in the network.

Transit Network Preparation

The transit systems assumed for these simulations are as follows:

| | |
|---|---|
| 1970 | The existing services as provided by the MTA and five suburban operators included with the latter's "closed-door" operations within the city. |
| 1980 | A unified transit system consisting of the Phase I approved rail rapid lines to Marley and Owings Mills and coordinated bus operators. Several bus routes are assumed to be extended from existing terminal points; Columbia is linked to downtown Baltimore via MTA express bus routes on I-70N and I-95. |
| 1995 | The 6-legged rapid transit network in the latest transit study, T9-6, was used. (2) The four Phase II rapid transit legs use tentative alignments with terminals at Sparrows Point and Essex, Timonium, Belair Road and Joppa Road, and Metropolitan Boulevard west of the Social Security Administration Center. |

The future year transit systems also contain expanded crosstown bus service and extensive feeder bus routes to rail stations. A map of the rail systems is shown in Figure IV-9 . The fare systems assumed for the tests are described in a separate memorandum. (3)

The 1970 transit system was coded using data obtained from the MTA and MDOT. The 1980 network was developed after discussions with MTA concerning policies for unification of the suburban operations and likely additions in service between 1973 and 1980. The 1995 transit network was that used in MTA/RPC studies, modified to be compatible with the system of 498 traffic analysis zones. Line frequencies and routings were not modified.

PERSON TRIP GENERATION

The person trips produced and attracted in each of the 498 transportation analysis zones were forecast on a 24-hour basis for each alternative, using the trip generation equations developed by AMV in the 1967 transit study, T9-1, and the socioeconomic forecasts presented in Technical Memorandum 1 of this study. (4) Table IV-2 presents the trip generation equations. Since the original formulation treated only external-internal travel, the equations were factored by the following ratios determined from the 1962 O-D survey to account for internal-external travel.

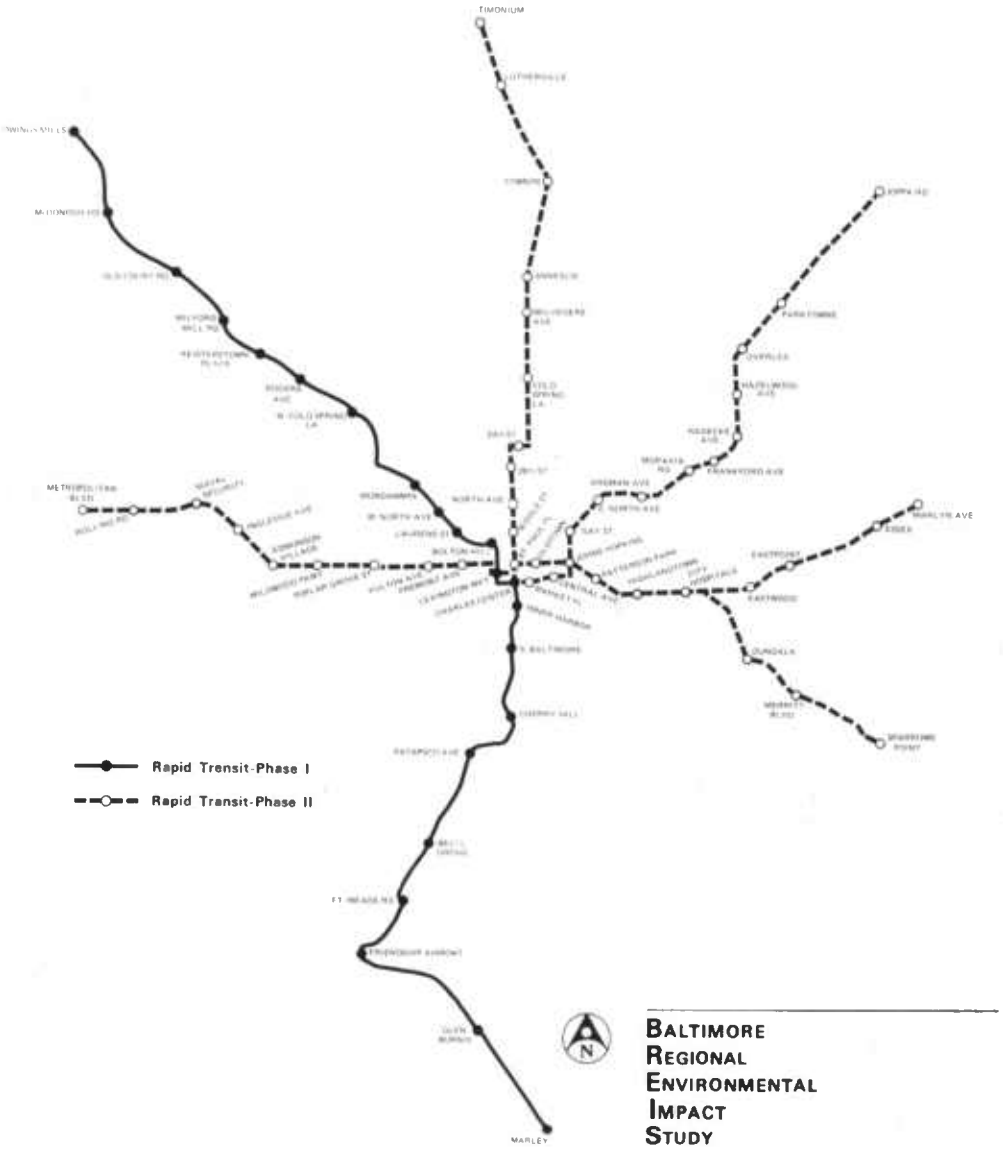


FIGURE IV–9
ASSUMED RAPID TRANSIT LINES AND STATIONS

Table IV-2

TRIP GENERATION EQUATIONS[1/]

Home-Based Work Productions = -34.8 + 1.51 (Labor Force)
Home-Based Work Attractions = -13.7 + 1.60 (Total Employment)

Home-Based Shop Productions = -33.9 + 0.79 (Automobiles)

Home-Based Shop Attractions[2/] = 102.9 + 2.45 (Retail Employment)
-43.4 (Service Employment)

Home-Based Shop Attractions[3/] = 710.15 + 8.30 (Retail Employment)

Home-Based Social/Recreation Productions = -26.4 + 0.788 (Automobile)

Home-Based Social/Recreation Attractions[4/] = 51.5 + 0.702 (Retail, Service, and Public Employment) + 0.0148 (Population) (Logarithm of Income)[7/]

Home-Based Social/Recreation Attractions[5/] = -44.5 + 0.225 (Retail, Service and Public Employment) + 0.012 (Population) (Logarithm of Income)[7/]

Home-Based Personal Business Productions = 8.0 + 0.527 (Automobiles)

Home-Based Personal Business Attractions[4/] = 3.06 + 0.554 (Retail, Service, and Public Employment) + .896 (Population)

Home-Based Personal Business Attractions[5/] = -75.0 + 0.416 (Retail, Service, and Public Employment) + 0.534 (Population)

Home-Based School Productions = 18.5 + 0.374 (Automobiles) + 5.00 (Resident Students/Residential Density)
Home-Based School Attractions = 65.0 + 0.46 (Non-college students) + 2.48 (Attendant students/Residential Density)

Non-Home Based Trip Ends[6/] = 9.97 + 0.48 (Population) + 0.80 (Retail Employment) + 0.169 (Public Employment) + 0.385 (Service Employment)

1/ For Internal - Internal Trips

2/ For zones with no formal shopping centers

3/ For zones with a formal shopping center

4/ For low density zones (less than 50 people per residential acre and less than 90 employees per gross acre)

5/ For high density zones ( more than 50 people per acre or more than 90 employees per gross acre)

6/ Same equation used for attractions and productions. Equation predicts auto driver trip ends.

7/ All logarithms are natural logarithms

| | |
|---|---|
| Home-Based Work | 1.03 |
| Home-Based Shop | 1.05 |
| Home-Based Social/Recreation | 1.05 |
| Home-Based School | 1.01 |
| Home-Based Personal Business | 1.05 |
| Non-Home-Based | 1.05 |
| Light Trucks | 1.06 |
| Heavy Trucks | 1.06 |

Following application of the models for 1970 travel data, it was determined, based on a review of the 1962 travel survey accuracy check, that further adjustment was required to the non-work, non-school trips. These adjustments were to factor internal home-based other trips by 1.21 and internal non-home-based trips by 1.61.

The independent variables for each forecasting equation were obtained from the socioeconomic forecasts described in Technical Memorandum 1. It should be noted that all the equations for forecasting home-based travel generation include travel by all vehicular modes (person trips) while the non home-based equation is for auto driver trips only.

The results of the internal trip generation model for each alternative are presented in Table IV-3. Since independent equations were used to estimate productions and attractions, the production and attraction forecasts do not match. In each case, trip productions at the residential trip end were used as control totals. Although the non-home-based trip generation equation forecasts auto driver trips, the person trip figures for non-home based trips shown are those obtained after application of the mode choice models.

External trip ends (trips crossing the cordon line) were estimated by two methods. Trip ends at external stations for trips with the other end in an internal zone were forecast based on the estimate of work travel crossing the cordon line developed by the Urban Systems Model (USM) used for socioeconomic activity allocation. (5) For each alternative system, the ratio of work trip crossings estimated by the USM to the 1970 estimated work trip crossings was computed. This factor was applied directly to external station work trip ends. For non-work trip ends, the computed factor was multiplied by 1.3 to account for the relatively faster growth of non-work travel. The total number of these trips for each system is shown near the bottom of Table IV-3.

Table IV-3

PERSON TRIP GENERATION RESULTS

24-Hour Trip Productions(P) and Attractions (A) (x 1000)

| PURPOSE: | | Alternative 1970 | 1980 | | | 1995 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Home-Based Work | P | 1,133 | 1,280 | 1,276 | 1,259 | 1,601 | 1,534 | 1,554 | 1,482 |
| | A | 1,317 | 1,497 | 1,495 | 1,488 | 1,885 | 1,824 | 1,857 | 1,781 |
| Home-Based School | P | 189 | 250 | 250 | 248 | 309 | 297 | 312 | 300 |
| | A | 182 | 188 | 223 | 182 | 237 | 228 | 228 | 220 |
| Home-Based Shop | P | 564 | 823 | 822 | 819 | 1,097 | 1,051 | 1,058 | 1,011 |
| | A | 736 | 839 | 842 | 851 | 1,036 | 1,055 | 988 | 972 |
| Home-Based Soc/Rec | P | 567 | 827 | 825 | 822 | 1,099 | 1,053 | 1,060 | 1,014 |
| | A | 619 | 730 | 729 | 730 | 950 | 907 | 904 | 883 |
| Home-Based Per/Bus | P | 395 | 569 | 568 | 566 | 751 | 720 | 725 | 694 |
| | A | 442 | 549 | 547 | 547 | 707 | 673 | 677 | 659 |
| TOTAL Home-Based Other | P | 1,526 | 2,219 | 2,215 | 2,207 | 2,947 | 2,824 | 2,843 | 2,719 |
| | A | 1,797 | 2,118 | 2,118 | 2,128 | 2,693 | 2,635 | 2,569 | 2,514 |
| Non Home-Based (Total Trip Ends) | | 596 | 664 | 663 | 660 | 848 | 827 | 824 | 789 |
| TOTAL Internal Person Trips | P | 3,444 | 4,413 | 4,404 | 4,374 | 5,705 | 5,482 | 5,533 | 5,290 |
| | A | 3,892 | 4,467 | 4,499 | 4,458 | 5,663 | 5,514 | 5,478 | 5,304 |
| TOTAL Through Person Trips | P | 146 | 233 | 236 | 237 | 339 | 335 | 227 | 224 |
| TOTAL Person Trip Productions | | 3,590 | 4,650 | 4,640 | 4,611 | 6,044 | 5,817 | 5,760 | 5,514 |

The second external trip estimates were for through trips which pass through the study area without stopping. These trips, substratified as auto drivers, light trucks, and heavy trucks, were estimated for future years using the Fratar growth factor technique. The growth factors were obtained by studying projected population growth rates in radial corridors of approximately 300 miles focused on Baltimore. It is from within this area that the majority of through trips originate. The population forecast data were obtained from the Office of Business Economics of the U.S. Department of Commerce. Through trips are summarized along with truck trips in Table IV-4.

For 1980, the trip production estimates differ little by system, reflecting the similarity in population size and the inertia of current development trends. For 1995, however, the trip production estimates vary according to the growth in population, which was in turn forecast on the basis of the accessibility provided by the highway alternatives. Accordingly, the complete 3-A system with the full planned network (Alternative 6), having the greatest amount of improvement, generates over 6 million daily person trips with at least one end in the study area. The no-build alternative (Alternative 9) is forecast to handle just over 5.5 million such trips.

The projected growth in personal travel from 1970 to 1980 is 30 percent if the 3-A improvements are completed on schedule (Alternative 3). Without the 3-A system, the growth to 1980 would be slightly less at 28 percent (Alternative 5). To 1995, the growth in person trips ranges between 54 percent (Alternative 9) and 68 percent (Alternative 6). It must be recognized, of course, that population growths from 1990 to 1995 are also quite dependent on the alternative, being 33 percent for Alternative 9 and 44 percent for Alternative 6. See Technical Memorandum 1, page II-3.

The growth by purpose of travel should also be noted. In 1970, work trips accounted for 33 percent of the internal person trip productions. These percentages are expected to fall to 29 and 28 in 1980 and 1995, respectively, regardless of the alternative within the year. The relatively faster growth for non-work trips is due to higher incomes and higher automobile ownership.

Through trips are constant for every alternative in a given year, reflecting their insensitivity to activity within the study area. (See Table IV-4.)

TRIP DISTRIBUTION

Using the Gravity Model, trips were distributed for eight purposes. Friction factors were previously developed as part of the 3-C Process, along with

Table IV-4

THRU AND TRUCK TRIP GENERATION RESULTS

24-Hour Vehicle Trip Productions (x1000)

| | Alternative | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1970 | 1980 | | | 1995 | | | |
| | 1 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| LIGHT TRUCKS | | | | | | | | |
| Internal | 382 | 428 | 427 | 424 | 514 | 497 | 499 | 481 |
| External-Internal | 2 | 11 | 11 | 11 | 15 | 15 | 10 | 10 |
| Thru | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 |
| TOTAL | 386 | 441 | 440 | 437 | 532 | 515 | 512 | 494 |
| HEAVY TRUCKS | | | | | | | | |
| Internal | 27 | 29 | 29 | 29 | 34 | 33 | 34 | 33 |
| External-Internal | 5 | 7 | 7 | 7 | 9 | 9 | 6 | 6 |
| Thru | 5 | 5 | 5 | 5 | 7 | 7 | 7 | 7 |
| TOTAL | 37 | 41 | 41 | 41 | 50 | 49 | 47 | 46 |
| TOTAL TRUCKS | 423 | 482 | 481 | 478 | 582 | 564 | 559 | 540 |
| THRU AUTO DRIVERS | 47 | 54 | 54 | 54 | 66 | 66 | 66 | 66 |
| TOTAL THRU TRIPS | 54 | 61 | 61 | 61 | 76 | 76 | 76 | 76 |

a set of socioeconomic adjustment factors. (6) The principal results for each of the eight trip purposes are presented in Table IV-5. The distributed trips include internal trips, internal-external trips, and external-internal trips.

With the exception of work and truck trips, uncongested mean travel times do not change appreciably. Work trips are estimated to increase in length by approximately one-half minute in 1980 and by about one minute by 1995. Truck trip length increases are more substantial, depending on the alternative and the classification.

The through trip distribution for 1980 and 1995 was obtained by factoring the 1970 through trip distribution with factors based on activity outside BMATS.

TWENTY-FOUR HOUR MODE CHOICE

Two models, one for the total day and the other for the peak period, for forecasting the allocation of travel among competing modes are used in the Baltimore planning process. Both models were developed from data collected in the 1962 origin-destination survey. (7)

The 24-hour mode choice model consists of six equations developed by regression analysis. For each of the three home-based purposes (work, school, and other), there is one set of equations to forecast the percent of person trips made by transit and another set to forecast the percent of automobile person trips made as either a passenger or as a driver. These equations are presented in Table IV-6.

No explicit forecast is made for non-home-based transit travel. Rather, it is assumed to be uniformly 4 percent of the total home-based transit travel. An auto occupancy factor of 1.30 computed from 1962 survey data was used to obtain non-home-based highway trips.

The mode choice results for the alternatives are presented in Table IV-7. Between 1970 and 1980, transit travel is forecast to increase by 16 percent if the 3-A system is built (Alternative 3). Without the 3-A (Alternative 5), population growth and, hence, transit growth would be less. The first phase of the rapid transit system is mainly responsible for the transit patronage growth. It should be noted that in 1980 a greater proportion of the region's population will reside in the suburbs, so that on a regional basis the transit mode choice is lower.

Table IV-5

TRIP DISTRIBUTION RESULTS

| PURPOSE: | | Alternative | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1970 | 1980 | | | 1995 | | | |
| | | 1 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Work: | T.D.[1/] | 1,183.0 | 1,342.0 | 1,338.0 | 1,321.0 | 1,690.0 | 1,622.0 | 1,613.0 | 1,540.0 |
| | INTRA[2/] | 17.2 | 19.0 | 19.0 | 19.5 | 26.8 | 27.6 | 28.4 | 28.5 |
| | M.T.L.[3/] | 20.2 | 20.6 | 20.6 | 20.7 | 21.3 | 21.4 | 20.8 | 20.9 |
| School: | T.D. | 191.0 | 254.0 | 253.0 | 252.0 | 313.0 | 302.0 | 315.0 | 302.0 |
| | INTRA | 13.0 | 20.3 | 18.0 | 20.3 | 25.5 | 24.9 | 26.8 | 25.9 |
| | M.T.L. | 12.6 | 12.7 | 13.1 | 12.7 | 13.4 | 13.5 | 12.8 | 12.8 |
| Shop: | T.D. | 578.0 | 842.0 | 841.0 | 838.0 | 1,123.0 | 1,078.0 | 1,075.0 | 1,028.0 |
| | INTRA | 31.1 | 62.5 | 62.6 | 63.5 | 99.2 | 94.4 | 95.0 | 89.5 |
| | M.T.L. | 12.7 | 13.1 | 13.0 | 13.0 | 13.5 | 13.6 | 13.1 | 13.2 |
| Soc/Rec: | T.D. | 596.0 | 864.0 | 863.0 | 860.0 | 1,153.0 | 1,106.0 | 1,097.0 | 1,050.0 |
| | INTRA | 25.4 | 46.8 | 46.9 | 47.6 | 74.2 | 74.9 | 74.8 | 72.1 |
| | M.T.L. | 16.6 | 17.0 | 17.0 | 17.0 | 17.6 | 17.5 | 16.9 | 16.9 |
| Per/Bus: | T.D. | 482.0 | 684.0 | 683.0 | 681.0 | 919.0 | 883.0 | 837.0 | 840.0 |
| | INTRA | 45.4 | 77.2 | 77.2 | 78.3 | 112.2 | 112.0 | 110.9 | 107.1 |
| | M.T.L. | 17.0 | 17.5 | 17.5 | 17.5 | 17.9 | 17.8 | 16.8 | 16.9 |
| N.H.B.:[4/] | T.D. | 442.0 | 498.0 | 497.0 | 495.0 | 633.0 | 618.0 | 613.0 | 588.0 |
| | INTRA | 8.7 | 33.3 | 33.4 | 34.5 | 47.9 | 49.0 | 47.3 | 47.1 |
| | M.T.L. | 14.0 | 14.2 | 14.2 | 14.2 | 14.2 | 14.6 | 14.4 | 14.4 |
| Light Trucks: | T.D. | 384.0 | 439.0 | 438.0 | 435.0 | 529.0 | 512.0 | 509.0 | 491.0 |
| | INTRA | 77.4 | 92.1 | 92.0 | 92.6 | 120.4 | 117.3 | 115.8 | 113.1 |
| | M.T.L. | 11.6 | 12.5 | 12.5 | 12.5 | 13.3 | 13.4 | 12.6 | 12.7 |
| Heavy Trucks: | T.D. | 32.0 | 36.0 | 36.0 | 36.0 | 43.0 | 42.0 | 41.0 | 39.0 |
| | INTRA | 1.3 | 1.3 | 1.3 | 1.3 | 1.4 | 1.4 | 1.6 | 1.6 |
| | M.T.L. | 22.6 | 24.9 | 24.9 | 25.1 | 25.9 | 26.1 | 25.4 | 25.7 |

1/ T.D. is Trips Distributed (x1000), included Internal-Internal, Internal-External, and External-Internal 24-hour person trips

2/ INTRA is Intrazonal Trips (x1000)

3/ M.T.L. is Mean Trip Length (in minutes)

4/ Based on Auto Drivers only

Table IV-6

24-HOUR MODE CHOICE EQUATIONS

Home-Based Work

Percent Transit = 307.5

| | |
|---|---|
| -0.323 | (Excess Time Difference) |
| -0.152 | (Running Time Difference) |
| -0.168 | (Cost Difference) |
| +4.15 | (Logarithm of Employment Density) |
| -33.62 | (Logarithm of Income) |
| -0.6 | (Income Adjustment Factor) |

Percent Auto Passenger = 4.73

| | |
|---|---|
| +0.229 | (Transit Excess Time) |
| +3.22 | (Logarithm of Residential Density) |
| +2.06 | (Logarithm of Employment Density) |

Home-Based Other

Percent Transit = 249.0

| | |
|---|---|
| -0.022 | (Total Time Difference) |
| -0.099 | (Cost Difference) |
| +9.38 | (Logarithm of Employment Density) |
| -29.6 | (Logarithm of Income) |

Percent Auto Passenger = 30.6

| | |
|---|---|
| +0.078 | (Transit Excess Time) |
| +0.056 | (Highway Distance) |
| -0.023 | (Employment Density) |
| +0.874 | (Logarithm of Residential Density) |

Home-Based School

Percent Transit = 457.3

| | |
|---|---|
| -0.362 | (Total Time Difference) |
| -0.237 | (Cost Difference) |
| -46.73 | (Logarithm of Income) |
| +2.27 | (Logarithm of Employment Density) |

Percent Auto Passenger = -235.44

| | |
|---|---|
| +.622 | (Transit Excess Time) |
| -1.04 | (Highway Running Time) |
| +34.69 | (Logarithm of Income) |
| -8.22 | (Logarithm of Employment Density) |

Notes:

1. Logarithms are natural logarithms
2. Difference barameters are in terms of transit value minus highway value.
3. Income is average zonal income
4. Income Adjustment Factor = 0 for Income $\leq$ 8000

   $= \frac{\text{Income} - 8000}{1000}$ for Income > 8000
5. Multiply school transit trips by 1.15 if home end is in Baltimore City; multiply by 0.547 if home end is not in Baltimore City.

Table IV -7

24-HOUR MODE CHOICE RESULTS[1/]

| | | TRIPS BY MODE | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Alternative | | | | | | | |
| | | 1970 | 1980 | | | 1995 | | | |
| PURPOSE | MODE | 1 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| WORK: | TOTAL (000) | 1,183 | 1,343 | 1,338 | 1,321 | 1,689 | 1,623 | 1,613 | 1,540 |
| | Auto Driver (000) | 752 | 874 | 871 | 865 | 1,082 | 1,048 | 1,007 | 964 |
| | Auto Passenger (000) | 254 | 261 | 260 | 256 | 290 | 278 | 284 | 268 |
| | Transit Passenger (000) | 177 | 208 | 207 | 200 | 317 | 297 | 322 | 308 |
| | Percent Transit | 15.80 | 15.50 | 15.50 | 15.10 | 18.80 | 18.30 | 19.90 | 20.00 |
| | Percent Auto Driver | 63.60 | 65.10 | 65.10 | 65.40 | 64.10 | 64.60 | 62.40 | 62.60 |
| | Auto Occupancy | 1.34 | 1.30 | 1.30 | 1.30 | 1.27 | 1.27 | 1.28 | 1.28 |
| OTHER: | TOTAL (000) | 1,619 | 2,388 | 2,387 | 2,377 | 3,194 | 3,067 | 3,008 | 2,881 |
| | Auto Driver (000) | 920 | 1,397 | 1,395 | 1,393 | 1,863 | 1,794 | 1,752 | 1,676 |
| | Auto Passenger (000) | 603 | 853 | 855 | 852 | 1,129 | 1,086 | 1,036 | 1,001 |
| | Transit Passenger (000) | 96 | 138 | 137 | 132 | 202 | 187 | 221 | 205 |
| | Percent Transit | 6.00 | 5.70 | 5.70 | 5.60 | 6.30 | 6.10 | 7.30 | 7.10 |
| | Percent Auto Driver | 56.80 | 58.50 | 58.40 | 58.60 | 58.30 | 58.50 | 58.20 | 58.20 |
| | Auto Occupancy | 1.65 | 1.61 | 1.61 | 1.61 | 1.61 | 1.61 | 1.59 | 1.60 |
| SCHOOL: | TOTAL (000) | 191 | 253 | 253 | 252 | 313 | 302 | 315 | 303 |
| | Auto Driver (000) | 31 | 44 | 47 | 44 | 48 | 46 | 44 | 42 |
| | Auto Passenger (000) | 74 | 129 | 125 | 129 | 152 | 148 | 149 | 145 |
| | Transit Passenger (000) | 86 | 80 | 81 | 79 | 113 | 108 | 122 | 116 |
| | Percent Transit | 45.20 | 31.70 | 32.00 | 31.40 | 36.10 | 35.70 | 38.60 | 38.20 |
| | Percent Auto Driver | 16.30 | 17.40 | 18.60 | 17.40 | 15.30 | 15.30 | 14.00 | 13.80 |
| | Auto Occupancy | 3.37 | 3.93 | 3.64 | 3.94 | 4.20 | 4.25 | 4.38 | 4.44 |
| NHB: | TOTAL (000) | 596 | 664 | 662 | 659 | 848 | 827 | 823 | 788 |
| | Auto Driver (000) | 442 | 498 | 496 | 495 | 633 | 618 | 613 | 588 |
| | Auto Passenger (000) | 132 | 149 | 149 | 148 | 190 | 185 | 184 | 176 |
| | Transit Passenger (000) | 22 | 17 | 17 | 16 | 25 | 24 | 26 | 25 |
| | Percent Transit | 3.70 | 2.60 | 2.60 | 2.50 | 3.00 | 2.90 | 3.20 | 3.20 |
| | Percent Auto Driver | 74.10 | 75.00 | 75.00 | 75.10 | 74.60 | 74.80 | 74.50 | 74.50 |
| | Auto Occupancy | 1.30 | 1.30 | 1.30 | 1.30 | 1.30 | 1.30 | 1.30 | 1.30 |
| TOTAL AUTO DRIVERS (000) | | 2,145 | 2,812 | 2,809 | 2,797 | 3,626 | 3,506 | 3,416 | 3,269 |
| TOTAL TRANSIT PASSENGERS (000) | | 382 | 443 | 442 | 427 | 657 | 615 | 690 | 653 |
| TOTAL PERSON TRIPS (000) | | 3,590 | 4,650 | 4,640 | 4,611 | 6,044 | 5,817 | 5,760 | 5,514 |
| OVERALL PERCENT TRANSIT | | 10.60 | 9.50 | 9.50 | 9.30 | 10.90 | 10.60 | 12.00 | 11.90 |
| OVERALL AUTO OCCUPANCY | | 1.50 | 1.50 | 1.49 | 1.50 | 1.49 | 1.48 | 1.48 | 1.49 |

1/ Through trips were excluded from modal split analysis.

Transit travel is estimated to grow from 61 to 81 percent between 1970 and 1995, depending on the alternative. Estimates of transit travel are greatest given the complete 3-A with no other facilities (Alternative 8), which has the highest population and employment growth in Baltimore City.

It is estimated that, overall, auto occupancies change little into the future; however, the auto occupancy for work is expected to decline while auto occupancy for school trips should increase. This is a function of the increasing trip length for these purposes.

## TWENTY-FOUR HOUR SYSTEM LOADING

### Highway

Assignments of travel to the highway network for each system were made using a "capacity restraint technique" which included separate loading of automobiles, light duty (2-axle) trucks, and heavy duty trucks. The basic technique of traffic assignment involves finding the fastest route between any two zones in the area and assigning all travel between the two zones to that single route. Capacity restraint assignments reflect the fact that, as the demand on a facility approaches or exceeds capacity, the travel speed decreases and another route becomes faster.

For this analysis, the capacity of a road was taken to be the Level of Service C, as defined in the Highway Capacity Manual. (8) This is the amount of traffic that may be carried without significant delay, although freedom of movement is somewhat restricted. For traffic volumes at less than 80 percent of capacity, speed was assumed constant. Above 80 percent, speed was assumed to decrease linearly to a minimum value of 20 percent of free flow speed at 1.8 times capacity. Thus, a severely overloaded facility would operate at a speed between 5 and 10 mph.

The technique for loading trips on the network assumed that 40 percent of all automobiles and trucks would use the path which was initially the fastest. Travel speeds were then adjusted to account for traffic conditions, and a new "fastest" path was found.

An additional 20 percent of the automobile travel was then assigned to the new paths. This process was repeated until all travel had been assigned to the network. The computed travel speed on each road segment at the end of this process is assumed to be the actual travel speed and is used in all subsequent tabulations.

In addition, for those alternatives including rapid transit, transit travel was analyzed to determine the magnitude and orientation of trips using rapid transit for the major portion of the trip but using auto for access to the transit system (park-ride, kiss-'n-ride). The portion of these trips between home and station were also assigned to the highway system.

Several important statistics from the highway assignments are displayed in Table IV-8. Estimates of vehicle-miles of travel (VMT), as well as the vehicle-hours of travel (VHT), on all link classes are shown by jurisdiction for each alternative. In addition, the ratio of VMT/VHT, which represents the average system speed, has been computed. This ratio may also be construed as the average trip speed, with each trip being weighted by its length in miles. Similar values for the peak period are presented later in this report.

Between 1970 and 1995, the growth in VMT parallels the growth in population and employment but depends upon which alternative highway system is implemented. For the full highway system (Alternative 6), there is estimated a 46 percent growth in population and a 91 percent growth in VMT. For the no-build (Alternative 9), population growth is estimated at 33 percent and VMT growth at 60 percent; the no-build travel speeds, however, is appreciably lower.

In 1970, the ratio of VMT/VHT for Baltimore City (19.7) and the study area portions of Anne Arundel County (19.4) are appreciably lower than in Baltimore County (27.1) and Howard County (23.3). In 1980, the ratios in the suburbs fall slightly as they continue to develop; however, the situation in the City depends on the extent of the 3-A construction. With the 3-A system (Alternative 3), traffic conditions are faster than in 1970; however, without it (Alternative 5), traffic slows to an average of 18.7 mph.

An analysis of 1995 traffic speeds must take into consideration both the level of highway improvement and the growth and distribution of population and employment. If the full system of GPD, including 3-A improvements, is completed, regional population and employment are forecast at their highest levels. In addition, traffic in all jurisdictions will move faster than in any of the 1970 or 1980 alternatives.

If the 3-A system is dropped (Alternative 7) from the program, the population and employment in Baltimore City is forecast to decline somewhat, and average travel speeds over the entire day in the City are considerably slower (18.8 mph versus 22.3 mph). Speeds in the other jurisdictions are relatively unaffected.

Table IV-8

24-HOUR ASSIGNMENT STATISTICS

| | Alternative | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1970 | 1980[5] | | | 1995[5] | | | |
| | 1 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| VMT[1] (x 1,000) | | | | | | | | |
| Baltimore City | 5,878 | 7,263 | 7,234 | 6,727 | 8,005 | 7,192 | 8,693 | 7,696 |
| Anne Arundel Co. | 3,496 | 4,952 | 4,983 | 5,113 | 7,142 | 7,039 | 5,043 | 4,884 |
| Baltimore County | 6,553 | 9,872 | 9,878 | 9,990 | 13,037 | 12,877 | 11,355 | 11,089 |
| Howard County | 1,069 | 2,665 | 2,681 | 2,596 | 4,096 | 3,920 | 3,476 | 3,327 |
| External | 845 | 1,225 | 1,223 | 1,216 | 1,866 | 1,799 | 1,649 | 1,604 |
| Total | 17,842 | 25,977 | 26,000 | 25,642 | 34,146 | 32,826 | 30,217 | 28,599 |
| VHT[2] (x 1,000) | | | | | | | | |
| Baltimore City | 299 | 324 | 334 | 359 | 359 | 383 | 449 | 486 |
| Anne Arundel Co. | 180 | 258 | 261 | 276 | 308 | 303 | 386 | 362 |
| Baltimore County | 242 | 377 | 374 | 384 | 455 | 459 | 541 | 508 |
| Howard County | 46 | 122 | 122 | 118 | 166 | 155 | 215 | 202 |
| External | 19 | 27 | 28 | 27 | 39 | 37 | 34 | 33 |
| Total | 786 | 1,108 | 1,120 | 1,165 | 1,326 | 1,337 | 1,624 | 1,591 |
| VMT/VHT | | | | | | | | |
| Baltimore City | 19.7 | 22.4 | 21.6 | 18.7 | 22.3 | 18.8 | 19.4 | 15.8 |
| Anne Arundel Co. | 19.4 | 19.2 | 19.1 | 18.5 | 23.2 | 23.2 | 13.1 | 13.5 |
| Baltimore County | 27.1 | 26.2 | 26.4 | 26.0 | 28.7 | 28.1 | 21.0 | 21.8 |
| Howard County | 23.3 | 21.9 | 21.9 | 22.0 | 24.7 | 25.3 | 16.2 | 16.5 |
| External | 45.4 | 44.3 | 44.3 | 44.3 | 48.2 | 48.1 | 48.7 | 48.5 |
| Regional[3] | 22.7 | 23.4 | 23.2 | 22.0 | 25.8 | 24.5 | 18.6 | 18.0 |
| Regional[4] | 22.2 | 22.9 | 22.7 | 21.5 | 25.1 | 23.9 | 18.0 | 17.3 |

Footnotes:
1. Vehicle-Miles of Travel
2. Vehicle-Hours of Travel
3. Includes travel on external links (those routes within the Baltimore region but outside the detailed study area)
4. Excludes travel on external links
5. 1980 contains vehicle trips carrying patrons to and from rapid transit stations. For 1995, these data were prepared separately. They were excluded from this tabulation in order to maintain consistency.

Under the assumption of Alternative 8, the 3-A system is completed but other highway improvements are not. Population and employment are forecast to reach their highest levels in the City, but average traffic speeds are still under the Alternative 6 values (19.4 mph versus 22.3 mph). As shown in Table IV-8, suburban speeds are even worse off; in Anne Arundel County, for examples, the average speed is 13.1 mph compared to the 23.2 mph of Alternative 6.

If neither the 3-A nor other GDP highway improvements are made, population and employment levels are forecast to be lowest (Alternative 9). Despite the decrease in regional activity, traffic in Baltimore City reaches its lowest average speed (15.8 mph) and traffic in the counties is only marginally ahead of the Alternative 8 values. From the above discussions, it can be seen that, regardless of the alternative or the jurisdiction, if the highway improvements are not made, traffic speeds go down despite the decreased land use activity.

A second measure of level of service is provided by the highway classificaiton which compares highway demand with the practical capacity of individual link segments as defined in the Highway Capacity Manual. (8) Table IV-9 indicates the number of miles of facility estimated to be in each volume/capacity classification for each alternative. Using this criteria, 1980 highway travel is estimated to be not as good in 1970, even with the 3-A system completed by 1980. A greater proportion of the system is congested (Level of Service E or F) and proportionally fewer miles operate under free-flow conditions (Level of Service A or B). The deterioration in traffic conditions is slight with the 3-A system, but more pronounced without it. One of the reasons for this is due to the fact that the highway construction in the suburbs between 1970 and 1980 is minor, as most of the improvements are concentrated in the City. Hence, the longer suburban links will become more congested as adjacent activities increase.

In 1995, the results of highway construction are more pronounced. With the full 3-A and other GDP improvements (Alternative 6), traffic could actually be better off than in 1970. There would be more miles of roadway at uncongested levels (A and B) and fewer at congested levels (E and F). Elimination of the 3-A (Alternative 7) causes little change; however, the congestion under the alternatives which eliminate suburban construction (Alternatives 8 and 9) is more pronounced than in 1970. Under the null alternative (Alternative 9), the percentage of miles at free flow declines from 67.1 to 49.5, and the percentage which is congested increases from 16.5 to 31.4, compared to 1970.

Table IV-9

MILES OF FACILITY AT EACH LEVEL OF SERVICE

24-HOUR PERIOD

| Level of Service | 1970 | | 1980 | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Alternative 1 | | Alternative 3 | | Alternative 4 | | Alternative 5 | |
| | Miles | Percent | Miles | Percent | Miles | Percent | Miles | Percent |
| A | 710 | 53.2 | 736 | 48.4 | 721 | 47.7 | 670 | 45.1 |
| B | 185 | 13.9 | 240 | 15.8 | 241 | 15.9 | 226 | 15.3 |
| C | 105 | 7.8 | 117 | 7.7 | 115 | 7.7 | 111 | 7.4 |
| D | 115 | 8.6 | 135 | 8.9 | 136 | 9.0 | 154 | 10.4 |
| E | 190 | 14.3 | 229 | 15.1 | 238 | 15.7 | 257 | 17.3 |
| F | 29 | 2.2 | 63 | 4.1 | 62 | 4.0 | 66 | 4.5 |
| TOTAL | 1,334 | 100.0 | 1,520 | 100.0 | 1,513 | 100.0 | 1,484 | 100.0 |

| | 1995 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Alternative 6 | | Alternative 7 | | Alternative 8 | | Alternative 9 | |
| | Miles | Percent | Miles | Percent | Miles | Percent | Miles | Percent |
| A | 875 | 52.1 | 834 | 50.8 | 516 | 36.2 | 490 | 35.2 |
| B | 295 | 17.6 | 283 | 17.2 | 215 | 15.0 | 198 | 14.3 |
| C | 125 | 7.5 | 121 | 7.4 | 112 | 7.8 | 114 | 8.2 |
| D | 159 | 9.4 | 159 | 9.6 | 159 | 11.2 | 151 | 10.9 |
| E | 200 | 11.9 | 217 | 13.2 | 308 | 21.5 | 329 | 23.6 |
| F | 26 | 1.5 | 30 | 1.8 | 119 | 8.3 | 109 | 7.8 |
| TOTAL | 1,680 | 100.0 | 1,644 | 100.0 | 1,429 | 100.0 | 1,391 | 100.0 |

Source: Highway Capacity Manual (18)

## Transit

Estimates of transit travel were developed in the course of making highway travel forecasts. These trips were assigned for five of the alternatives. Table IV-10 presents some summary statistics for the five transit assignments performed. The classification of rail trips includes all transit riders who used the rail system for at least a part of their trip. The bus-only trips are those riders who use at least one bus line but not the rail system. The miscellaneous trips represent transit travel which could not be assigned to the a.m. peak representation of the transit network used for computer simulation. In the future alternatives, there is more population in the suburbs, and the improved rail service allows transit to compete more effectively with the autmobile for radial travel. Hence, the average distance traveled per rider on the system increases. However, because of the rail system and its significantly faster operating speed, mean riding times decrease. In 1995, the no-build test (Alternative 9) has more population in the City and less in the suburbs than the other two alternatives; hence, both trip distances and trip times are less.

Average boardings per trip are computed by dividing the number of total vehicle boardings (i.e., each time a person gets on a new vehicle) on bus and rail by the number of patrons in the 24-hour period. In the future year alternatives, this value increases since the bus and rail routes are designed to provide overall better service by encouraging the use of feeder buses. For the typical rider, significant travel time savings are provided by supplying rapid rail transit in place of conventional buses for line-haul service. Also, a large proportion of the transfers are rail-to-rail transfers which are much less onerous on the patron because of the greater reliability and frequency of rail as compared to bus. For example, in the full construction alternative (Alternative 6), the number of rail-to-rail transfers is 135,333, or 22 percent of the total number of transfers.

## Peak Period Trip Factoring

Recognizing that the full effects of congestion and environmental impacts require not only a total day analysis but also a more detailed evaluation of peak period effects, the Regional Planning Council in 1968-69 sponsored development of a model designed to forecast for each area-to-area movement the amount of total day travel which would occur in the two-hour p.m. peak period. This model, described in detail in reference 9, treats each travel purpose separately and recognizes that different industries require different types of working hours and that the working hour requirements of individual

Table IV-10

24 - HOUR TRANSIT ASSIGNMENT STATISTICS

| | Alternative | | | | |
|---|---|---|---|---|---|
| | 1970 | 1980 | 1995 | | |
| | 1 | 3 | 6 | 7 | 9 |
| Rail Trips | 0 | 138,377 | 450,018 | 417,803 | 439,782 |
| Bus Only Trips | 363,908 | 288,711 | 186,751 | 177,245 | 192,126 |
| Miscellaneous Trips | 18,197 | 15,487 | 20,941 | 20,235 | 21,309 |
| TOTAL Rail & Bus Trips | 363,908 | 427,088 | 636,769 | 595,048 | 631,908 |
| TOTAL Transit Trips | 382,105 | 442,575 | 657,710 | 615,283 | 653,217 |
| Passenger-Mile Rail | 0 | 668,966 | 2,695,121 | 2,514,159 | 2,435,204 |
| Passenger-Mile Bus | 1,843,982 | 1,700,616 | 1,378,152 | 1,290,638 | 1,299,306 |
| TOTAL Passenger Miles | 1,843,982 | 2,369,582 | 4,073,273 | 3,804,797 | 3,734,510 |
| Passenger-Hour Rail | 0 | 20,477 | 78,747 | 73,327 | 71,947 |
| Passenger-Hour Bus | 161,967 | 135,421 | 90,934 | 85,140 | 88,376 |
| TOTAL Passenger Hours | 161,967 | 155,898 | 169,681 | 158,467 | 160,323 |
| Average Boardings/Trip | 1.80 | 2.22 | 2.90 | 2.88 | 2.86 |
| Average Trip Length 1/ - Miles | 4.82 | 5.55 | 6.40 | 6.39 | 5.91 |
| - Minutes | 26.7 | 21.9 | 16.0 | 16.0 | 15.2 |

1/ Miscellaneous trips are excluded.

employees vary with their status within the industry. Thus, low paid government workers are more likely to leave work in the peak period than low paid retail workers. Relationships of this type are embodied in the peak travel model.

For the environmental impact analysis, peak-period travel forecasts were made for 1970 (Alternative 1), 1980 (Alternative 3) and 1995 (Alternatives 6, 7, and 9). These were deemed sufficient to make judgments for the other alternatives. Table IV-11 contains the results by purpose for the internal and internal-external trips combined. While non-home-based peak period trip estimates were initially made for auto driver trips, person trip estimates obtained from the constrained modal split computations are presented for consistency. Data for truck and through trips in the peak period are also included in Table IV-11.

Overall, within any given purpose, there is little variation among alternatives in the percentage of 24-hour travel that the peak period travel represents. For the internal person trip purposes, the overall percentages are projected to drop between the present and the future; this is due to the fact that the highly peaking home-based work trips decline as a percentage of all trips. The truck and through trips are assumed to maintain the same percentages which were observed in the 1962 O-D survey.

Unconstrained Peak Period Mode Choice

During the peak period, mode choice is inherently different from that during the 24-hour period in that a greater proportion of peak trips are work oriented, making transit use more likely. In addition, highway congestion occurring in the peak period tends to encourage the use of transit.

The peak-period travel simulations involve two iterations through the mode choice and highway assignment plans. In the first iteration, a first estimate of transit patronage is obtained using unconstrained (assuming little highway congestion) highway travel times in the mode choice models. The peak-period modal choice relationships are based on the equivalent travel time difference of highway and transit travel with separate functions for each level of median family income and parking cost. (10) As with the 24-hour models, the outputs are in terms of zone-to-zone transit, auto passenger, and auto driver trips by purpose. The resulting vehicular trips are then loaded on the highway network using a capacity restraint process, i.e., speeds are lowered as trips are loaded onto the highway network. The constrained (assuming peak congestion) highway travel times are then input to the modal split which is over prior to a final capacity restrained highway assignment.

Table IV-11

2 HR. P.M. PEAK PERIOD TRAVEL FORECASTS
TRIPS (x1000) AND PERCENT OF 24-HOUR TRIPS

| PURPOSE: | Alternative | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1970 | | 1980 | | 1995 | | | | | |
| | 1 | | 3 | | 6 | | 7 | | 9 | |
| | Trips | Percent of Total Day | Trips | Percent of Total Day | Trips | Percent of Total Day | Trips | Percent of Total Day | Trips | Percent of Total Day |
| INTERNAL, EXTERNAL-INTERNAL, and INTERNAL-EXTERNAL: | | | | | | | | | | |
| Home-Based Work | 378 | 32.0 | 431 | 32.1 | 534 | 31.6 | 512 | 31.5 | 493 | 32.0 |
| Home-Based Other | 205 | 12.7 | 302 | 12.6 | 401 | 12.6 | 386 | 12.6 | 362 | 12.6 |
| Home-Based School | 21 | 11.0 | 28 | 11.1 | 34 | 10.9 | 33 | 10.9 | 33 | 10.9 |
| Non-Home Based* | 99 | 16.6 | 112 | 16.9 | 145 | 17.1 | 141 | 17.0 | 135 | 17.3 |
| TOTAL | 703 | 19.6 | 873 | 18.8 | 1,114 | 18.4 | 1,072 | 18.4 | 1,023 | 18.6 |
| Light Trucks | 43 | 11.3 | 49 | 11.3 | 60 | 11.3 | 58 | 11.3 | 55 | 11.3 |
| Heavy Trucks | 3 | 10.6 | 4 | 10.7 | 5 | 10.7 | 5 | 10.7 | 4 | 10.7 |
| THROUGH: | | | | | | | | | | |
| Auto Drivers | 8 | 16.9 | 9 | 16.9 | 11 | 16.9 | 11 | 16.9 | 11 | 16.9 |
| Light Trucks | 0.2 | 10.3 | 0.2 | 10.3 | 0.3 | 10.7 | 0.3 | 10.7 | 0.3 | 10.7 |
| Heavy Trucks | 0.5 | 11.1 | 0.6 | 11.1 | 0.7 | 11.2 | 0.7 | 11.2 | 0.7 | 11.2 |
| TOTAL Through Vehicles | 8.7 | 16.2 | 9.9 | 16.2 | 12.2 | 16.2 | 12.2 | 16.2 | 12.2 | 16.2 |

*Taken from Constrained Modal Split Results

## Initial Peak Period System Loading

In the first iteration of peak-period travel simulation, the highway network is loaded using the same type of capacity restraint technique used in 24-hour system loading, but instead of 24-hour capacities, peak period capacities are used in the restraint functions. This procedure provides an excellent estimate of the true peak period highway travel time for use in the second mode choice in the second iteration. All vehicle trips, including truck and through trips, are assigned.

## Constrained Peak Period Mode Choice

In the second iteration, refined mode choice estimates are made using the constrained highway travel times in order to represent the highway mode more precisely. Table IV-12 displays the constrained peak period mode choice results for the five alternatives which were simulated in the peak period. With the exception of school trips, the percentage of transit trips is higher in the peak period than for 24 hours (see Table IV-7).

Highway systems reach their highest congestion levels in the peak, whereas during the rest of the day the highways are much more amenable to auto travel. Work trips will continue as the predominant purpose of transit riders in the peak; the other three purposes will continue to grow on absolute and percentage bases as the rail system is implemented. Overall peak period transit travel will increase by 34 percent in 1980 and between 105 percent and 135 percent in 1995, depending on the highway and land use alternative.

A decrease in auto occupancy in the peak is estimated for 1980, and a further decrease is expected for 1995 for all purposes. With the exception of school trips, the same phenomenon occurs on a 24-hour basis. The principal cause here is increasing income and, hence, higher car ownership.

## Final Peak Period System Loading

After the peak period modal split was run for the second time, all auto driver and truck trips were combined again for the final assignment, using capacity restraint procedures as previously discussed. The results of this assignment are presented in Table IV-13 for the five alternatives loaded in the peak period. One result immediately apparent is the declining percentage of travel in the peak period over time. Reasons for this are the relative decrease in the proportion of work trips, which predominate in the peak, and the increasing use of transit in the peak period due to the rapid rail system.

Table IV-12

2 HR. P.M. PEAK PERIOD MODE CHOICE RESULTS[1/]

| | | Alternative | | | | |
|---|---|---|---|---|---|---|
| | | 1970 | 1980 | 1995 | | |
| PURPOSE | MODE | 1 | 3 | 6 | 7 | 9 |
| WORK: | TOTAL (000) | 378 | 431 | 534 | 512 | 493 |
| | Auto Driver (000) | 217 | 271 | 329 | 316 | 284 |
| | Auto Passenger (000) | 101 | 86 | 90 | 85 | 81 |
| | Transit Passenger (000) | 60 | 74 | 115 | 111 | 128 |
| | Percent Transit | 15.80 | 17.20 | 21.60 | 21.70 | 26.00 |
| | Percent Auto Driver | 57.40 | 62.80 | 61.50 | 61.70 | 57.60 |
| | Auto Occupancy | 1.47 | 1.32 | 1.27 | 1.27 | 1.29 |
| OTHER: | TOTAL (000) | 205 | 302 | 401 | 386 | 362 |
| | Auto Driver (000) | 141 | 209 | 270 | 260 | 242 |
| | Auto Passenger (000) | 53 | 71 | 92 | 89 | 78 |
| | Transit Passenger (000) | 11 | 22 | 39 | 37 | 42 |
| | Percent Transit | 5.50 | 7.30 | 9.70 | 9.60 | 11.60 |
| | Percent Auto Driver | 68.80 | 69.40 | 67.30 | 67.40 | 66.90 |
| | Auto Occupancy | 1.37 | 1.34 | 1.34 | 1.34 | 1.32 |
| SCHOOL: | TOTAL (000) | 21 | 28 | 34 | 33 | 33 |
| | Auto Driver (000) | 2 | 3 | 3 | 3 | 2 |
| | Auto Passenger (000) | 14 | 18 | 20 | 20 | 19 |
| | Transit Passenger (000) | 5 | 7 | 11 | 10 | 12 |
| | Percent Transit | 25.10 | 26.00 | 32.30 | 30.30 | 36.40 |
| | Percent Auto Driver | 7.30 | 8.90 | 8.80 | 9.10 | 6.10 |
| NHB: | TOTAL (000) | 99 | 112 | 145 | 141 | 135 |
| | Auto Driver (000) | 71 | 80 | 102 | 99 | 94 |
| | Auto Passenger (000) | 22 | 24 | 30 | 30 | 28 |
| | Transit Passenger (000) | 6 | 8 | 13 | 12 | 13 |
| | Percent Transit | 6.30 | 7.10 | 9.00 | 8.50 | 9.60 |
| | Percent Auto Driver | 71.60 | 71.40 | 70.30 | 70.20 | 69.60 |
| TOTAL AUTO DRIVERS (000) | | 431 | 563 | 703 | 678 | 622 |
| TOTAL TRANSIT PASSENGERS (000) | | 83 | 111 | 178 | 170 | 195 |
| TOTAL PERSON TRIPS (000) | | 704 | 873 | 1,114 | 1,072 | 1,023 |
| OVERALL AUTO OCCUPANCY | | 1.44 | 1.35 | 1.33 | 1.33 | 1.33 |
| OVERALL PERCENT TRANSIT | | 11.70 | 12.70 | 16.00 | 15.90 | 19.00 |

[1/] All figures exclude through trips.

Table IV-13

2 HR. P. M. PEAK PERIOD ASSIGNMENT STATISTICS

| | Alternative | | | | |
|---|---|---|---|---|---|
| | 1970 | 1980 | 1995 | | |
| | 1 | 3 | 6 | 7 | 9 |
| **Vehicle-miles of Travel (VMT) (x1000)** | | | | | |
| Baltimore City | 1,245 | 1,563 | 1,656 | 1,463 | 1,521 |
| Anne Arundel County | 695 | 971 | 1,369 | 1,346 | 934 |
| Baltimore County | 1,403 | 2,104 | 2,663 | 2,650 | 2,233 |
| Howard County | 220 | 576 | 858 | 819 | 680 |
| Outside Intensive Study Area | 133 | 192 | 298 | 288 | 254 |
| TOTAL | 3,966 | 5,407 | 6,844 | 6,565 | 5,622 |
| **Vehicle-Hours of Travel (VHT) (x1000)** | | | | | |
| Baltimore City | 79 | 81 | 87 | 96 | 113 |
| Anne Arundel County | 43 | 57 | 65 | 63 | 76 |
| Baltimore County | 63 | 98 | 111 | 114 | 122 |
| Howard County | 12 | 32 | 43 | 39 | 48 |
| Outside intensive study area | 3 | 4 | 6 | 6 | 5 |
| TOTAL | 200 | 273 | 312 | 318 | 365 |
| **VMT/VHT** | | | | | |
| Baltimore City | 15.8 | 19.2 | 19.0 | 15.3 | 13.4 |
| Anne Arundel County | 16.3 | 17.0 | 21.0 | 21.4 | 12.3 |
| Baltimore County | 22.2 | 21.5 | 24.0 | 23.3 | 18.3 |
| Howard County | 18.8 | 18.0 | 19.9 | 21.0 | 14.0 |
| External | 45.7 | 44.5 | 48.4 | 48.3 | 48.8 |
| Intensive Study Area Only | 19.9 | 19.8 | 21.9 | 20.7 | 15.4 |
| Area-Wide | 19.5 | 19.4 | 21.4 | 20.1 | 14.9 |
| PERCENT OF 24-HOUR VMT: | 22.2 | 20.8 | 20.0 | 20.0 | 19.7 |

Note: 1980 data contain auto trips carrying patrons to and from rapid transit stations. For 1995, these data were prepared separately for selected alternatives. They are excluded from this tabulation in order to maintain consistency.

As to be expected, the peak period travel speeds for all jurisdictions in all systems are appreciably slower than the comparable 24-hour values. The construction of the 3-A system appreciably helps the flow of traffic in Baltimore City in the peak as it does all day. However, in Anne Arundel County, 1980 peak period travel is slightly faster than the 1970 (17.0 mph versus 16.3 mph), but on a 24-hour basis there was little difference.

In 1995, the peak period effects of building or not building the proposed highway improvements are more pronounced than on a 24-hour basis. In Anne Arundel County, traffic would slow to 12.3 mph in the null alternative (Alternative 9) versus 21.0 mph if all improvements are completed (Alternative 6). In terms of area-wide travel, congestion under the no-build conditions (Alternative 9) would add 6.7 minutes to the typical trip as opposed to only 2.3 minutes with the full system (Alternative 6). (These results are discussed more fully in Section V). Such a difference would be even more pronounced with such a limited system if the population and employment were to grow the same amount with the no-build program as with the full system.

SUMMARY

This section has presented summaries of several of the important system measures on a regional level for the eight alternatives. Although considerable data on each of the travel simulations are available, for practical purposes it cannot all be presented here. Final scale detail is available on individual highway and transit links, on transit lines, and on other variables at the traffic zone, RPD, and jursidiction levels and can be obtained in the computer printouts on file with MDOT and the Regional Planning Council.

# V. ANALYSIS OF SIMULATION RESULTS

In the preceding section, several tables containing results of the travel simulations were presented. These tables illustrate the characteristics of travel at the areawide level for each of the eight alternatives tested. In this section, the simulation results are examined in more detail from two slightly different perspectives. First, two techniques are presented to identify and depict areas of highway congestion. Second, several alternatives have been selected for comparative analysis of how well they perform from the trip-maker's point of view.

## AREAS OF HIGHWAY CONGESTION

A major element in the evaluation of transportation service quality for the alternative network tests is the degree and location of congestion which would be experienced by travelers in the metropolitan study area, as well as in its various subsections. Two major techniques have been used to identify such congestion and to depict it for analysis and review--a "congested VMT" analysis which indicated by small area (RPD) the amount of traffic that will experience a high degree of congestion (Level of Service E or F as defined by the Highway Capacity Manual), and an analysis of the ratio of the vehicle-miles of travel to capacity-miles available within each regional planning district (RPD). The former measure is a summation of the conditions on individual highway links while the latter is a more generalized indication of conditions over an area.

### Traffic Congestion

Even though the capacity restraint technique used for traffic assignment to the highway system takes into account the increase in travel time which occurs when facilities are congested, there are still some routes for which there are no attractive alternatives and, therefore, will attract additional traffic even as they become congested. The Highway Capacity Manual defines six levels of service ranging from complete free flow (Level A) to complete breakdown (Level F). Typically urban facilities may be considered to be operating adequately when Levels of Service C and D are found. These correspond to heavy traffic with minor delays.

For the purpose of this analysis unsatisfactory conditions are defined as Levels of Service E and F or forecasted traffic as individual facilities which exceeds the Level C capacity by a ratio of 1.50 or greater.

Since congestion is mainly a peak phenomenona the analysis below is confined to the two-hour afternoon peak period. Similar conditions would also be found in most areas in the morning peak.

On an areawide basis, it is estimated that in 1970 approximately 44 percent of all peak travel was under congested conditions. (See Table V-1.) By 1980, even with the facilities already completed and planned, the growth in traffic will result in a slight rise to 45 percent.

The forecasts indicate that if the full GDP system is implemented by 1995, the percentage of congested travel would remain about the same (43 percent), even with large increases in total travel demand. However, if there were no additional facilities, the proportion of congested travel would rise significantly to 61 percent.

Table V-1

2-HR. PEAK PERIOD VMT UNDER CONGESTED CONDITIONS
WITHIN THE METROPOLITAN STUDY AREA

| | 1970 | 1980 | 1995 | |
|---|---|---|---|---|
| | | Alt. 3 | Alt. 6 | Alt. 9 |
| Congested VMT | 1,428,000 | 2,180,000 | 2,574,000 | 3,024,000 |
| Percent of Total VMT | 44 | 45 | 43 | 61 |

The degree of congested travel and the changes over time in congestion vary rather widely among the various areas and jurisdictions within the region. For examples, in Anne Arundel County in 1970 a great deal of the total VMT was on facilities such as the Harbor Tunnel Approach roads, the Baltimore Beltway and portions of the Baltimore-Washington Parkway. In peak periods these facilities experienced congestion effecting a great many trips so that 63 percent of all peak traffic in the county was under congested conditions. Baltimore City, on the other hand, had a greater amount of travel which experienced congestion but it constituted a lower population (41 percent).

The shifts in over time in this service measure depend on the total growth in activity and travel in each jurisdiction as well as the specific highway plan assumed. Table V-2 presents these values for 1980 and two of the 1995 alternatives.

TABLE V-2

P.M. PEAK PERIOD CONGESTED VMT WITHIN EACH JURISDICTION

| | 1970 | 1980 GDP | 1995 GDP | 1995 Null |
|---|---|---|---|---|
| Baltimore City | | | | |
| Congested VMT | 513,000 | 527,000 | 574,000 | 822,000 |
| 1970-Future Year Percent Increase | - | 3% | 12% | 60% |
| Percent of Total VMT that is congested | 41% | 38% | 39% | 63% |
| Anne Arundel County | | | | |
| Congested VMT | 415,000 | 516,000 | 652,000 | 695,000 |
| 1970-Future Year Percent Increase | - | 137% | 157% | 228% |
| Percent of Total VMT that is congested | 28% | 44% | 38% | 58% |
| Howard County | | | | |
| Congested VMT | 104,000 | 285,000 | 423,000 | 327,000 |
| 1970-Future Year Percent Increase | - | 174% | 307% | 214% |
| Percent of Total VMT that is congested | 52% | 55% | 56% | 55% |
| Metropolitan Study Area | | | | |
| Congested VMT | 1,428,000 | 2,180,000 | 2,575,000 | 3,024,000 |
| 1970-Future Year Percent Increase | | 53% | 80% | 112% |
| Percent of Total VMT that is congested | 44% | 45% | 43% | 63% |

FIGURE V-1
PERCENT OF CONGESTED VEHICULAR TRAVEL FORECAST
IN EACH REGIONAL PLANNING DISTRICT IN P.M. PEAK PERIOD

1970 ALTERNATIVE 1; 1980 ALTERNATIVE 3; 1995 ALTERNATIVES 6 AND 9

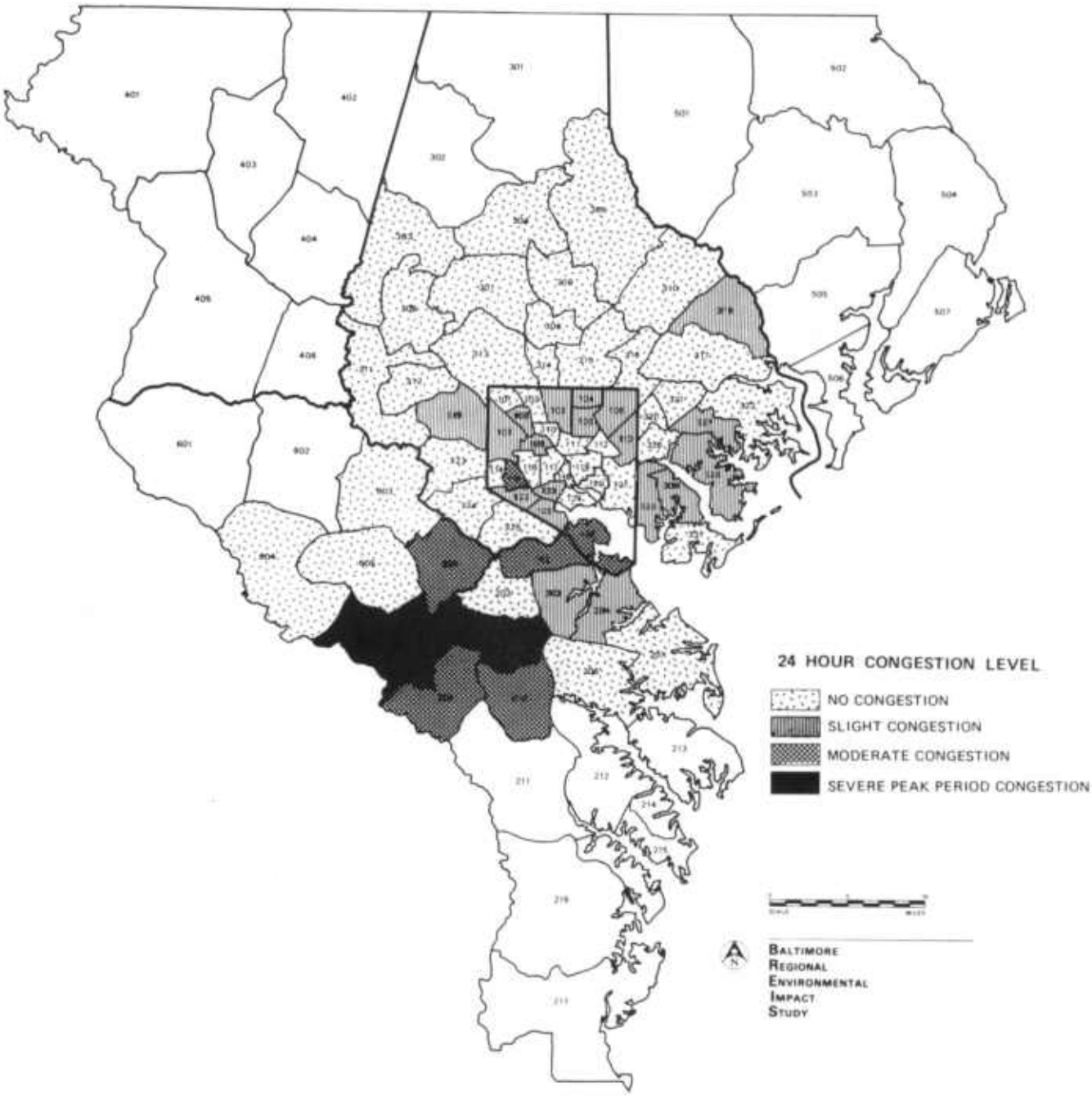


FIGURE V–2
1970 ALTERNATIVE 1
TRAFFIC CONGESTION LEVELS

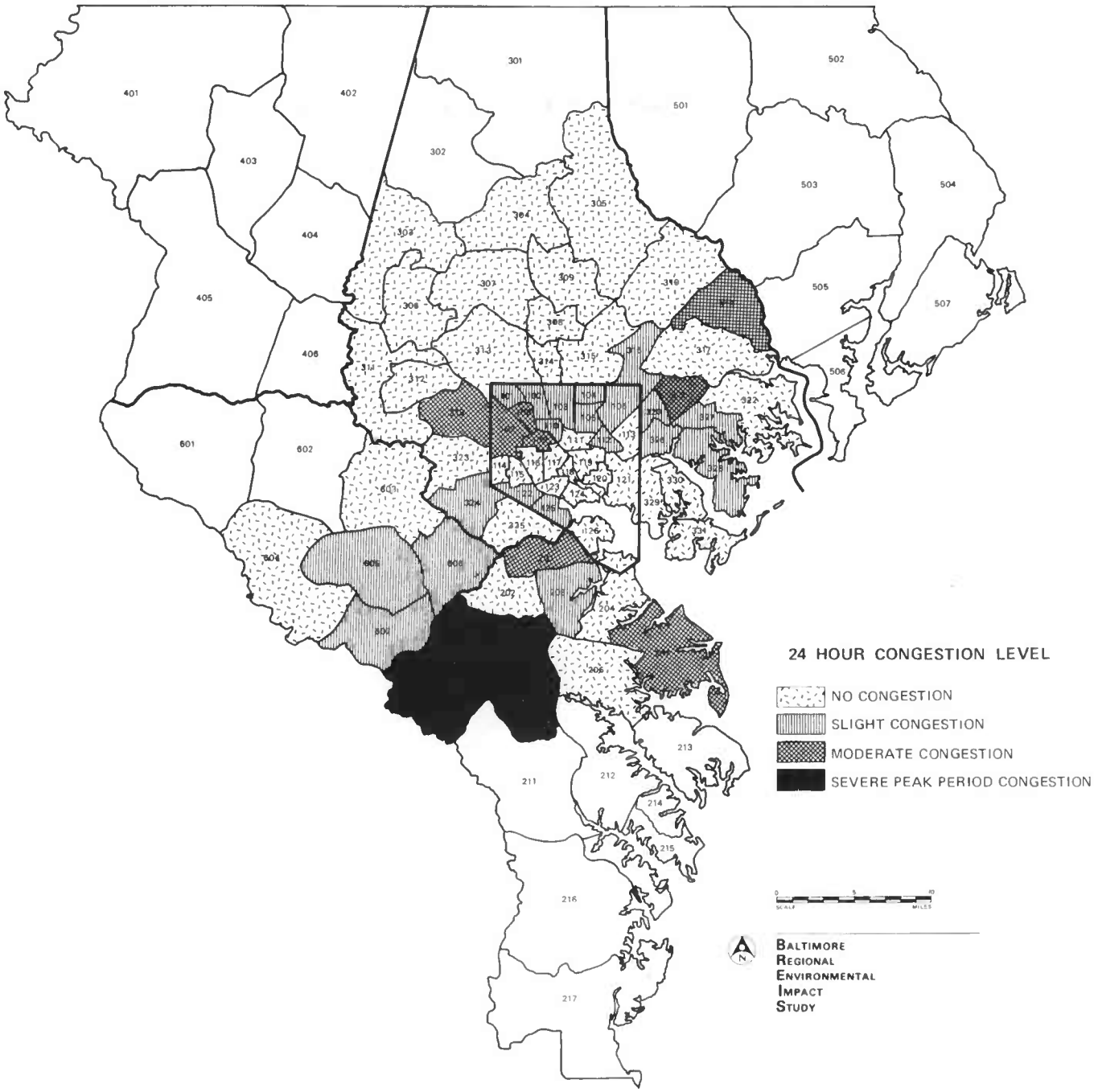


FIGURE V–3
1980 ALTERNATIVE–3
TRAFFIC CONGESTION LEVELS

This measure gives a good indication of corridors in which congestion is or may be a significant problem. Figure V-1 illustrates the p.m. peak 2-hour percent of congested VMT by small area (RPD) for 1970, 1980 (Alternative 3) and 1995 (Alternatives 6 and 9). In 1970, the greatest problems, in terms of proportion of travel, were in the corridor leading toward Washington. By 1980, this specific problem area will have some relief, but the overall regional peak congestion will have increased. By 1995, with the full GDP system, no single area is projected to have over 75 percent of peak travel experiencing congestion, although the southwest corridor and portions of Baltimore City would have between 50 and 75 percent. Without construction of new facilities (Alternative 9) major portions of the study area have peak congestion affecting 50-75 percent of all travel and several pockets, notably on the northwest corridor just outside the City, have congestion exceeding the 75 percent level.

In all year, of course, congestion is or will be worse on some facilities than on others. Even in areas showing high peak congestion levels many facilities will have uncongestion operation for most of the day. Conversely, in areas having low peak congestion levels certain individual facilities and intersections will have severe peak period congestion.

Regional Planning District Congestion Analysis

The second major analysis, that of comparing the ratio of vehicle-miles of travel to capacity-miles, is perhaps more revealing in that rather than attempting to analyze specific links or facilities which would be congested, the analysis focuses on the general amount of travel in each area versus the overall capacity provided. No differentiation is made between the specific facilities people use and the capacity on them, so that in a given area some links may be congested while others are completely free flowing.

However, given the tendency of drivers to seek out uncongested routes, this presentation gives a more easily discernible picture of those areas likely to experience mobility difficulties under each of the alternatives. Such a presentation is more consistent with the precision of the traffic forecasting techniques utilized.

Figures V-2 through V-9 present the ratio of vehicle-miles of travel to the capacity-miles for each RPD in the region, with four stratifications showing level of congestion. The first strata ratios, between 0 and 0.75, represent relatively free-flow travel conditions. The middle two strata, from 0.76 to 1.0 and 1.01 to 1.25, represent levels at which problems of congestion will begin to appear. The final category, 1.26 or greater, represents areas

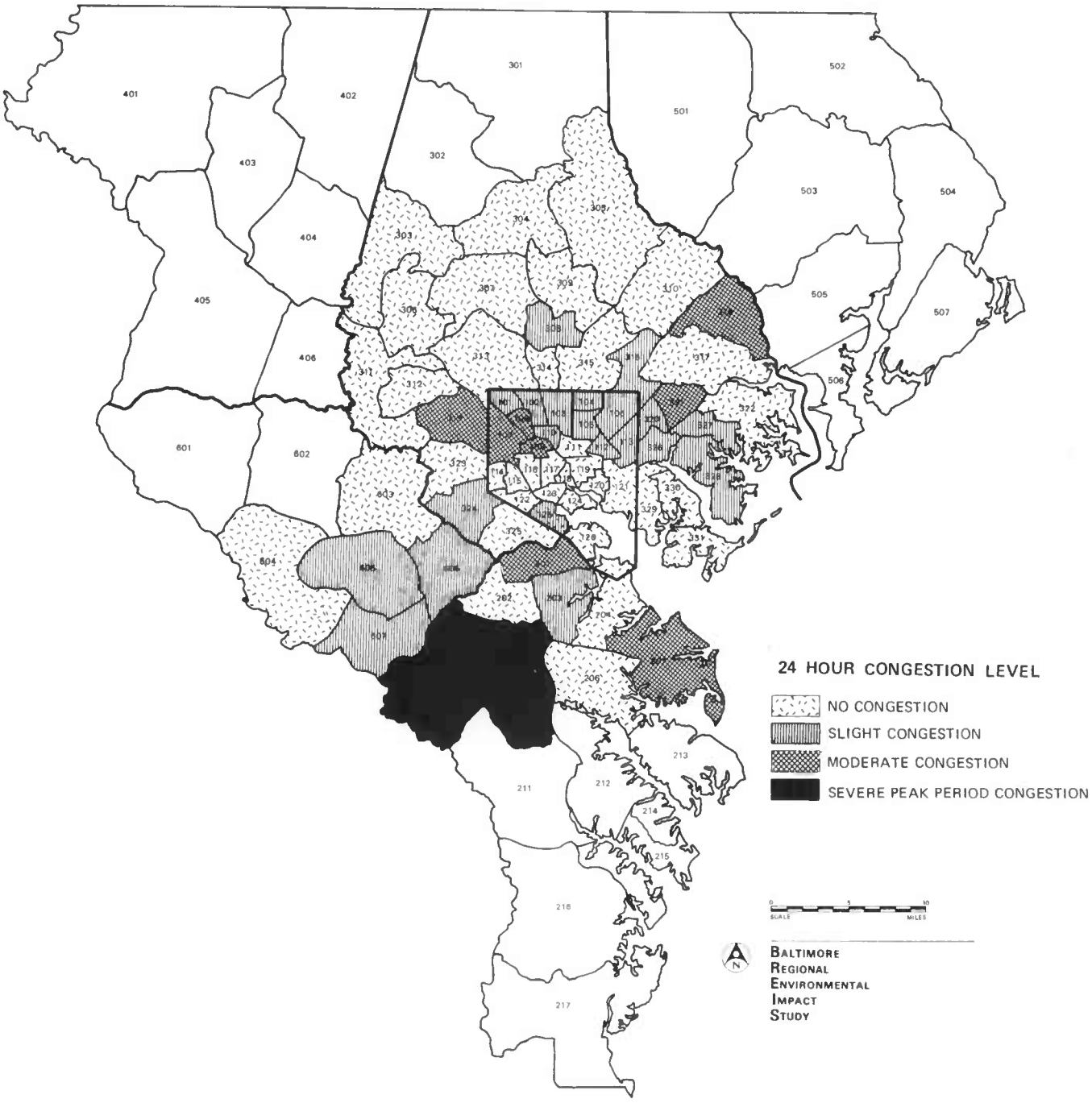


FIGURE V–4
1980 ALTERNATIVE–4
TRAFFIC CONGESTION LEVELS

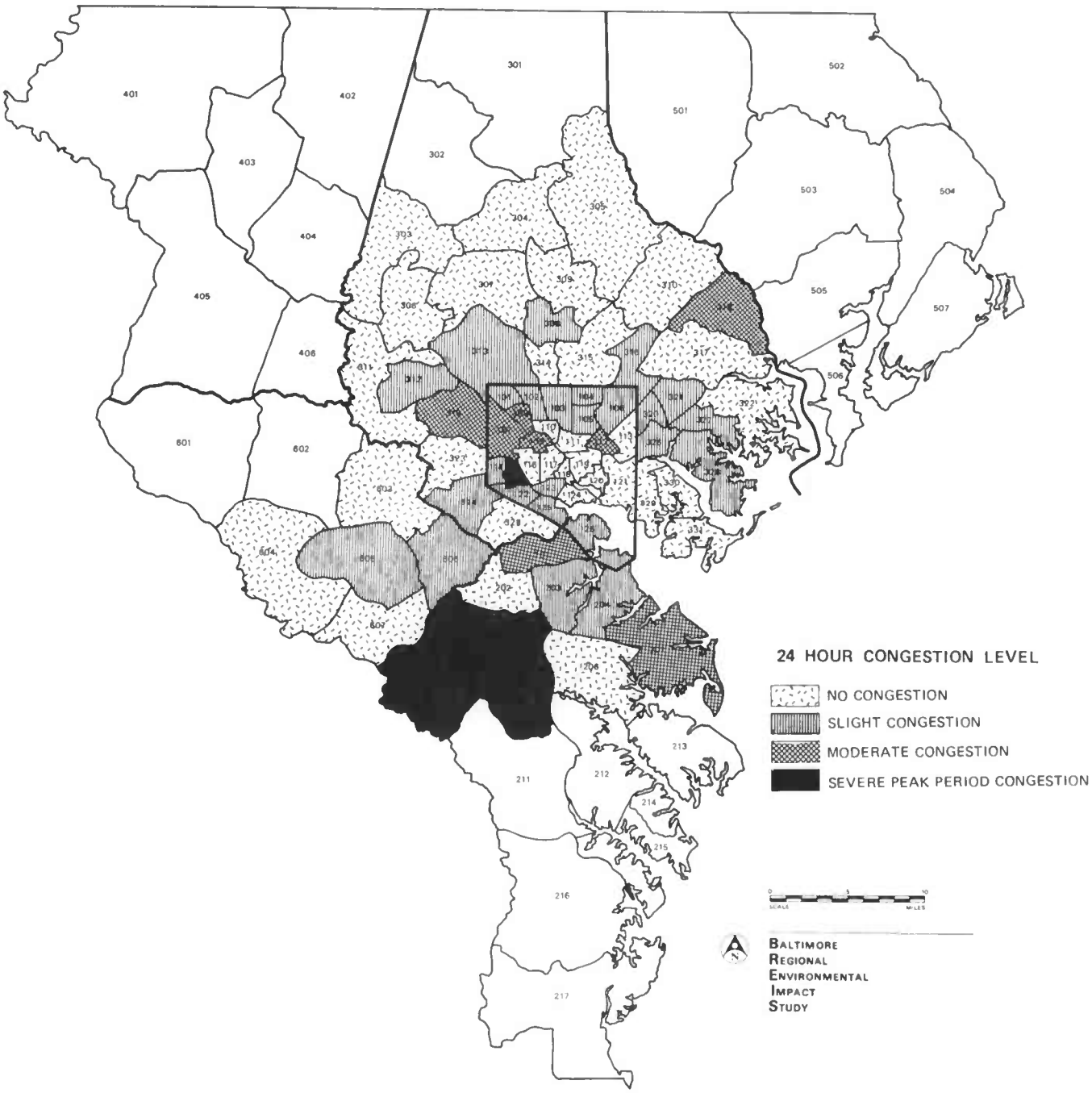


FIGURE V–5
1980 ALTERNATIVE–5
TRAFFIC CONGESTION LEVELS

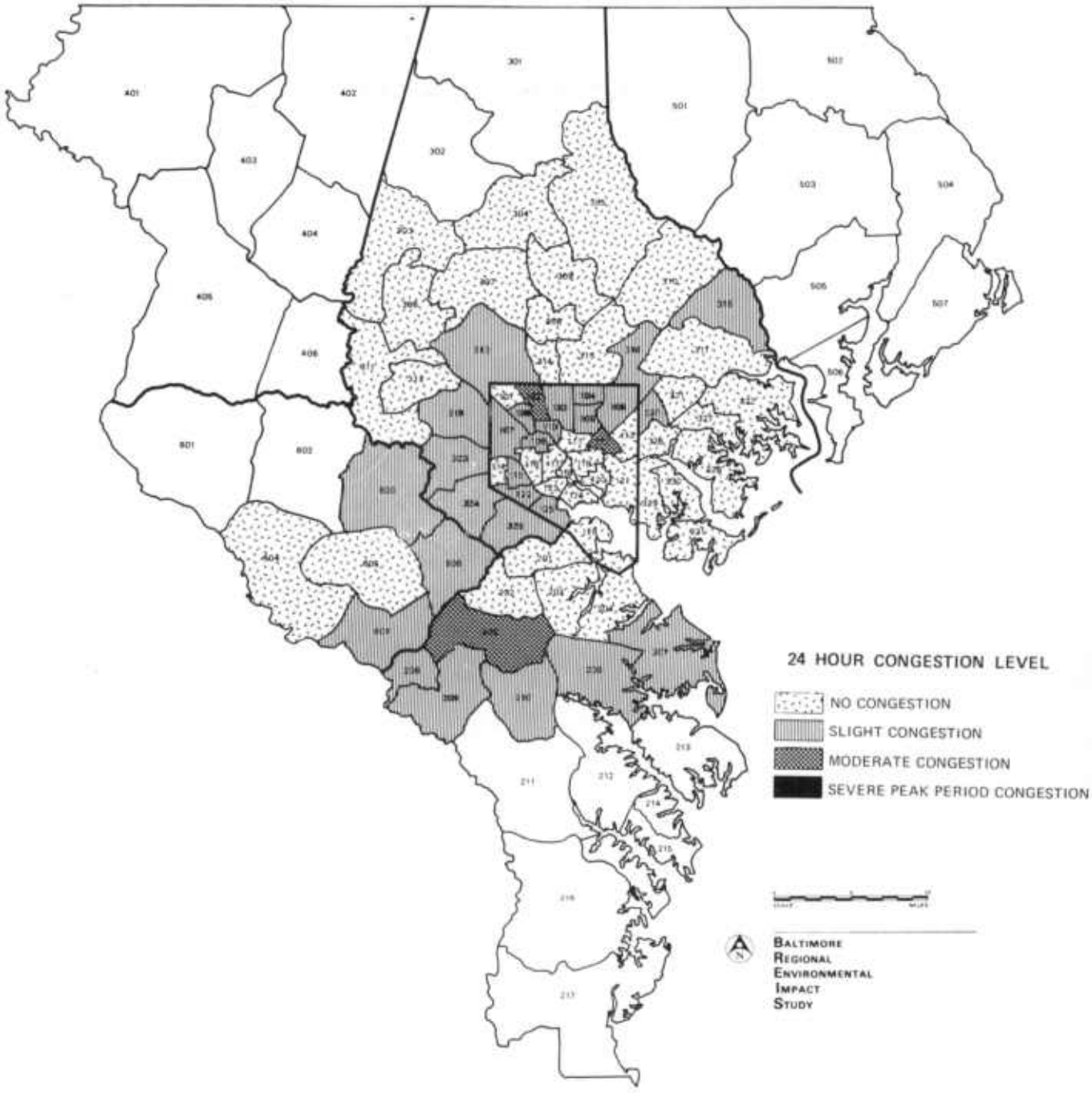


FIGURE V–6
1995 ALTERNATIVE 6
TRAFFIC CONGESTION LEVELS

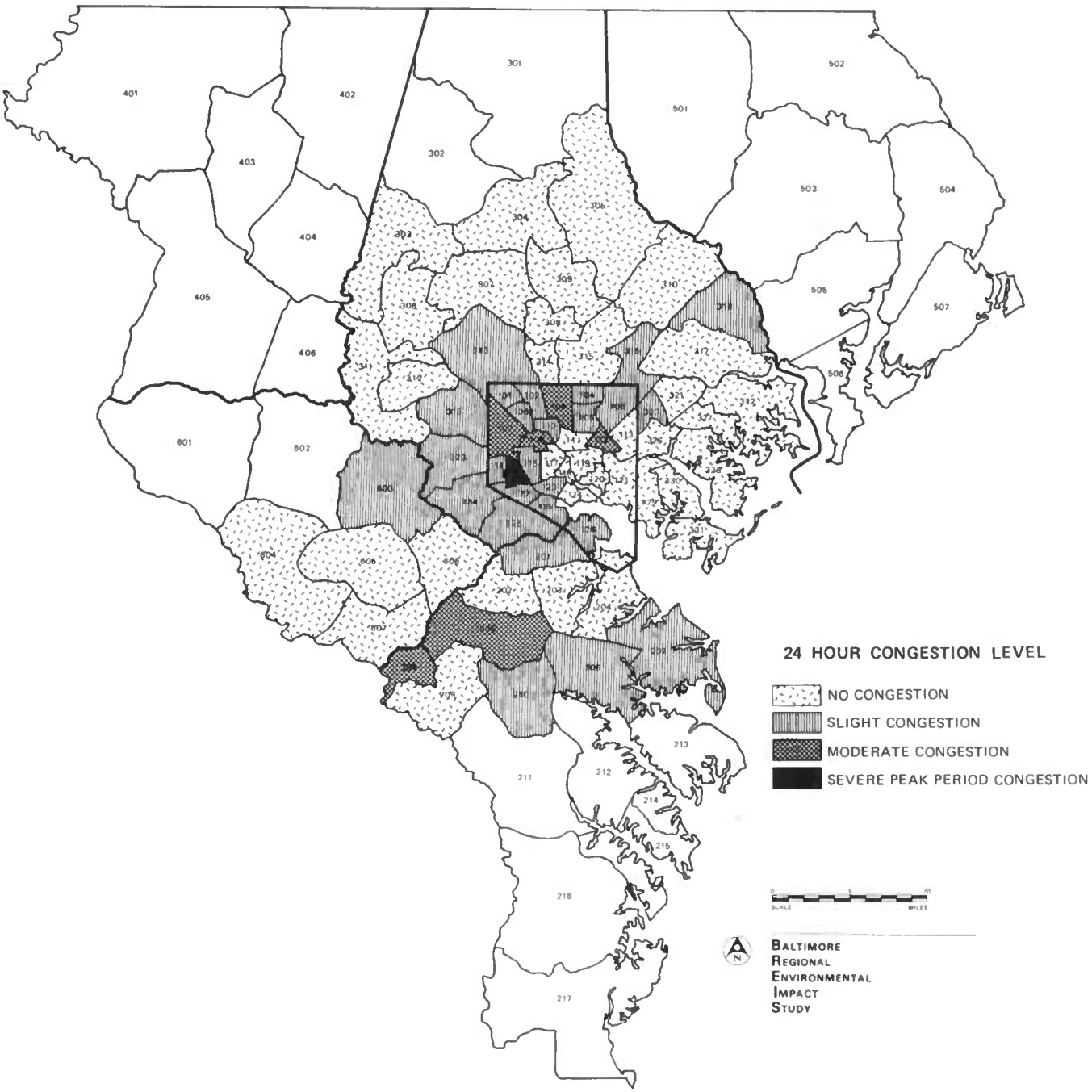


FIGURE V–7
1995 ALTERNATIVE 7
TRAFFIC CONGESTION LEVELS

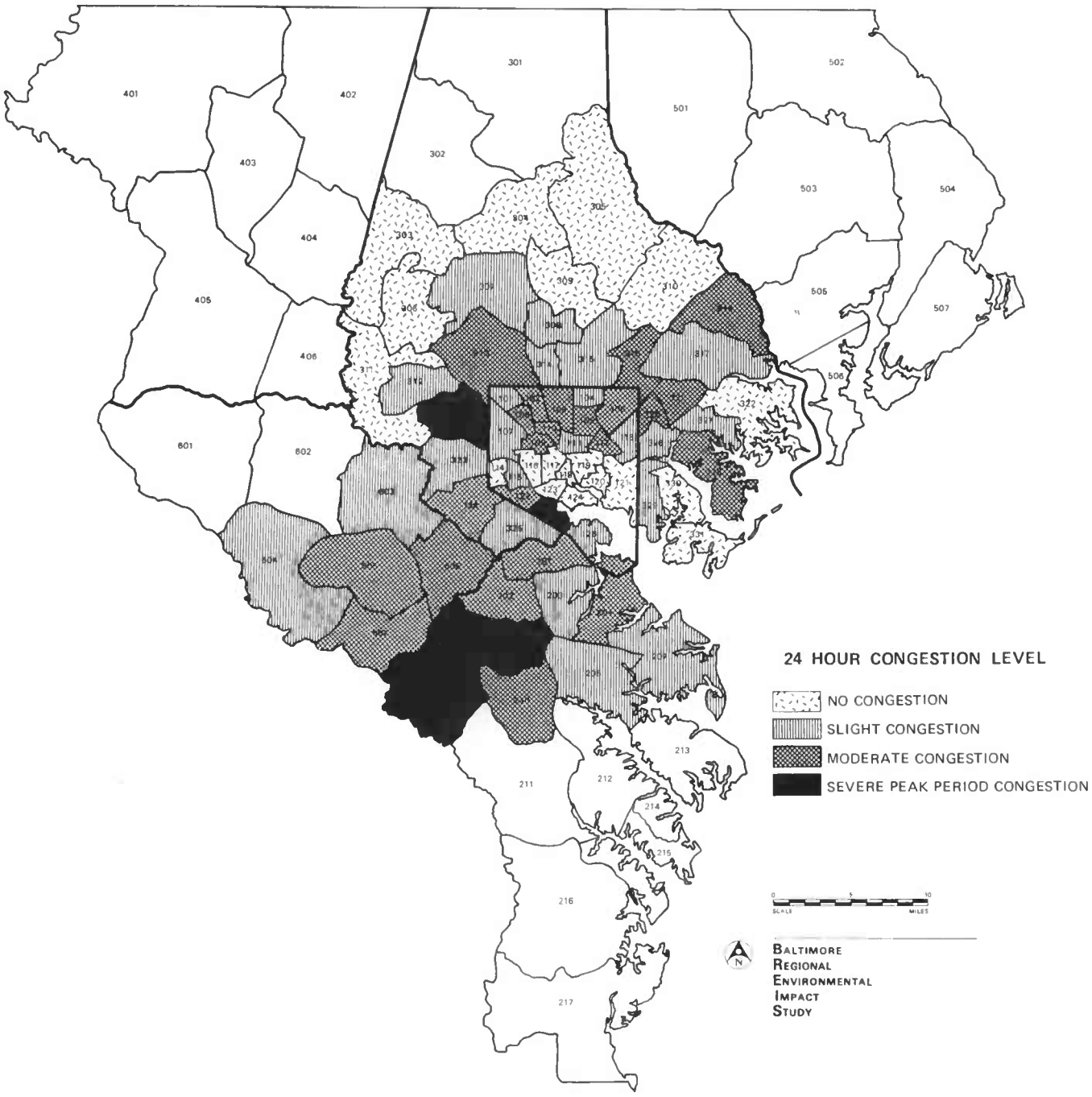


FIGURE V–8
1995 ALTERNATIVE 8
TRAFFIC CONGESTION LEVELS

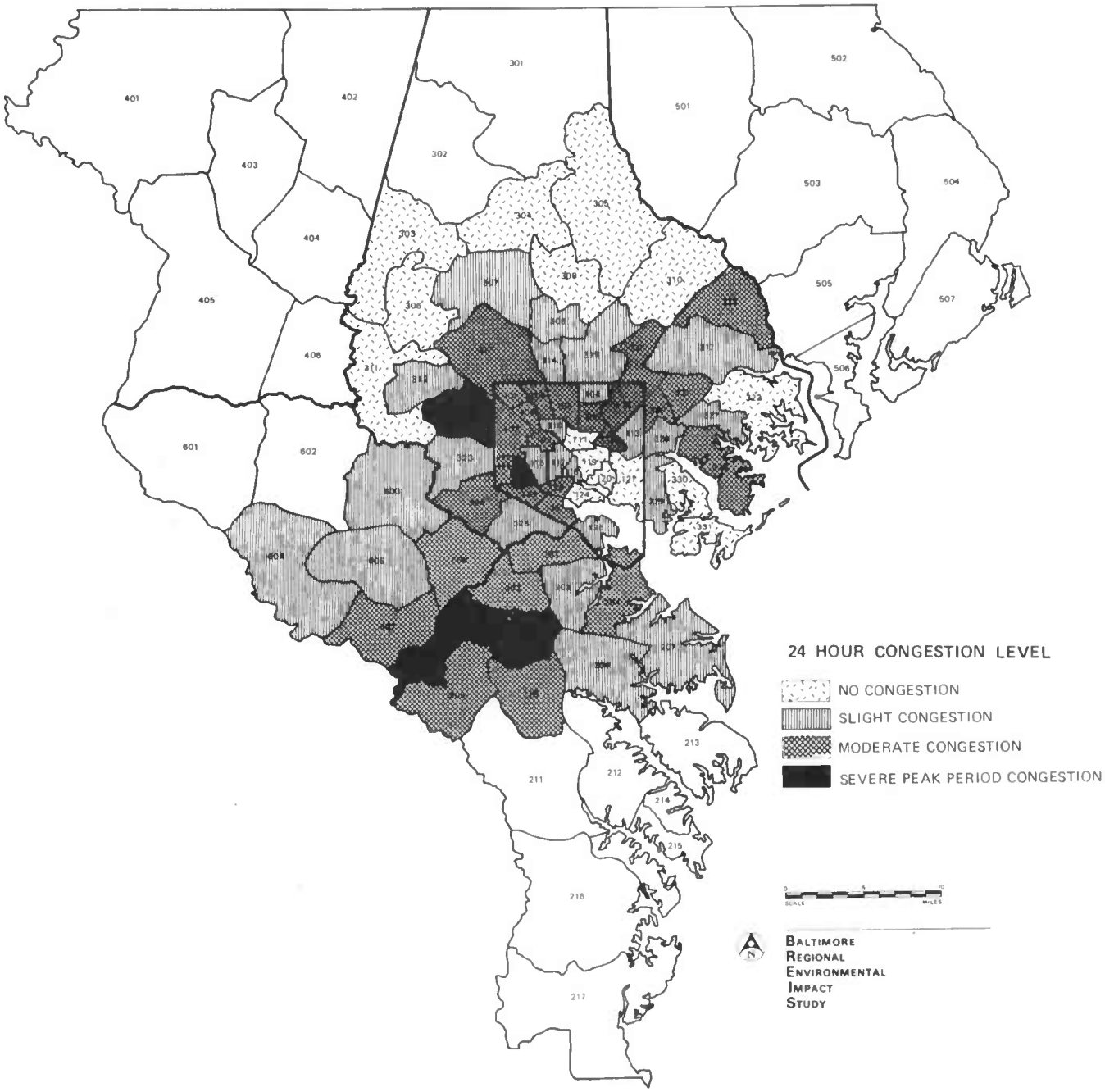


FIGURE V–9
1995 ALTERNATIVE 9
TRAFFIC CONGESTION LEVELS

where congestion on specific facilities will tend to become a major problem. Each of the analyses presented are for the 24-hour period, although the worst congestion would appear in peak hours.

Alternative 1 represents the 1970 system. In general, on a typical weekday, there were very few large problem areas and almost no areas of general congestion in Baltimore County. One area which stands out as a problem area in southern Howard and northern Anne Arundel Counties is in the I-95/ U.S.1/Baltimore-Washington Parkway corridor. This is due primarily to the lack of continuous arterial facilities in this area. The sections of Baltimore City which appear critical are western portions of Edmondson Avenue, some portions of the northwest corridor, and the northeastern area of the city.

Alternatives 3, 4, and 5 represent 1980 conditions. In each of the alternatives, general problems exist in the northwestern area of Anne Arundel County and the portion of Howard County including Columbia, although new construction of the basic arterial infrastructure helps to reduce these problems to some extent in 1980. The comparison of Alternatives 3 and 4 shows that deletion of the Fort McHenry Crossing does not create major traffic problems in any single RPD, and overall levels of congestion remain approximately the same. The major point to be noted in these two alternatives is the increasing tendency toward congestion problems found in a band across the entire northern portion of Baltimore City and extending out into Baltimore County.

Alternative 5, which eliminates the 3-A system, shows more general congestion throughout the region, with major problems in the northwestern area of Baltimore County and areas in the western section of Baltimore City. In fact, in Alternative 5 a band appears at approximately the Baltimore City boundary, extending in both the city and the county with potential congestion problems. This band runs fully around the city.

Alternatives 6 through 9 represent 1995 assumptions. In Alternative 6, there are large areas where congestion will not be a problem and also major areas where, while selected links may begin to experience difficulty, there will be no major area problems. In fact, in Alternative 6 there is no single RPD which appears to be heavily congested. The major areas which tend toward problems are in the western portion of Baltimore City, and the adjacent portion of Baltimore County, extending out into Howard County.

Alternative 7 presents a somewhat similar picture. This alternative, which provides for construction of highway improvements except for the 3-A system does show one area in the western portion of Baltimore along Edmondson

Avenue which would appear to have general areawide problems. Relief from congestion would be found in portions of Howard and Anne Arundel Counties which tended to be congested in the GDP system. This arises primarily from the reduction in the desire to travel toward the city, and hence, the congestion on arterial roads serving the radial movement. Some areas in the northwestern portions of Baltimore City show a greater tendency towards congestion under Alternative 7 than Alternative 6.

Alternative 8 represents a situation in which the 3-A system is built but there is no other highway construction. A major tendency toward congestion will be found under this alternative in the northwestern section of Anne Arundel County and the portion of Baltimore County directly adjacent to the city south of Reisterstown Road. In addition, a strong tendency toward congestion at certain hours appears in large portions of Baltimore County, Howard County, and northern Anne Arundel County. Even within the city where construction is carried out, there would be a strong tendency toward congestion in the entire northern half of the city.

Finally, Alternative 9 represents the do-nothing situation. In this alternative there is general congestion throughout the region except in the outlying reaches of Baltimore County and a few areas on the eastern side of the city in Baltimore. Major problem areas would appear in northwestern Anne Arundel County, portions of Baltimore County south of Reisterstown Road, the Edmondson Avenue Corridor, and portions of Baltimore City. A strong tendency for congestion appears at the major diagonal access running along the Baltimore-Washington Parkway through the city and out the Kennedy Expressway to the northeast. Similar tendency for congestion appears in the corridors running north toward Towson and northwest toward Reisterstown.

Travel Service Measurements

One of the principal purposes of any transportation system is to move persons between points throughout the region. It is appropriate, therefore, that an analysis be undertaken to determine how well travelers are being served. Up to this point, the analysis has focused on how well the alternative highway and transportation systems are performing as systems. It is possible that a system could be performing very efficiently and yet be providing very poor service to its users, and vice versa. Emphasis, therefore, will be on the door-to-door travel of the individual.

The analysis results detailed in this section have been provided with the aid of a special computer program. The principal inputs to this program are several simulated zone-to-zone impedance measures by the highway

and transit systems, as well as simulated person trip tables for auto drivers, transit trips, and total trips. In addition, several forecast zonal characteristics have been input. Among them are parking costs, highway terminal time, income levels, population, and employment. The program provides summaries for the trips produced in several sets of geographical areas--traffic zones, regional planning districts, jurisdictions, and the region as a whole. In the tables which follow, analysis results are presented at jurisdiction and regional levels. Further breakdowns according to the traffic zones and regional planning districts may be obtained with reference to the computer printouts.

The evaluations in this section were conducted for the 24-hour simulations of Alternatives 1, 3, and 6 and the peak period simulations for Alternatives 1, 3, 6, 7, and 9. The 24-hour simulations are for those alternatives which include the complete program of 3-A and other GDP improvements.

User Costs

The first sets of evaluation measures to be discussed are the trip travel costs. A basic assumption was made that the operating and ownership cost of an automobile is 13 cents per mile. (11) (It should be noted that the mode choice analysis uses a figure of 5 cents per mile to approximate operating costs, but it omits ownership costs.) In addition, the automobile costs also include one-half of the all-day parking costs at the destination end of the trip. The transit fares are based on the actual charges that a person would have to pay for each particular door-to-door trip that could be made on the system. For 1970, these fares were the rates in effect for the bus companies serving the area at that time. For 1980 and 1995, the fare systems developed after discussions with MTA personnel were applied. These fare systems assumed a central flat fare zone of 30 cents in constant dollars. Additional mileage charges were levied to rail riders, and zone fares were applied to the bus lines. In addition, all trips involving any transfer between bus lines or between the bus and rail system were charged an additional 5 cents. On express bus lines which were to exist in 1980, premium charges of 5 or 10 cents were levied. A further discussion of the transit fare coding is contained in a report being prepared by AMV on travel models. (3)

It should be remembered that each of the highway system alternatives results in a different land use pattern. Hence, all the statistics presented in this section are strongly dependent on the distribution of population and employment in the region and also upon the orientation of travel within it. An important point to remember is that each summary statistic presented is applicable only to those persons who would be resident in the particular jurisdiction

or RPD for the alternative being considered. It must also be remembered that in this particular evaluation the cost measures employed are sensitive only to travel distance and parking cost, and not to speed. In comparing the alternative systems 1980, residents in all jurisdictions are forecast to incur slightly lower trip costs than 1970 residents. Average trip costs in 1995 will depend on the alternative highway and land use system being discussed.

In comparing travel costs among jurisdictions, it can be seen that the peak-period travel costs for Howard County residents drop appreciably between 1970 and 1980, and also between 1980 and 1995. This is due in large measure to nonresidential growth in the county and the resulting shorter trips as the communities mature. For residents of the other three jurisdictions, travel costs in peak periods remain fairly stable. Baltimore City residents incur the lowest travel costs under all the alternatives, whereas travel costs will be highest for residents of Anne Arundel and Howard Counties.

For residents of Baltimore City and Baltimore County, the average transit cost will not change appreciably among the various alternatives. It is estimated that the average transit fare will drop appreciably for Anne Arundel County residents between 1970 and 1980. One reason is that in 1970 Anne Arundel County residents were served by several private operators whose fare systems were higher than the assumed future MTA levels. In additon, a number of riders living in this jurisdiction had to pay multiple fares when using the lines of more than one bus company. Tripmakers from Howard County are forecast to pay higher fares in 1980 and 1995 than in 1970. The reason for this is the fact that Howard County had insignificant local bus service in 1970; those transit trips made on the MTA were park-ride trips, where the tripmakers drove toward downtown Baltimore, bypassing many of the fare zone boundaries the future transit rider is expected to cross on bus or rapid transit lines. Although fares paid will be higher, these persons will be freed of the expenses for driving to and parking at the transit stop.

It can be seen for all the systems tested that peak period cost on the average would be higher than the average costs over the 24-hour period. Again, the reason for this is the predominance of the longer trips which cross more fare zone boundaries and make more bus-to-bus or bus-to-rail transfers than will the kind of trips which take place in the off-peak period. (See Table V-3.)

Travel Time

Several alternative methods of examining the travel time for individual trips are presented in Table V-4. These statistics are for all highway trips, whether or not the person was a driver or a passenger. However, through

Table V-3

TRAVEL COST COMPARISON
FOR RESIDENTS OF EACH JURISDICTION

| | Alternative | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Peak Period | | | | | 24-Hour Period | | |
| | 1970 | 1980 | 1995 | | | 1970 | 1980 | 1995 |
| | 1 | 3 | 6 | 7 | 9 | 1 | 3 | 6 |
| Average Cost per Highway Trip (cents) for residents of: | | | | | | | | |
| Baltimore City | 47 | 44 | 47 | 46 | 45 | 32 | 33 | 34 |
| Anne Arundel County | 83 | 79 | 82 | 82 | 73 | 49 | 52 | 53 |
| Baltimore County | 75 | 72 | 75 | 74 | 69 | 40 | 45 | 47 |
| Howard County | 99 | 83 | 83 | 81 | 73 | 55 | 54 | 54 |
| Metropolitan Area | 64 | 63 | 68 | 67 | 61 | 38 | 42 | 44 |
| Average Transit Cost (cents) for Residents of: | | | | | | | | |
| Baltimore City | 40 | 37 | 36 | 36 | 36 | 37 | 36 | 35 |
| Anne Arundel County | 87 | 57 | 55 | 55 | 54 | 80 | 56 | 56 |
| Baltimore County | 50 | 47 | 46 | 46 | 46 | 46 | 48 | 47 |
| Howard County | 40 | 69 | 67 | 67 | 68 | 40 | 70 | 65 |
| Metropolitan Area | 43 | 40 | 41 | 41 | 41 | | | |

Table V-4

HIGHWAY TRAVEL TIME COMPARISON

FOR RESIDENTS OF EACH JURISDICTION

| | Peak Period | | | | | 24-Hour Period | | |
|---|---|---|---|---|---|---|---|---|
| | 1970 | 1980 | 1995 | | | 1970 | 1980 | 1995 |
| | 1 | 3 | 6 | 7 | 9 | 1 | 3 | 6 |
| Average Door-to-Door Travel Time for Residents of | | | | | | | | |
| Baltimore City | 16 | 16 | 16 | 17 | 18 | 15 | 14 | 14 |
| Anne Arundel County | 25 | 25 | 23 | 23 | 30 | 21 | 22 | 21 |
| Baltimore County | 19 | 20 | 19 | 20 | 22 | 17 | 18 | 17 |
| Howard County | 25 | 26 | 24 | 24 | 31 | 22 | 22 | 22 |
| Metropolitan Area | 19 | 20 | 19 | 20 | 23 | 17 | 17 | 17 |
| Percent of Highway Trips with Constrained Travel Time/ Unconstrained Travel Time for residents of: | 1.25 | | | | | | | |
| Baltimore City | 17 | 21 | 16 | 26 | 40 | | | |
| Anne Arundel County | 40 | 43 | 25 | 30 | 61 | | | |
| Baltimore County | 14 | 16 | 9 | 14 | 39 | | | |
| Howard County | 29 | 60 | 35 | 34 | 66 | | | |
| Metropolitan Area | 19 | 25 | 17 | 23 | 46 | | | |
| Percent of Highway Trips Longer than 30 Minutes for Residents of | | | | | | | | |
| Baltimore City | 10 | 10 | 10 | 11 | 14 | 6 | 6 | 7 |
| Anne Arundel County | 34 | 34 | 29 | 30 | 42 | 25 | 26 | 23 |
| Baltimore County | 18 | 19 | 18 | 19 | 25 | 13 | 15 | 13 |
| Howard County | 32 | 38 | 32 | 31 | 48 | 26 | 29 | 26 |
| Metropolitan Area | 17 | 19 | 19 | 20 | 26 | 12 | 14 | 14 |
| Average Increase in Travel Time Due to Congestion | | | | | | | | |
| Time in Minutes | 3.0 | 3.8 | 2.9 | 3.3 | 6.7 | | | |
| Percentage Increase | 17% | 22% | 16% | 18% | 38% | | | |

trips are excluded. The first measure is the average door-to-door travel time for all the trips which were made by residents of each of the jurisdictions. In the 24-hour period, these averages within each jurisdiction will not change appreciably in 1980 or 1995 if the full program of GDP improvements is implemented (Alternatives 3 and 6). Door-to-door travel times presented include terminal times (parking and walking) at the origin and destination ends of the trip, and the travel time on the road system using the constrained times (taking into account both peak and off-peak conditions over the entire day) produced after the final iteration of the travel assignment process (see Section IV). The same phenomenon occurs in the peak period with Alternatives 1, 3, and 6. If the GDP without the 3-A (Alternative 7) is implemented, there will be a noticeable change in peak period travel times for Baltimore City and Baltimore County residents. If the do-nothing program (Alternative 9) is implemented, the travelers will notice appreciably longer travel times, particularly for residents of Anne Arundel and Howard Counties.

The second measure used to evaluate travel time is based on the amount of congestion the typical tripmaker will encounter. The particular evaluation measure is the ratio of the travel time under peak conditions to the travel time under off-peak conditions for each trip made. Peak travel time is the travel time on the highway system resulting from a complete capacity restrained loading, as described in Section IV. Both the constrained and unconstrained travel times include terminal times as well as the over-the-road travel times.

Since the analysis using this measure is exploratory in nature, the critical value for the ratio was set arbitrarily at 1.25. Table V-5 shows percentage of trips by residents of each jurisdiction for which the ratio is greater than 1.25.

A significantly larger number of people would encounter ratios of 1.25 and above in 1980 as compared with 1970. In fact, 60 percent of the trips made by residents of Howard would experience this congestion in 1980 (Alternative 3). This would drop back to 35 percent if the full system of GDP improvements is complete in 1995 (Alternative 6). Without the 3-A system (Alternative 7) in the peak period, residents of all jurisdictions but Howard County are forecast to encounter more congestion than under the conditions of the full system (Alternative 6). In the peak period, 46 percent of the highway tripmakers would encounter a constrained travel time ratio greater than 1.25 if the GDP and 3-A improvements are not built (Alternative 9). For this alternative, the highest percentages are recorded for all jurisdictions and the comparison with peak-period travel under the full system test (Alternative 6) is most marked.

Table V-5

TRANSIT TRAVEL TIME COMPARISON
FOR RESIDENTS OF EACH JURISDICTION

| | Alternative | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Peak Period | | | | | 24-Hour | | |
| | 1970 | 1980 | 1995 | | | 1970 | 1980 | 1995 |
| | 1 | 3 | 6 | 7 | 9 | 1 | 3 | 6 |
| **Average Door-to-Door Travel Time for Residents of** | | | | | | | | |
| Baltimore City | 41 | 36 | 27 | 27 | 27 | 41 | 37 | 30 |
| Anne Arundel County | 80 | 53 | 47 | 48 | 47 | 92 | 70 | 62 |
| Baltimore County | 59 | 51 | 37 | 37 | 37 | 66 | 58 | 44 |
| Howard County | 78 | 62 | 57 | 56 | 56 | 135 | 100 | 72 |
| Metropolitan Area | 46 | 40 | 31 | 32 | 32 | 51 | 45 | 37 |
| **Percent of Highway Trips Longer than 30 Minutes for Residents of** | | | | | | | | |
| Baltimore City | 60 | 53 | 29 | 29 | 30 | 58 | 51 | 26 |
| Anne Arundel County | 91 | 86 | 83 | 85 | 84 | 81 | 87 | 84 |
| Baltimore County | 86 | 79 | 64 | 64 | 64 | 88 | 83 | 68 |
| Howard County | 96 | 98 | 95 | 94 | 95 | 94 | 88 | 89 |
| Metropolitan Area | 66 | 61 | 44 | 45 | 45 | 66 | 61 | 43 |

The third measure used to evaluate travel time is the percentage of highway trips which exceed specified travel time. In this evaluation, the standard has been arbitrarily set at 30 minutes. On a 24-hour basis, there is little variance among Alternatives 1, 3, and 6 in each of the jurisdictions. Overall, 12 percent of the 1970 trips took longer than 30 minutes; this percentage would rise to 14 percent under the conditions of Alternatives 3 and 6. In the peak period, the regional comparison for Alternative 1, 3, and 6 provides a similar rise--from 17 to 19 percent. It should be noted, however, that in Howard County the percentage of trips longer than 30 minutes would rise to 38 percent in 1980 but drop back to 32 percent for the full system in 1995. This measure shows little difference between trips made in Alternatives 6 and 7. However, under the conditions of the no-build alternative (Alternative 9), more highway travelers are likely to find their trip lengths longer than 30 minutes. It should be emphasized that the standard of 30 minutes is not a magic number and has been arbitrarily set.

The final measure concerning travel time is the increase in travel time caused by the fact that the highway networks operate with some congestion. The measure used is the difference between the average constrained and unconstrained travel times. The regional average increases have been computed for each system and are shown on the second last line of Table V-4. The bottom line indicates what percentage of the unconstrained travel time this increase represents.

In the peak period, 1980 Alternative 3 presents a higher values than Alternatives 1 or 6. The effects of not building the 3-A system can be seen in the Alternative 7 value, which is 3.3 minutes. If none of the GDP improvements is built in 1995 (Alternative 9), congestion will increase residents' travel time an average of 6.7 minutes, or 39 percent above free-flow conditions.

The value of 2.1 minutes computed for the full 1995 system (Alternative 6), does not seem like a very high number. However, when it is applied to the 4,274,000 daily vehicle trips, it amounts to 150,000 vehicle-hours of additional travel time over a 24-hour period. This value becomes even larger for Alternatives 7 and 9 with less amounts of highway construction.

Evaluation of transit travel time (Table V-5) is most markedly affected by the institution of the rapid transit system. It is estimated that the average trip time on a 24-hour basis using the existing all-bus system is 51 minutes in 1970. For 1980 Alternative 3, the mean would drop to 45 minutes, and the 1995 population (Alternative 6) would encounter a 36-minute average trip time. The changes from jurisdiction to jurisdiction should also be noted.

In Baltimore City, the average travel time would drop from 41 to 37 minutes in 1980 and to 30 minutes in 1995. However, in the suburban counties the travel time reduction would be much more pronounced. In Anne Arundel County, the Phase I system would reduce average transit travel time from 92 to 70 minutes. Although the rail trip from Marley to Charles Center takes only 23 minutes, it must be remembered that each rider has to get to and from the rail line at each end of his trip and that transit trip will be made to many of the destinations. The addition of the remainder of the rail system helps to reduce the travel time of Anne Arundel to 62 minutes in 1995.

For all Baltimore County residents. the Phase I rail system reduces a typical transit trip by an average of 8 minutes, but the completion of the full 6-legged system would reduce the 1970 average travel times by a third. In Howard County, the value of 135 minutes in 1970 reflects the fact that this jurisdiction is not conveniently served by any transit connecting it with the rest of the region. The drop to 100 minutes in 1980 indicates that this jurisdiction is not well served by public transit. A loss trip is required just to get to the rail system. As with travelers in Anne Arundel County, they must still get to either the rail stations or the express bus stops to utilize these systems. In 1995, expanded express bus service and completion of the western rapid transit line to Rolling Road reduces average transit travel time of Howard County residents to 72 minutes.

The institution of the rapid transit system significantly affects peak-period travel. Because a greater proportion of the peak period transit trips are radially oriented and because transit service is better in a radial direction, the peak period travel times for each alternative are less than the 24-hour trip times. On a region-wide basis, the first phase of the rail system will lower average transit times from 46 minutes to 40 minutes in 1980, and to 31 or 32 minutes by 1995, depending on the alternative. The minor differences between alternatives in the 1995 peak-period travel times are due to the distribution (i.e., the origin and destination pattern) of transit travel rather than to any differences in the assumed transit system service levels.

Table V-5 also shows the percent of transit trips which are longer than 30 minutes for each of the eight alternatives. The effects of instituting the rail system are most noted for residents of Baltimore City and Baltimore County. In Anne Arundel and Howard Counties, even with the 6-legged system, many transit trips have travel times appreciably longer than 30 minutes.

Accessibility

An important measure for evaluating transportation systems is the accessibility they provide to jobs and other activities throughout the study area. One

measure of accessibility is the mean travel time to all jobs in the region. Accessibility to employment via both highway and transit has been summarized by jurisdiction. Additionally, the accessibility of all the residents in the study area to Charles Center by highway and transit is presented.

The accessibility measure used in this evaluation has been labeled the opportunity time. For residents of a particular area, the opportunity time to employment represents the mean travel time from that zone to all jobs in the metropolitan area. Data for each zone are contained in the printouts from the eight system evaluations completed. In addition, the opportunity time to employment has also been computed at the RPD, jurisdiction, and regional levels. In each case, the opportunity time for these larger areal units is an unweighted average of the opportunity times of the zones in that particular geographic area. As with the tabulations presented in previous tables, it should be remembered that the statistics presented are dependent not only on the highway and transit system in each particular alternative, but also on the distribution and amount of population and employment. It can be seen from Table V-6 that the opportunity times to population and employment under the conditions of Alternatives 1 (1970), 3 (1980) and 6 (1995) differ very little on a 24-hour basis. In the peak period, the opportunity times increase slightly for the 1995 GDP (Alternative 7) and more substantially for the 1995 no-build (Alternative 9), particularly for Anne Arundel and Howard Counties. In the Alternative 9 situation, as well as there being no highway improvements between 1970 and 1995, there is very little growth of employment in these jurisdictions. As the road system is more overloaded, the opportunity times will be appreciably greater than the 1970 values.

The opportunity times via transit are markedly affected by the implementation of the rapid transit system. The regional value in 1970 is 90 minutes via transit. In 1980 the completion of the first 2 legs of the rapid transit system is expected to lower the opportunity time to 73 minutes. With the completion of the full-scale rapid transit system expected in 1995, the regional value will be 54 minutes, in other words, a 40 percent drop from the 1970 values. The opportunity times for Alternative 7 and 9 via transit are little different from Alternative 6, as the same transit network and same transit travel times and frequencies are assumed for all the 1995 alternative system simulations. The decreases in opportunity times to employment via transit are equally as dramatic in each of the four political jurisdictions being studied as they are on a region-wide basis, as the statistics in Table V-6 indicate.

As an example of the use of opportunity time as an accessibility measure of destination service, the opportunity times for the region's residents to Charles Center via highway and transit have been tabulated at the bottom

Table V-6

OPPORTUNITY TIME COMPARISON
FOR RESIDENTS OF EACH JURISDICTION

| | Alternative | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Peak Period | | | | | 24-Hour | | |
| | 1970 | 1980 | 1995 | | | 1970 | 1980 | 1995 |
| | 1 | 3 | 6 | 7 | 9 | 1 | 3 | 6 |
| Highway Opportunity Time for Residents of: | | | | | | | | |
| Baltimore City | 23 | 22 | 23 | 25 | 28 | 21 | 21 | 21 |
| Anne Arundel County | 42 | 39 | 36 | 37 | 52 | 37 | 36 | 34 |
| Baltimore County | 31 | 31 | 30 | 32 | 38 | 31 | 30 | 30 |
| Howard County | 42 | 39 | 35 | 38 | 49 | 37 | 34 | 33 |
| Metropolitan Area | 29 | 28 | 28 | 30 | 36 | 28 | 27 | 27 |
| Transit Opportunity Time for Residents of: | | | | | | | | |
| Baltimore City | 69 | 60 | 45 | 45 | 44 | 69 | 60 | 45 |
| Anne Arundel County | 109 | 76 | 64 | 64 | 63 | 109 | 76 | 64 |
| Baltimore County | 104 | 84 | 58 | 58 | 57 | 104 | 84 | 58 |
| Howard County | 113 | 85 | 68 | 68 | 68 | 113 | 85 | 68 |
| Metropolitan Area | 90 | 73 | 54 | 54 | 53 | 90 | 73 | 54 |
| Time to Charles Center for all Residents | | | | | | | | |
| Highway | 27 | 28 | 29 | 31 | 34 | 24 | 25 | 26 |
| Transit | 55 | 50 | 42 | 44 | 41 | 55 | 50 | 42 |

of Table V-6. (The data for other activity sites can be obtained from the print-outs prepared for this evaluation work.) These data indicate that in 1970 the average travel time to Charles Center via highway was 24 minutes on a 24-hour basis. This value is expected to rise to 25 and 26 minutes, respectively, in 1980 and 1995 if all GDP system improvements are implemented. In the peak period, the corresponding highway travel times to Charles Center are 27, 28, and 29 minutes. Under the conditions of Alternatives 7 or 9, these times would increase further to 30 or 34 minutes. As can be seen on the bottom line, the opportunity times by transit decrease over time due to the expected implementation of the rapid transit system. The differences among Alternatives 6, 7, and 9 for transit opportunity time are dependent upon the distribution of population in the region. Alternative 7 contains more population in the suburbs relative to Alternative 6, and hence the opportunity time to Charles Center is slightly higher. In Alternative 9, with relatively more of the region's population in Baltimore City, the opportunity time provided is one minute less than the Alternative 6 value.

Transit Usage

In addition to the user service measures discussed above, the evaluation summarizes the number of trips by mode produced in each zone, RPD, and jurisdiction as well as giving regional totals. The transit trip data and percent transit for each jurisdiction are presented in Table V-7. In the peak period in 1970, the 82,586 transit trips represent 11 percent of all peak-period person trips. These figures are forecast to increase by as much as 194,580 trips (16 percent) in 1995 if the do-nothing highway alternative is adopted and the land use patterns come about as predicted. Transit ridership will be less in 1995 without the 3-A system than with the 3-A system, primarily due to the activity patterns projected.

The growth in transit ridership will be most pronounced for residents of the suburbs. In 1970, the suburban counties produced less than 23 percent of the peak period transit trips. In 1995 they can be expected to produce between 35 percent (Alternative 9) and 37 percent (Alternative 7) of peak period transit travel.

The implementation of the rapid transit system affects both the absolute number of transit trips and the mode choice percentage in all jurisdictions. In Baltimore City, this percentage would rise from 16 percent in 1970 to 18 percent in 1980 and 22 or 23 percent in 1995. In the suburbs, the mode choice percentages will more than double in all jurisidctions between 1970 and 1995 if the rapid transit system is implemented and the land use forecasts are realized.

TABLE V-7

SUMMARY OF MODE CHOICE FOR RESIDENTS OF EACH JURISDICTION

| Transit Trips by Mode for Residents of: | Peak Period* | | | | | 24-Hour Period | | |
|---|---|---|---|---|---|---|---|---|
| | 1970 | 1980 | 1995 | | | 1970 | 1980 | 1995 |
| | 1 | 3 | 6 | 7 | 9 | 1 | 3 | 6 |
| Baltimore City | 63,754 | 80,981 | 114,357 | 107,561 | 126,920 | 259,620 | 302,293 | 402,225 |
| Anne Arundel County | 3,513 | 7,812 | 14,066 | 14,978 | 16,212 | 12,810 | 24,797 | 46,431 |
| Baltimore County | 14,719 | 20,177 | 43,937 | 42,673 | 44,694 | 78,132 | 78,935 | 146,438 |
| Howard County | 600 | 1,830 | 5,508 | 5,366 | 6,748 | 4,808 | 7,783 | 20,802 |
| Metropolitan Area | 82,506 | 110,808 | 177,868 | 170,578 | 194,580 | 355,370 | 413,806 | 615,896 |
| **Percent of Person Trips for Residents of:** | | | | | | | | |
| Baltimore City | 20 | 22 | 28 | 29 | 30 | 17 | 17 | 19 |
| Anne Arundel County | 5 | 8 | 9 | 10 | 13 | 3 | 4 | 5 |
| Baltimore County | 6 | 7 | 11 | 11 | 13 | 6 | 5 | 7 |
| Howard County | 3 | 3 | 5 | 5 | 7 | 4 | 2 | 3 |
| Metropolitan Area | 12 | 13 | 17 | 17 | 20 | 10 | 9 | 11 |
| **Proportion of 1970 Transit Trips for Residents of:** | | | | | | | | |
| Baltimore City | 1.00 | 1.27 | 1.79 | 1.69 | 1.99 | 1.00 | 1.16 | 1.55 |
| Anne Arundel County | 1.00 | 2.22 | 4.00 | 4.26 | 4.61 | 1.00 | 1.94 | 3.62 |
| Baltimore County | 1.00 | 1.37 | 2.99 | 2.90 | 3.04 | 1.00 | 1.01 | 1.87 |
| Howard County | 1.00 | 3.06 | 3.18 | 8.94 | 11.25 | 1.00 | 1.62 | 4.33 |
| Metropolitan Area | 1.00 | 1.34 | 1.43 | 2.07 | 2.36 | 1.00 | 1.16 | 1.73 |

* The miscellaneous trips are excluded from the 24-hour statistics. Park-and-ride trips are included for both the peak and 24-hour periods as transit trips.

## SUMMARY

This section has summarized some of the findings from the evaluations of transportation service measures. The statistics displayed are as much a result of the distribution of population and employment as they are of the particular highway system being implemented. It is apparent from the analysis in this section, as well as that in Section IV, that completion of the committed and programmed portion of the 3-A system will maintain current levels of highway service. The do-nothing alternative for 1980 (Alternative 5) did show some signs of deteriorating highway service.

The data output from the evaluation program has helped to clarify the travel results for 1995 as well as the changes between 1970 and 1980 and 1970 and 1995. A comparison of highway travel in 1970 and in 1995 if all the GDP improvements are implemented (Alternative 6) depends on the criteria used. However, without the 3-A system, travel within Baltimore City would clearly be more congested. Even though no-build system assumptions contain fewer persons in the region, travel is most congested of all alternatives tested.

The implementation of the rapid transit will have noticeable effects on travel in the future. For those people using it, travel will be much faster than the current all-bus arrangement. It will also be a viable alternative to those travelers wishing to avoid the congestion of the alternatives with limited highway improvements. Although transit will carry more riders in the future, it is forecast not to carry enough to eliminate the highway congestion forecast for all alternatives, but most particularly for Alternatives 8 and 9.

## LIST OF REFERENCES -- CHAPTERS IV AND V


1a. Alan M. Voorhees and Associates, "Travel Forecasting and Patronage and Revenue Estimates for Baltimore Region Rapid Transit System". Prepared for the Mass Transit Steering Committee, Regional Planning Council, Baltimore, Maryland, July, 1968.

b. Alan M. Voorhees and Associates, "Development and Calibration of a Model for Predicting Peak Period Travel". Prepared for the Baltimore Regional Planning Council, August, 1963.

c. Alan M. Voorhees and Associates, "A Report in Mode Choice Analysis for the Baltimore Region". Prepared for the Baltimore Regional Planning Council, 1969.

2. See Reference 1c.

3. To be included in a report on travel models being prepared by AMV for MdDOT (UTPP).

4. See Reference 1a.

5. See Technical Memorandum 1, Section VI.

6. See Reference 1a, pp. 15-31.

7. See Reference 1a, pp. 31-37.

8. National Academy of Sciences, Highway Capacity Manual, 1965.

9. See Reference 1b.

10. See Reference 1c.

11. See Reference 3.

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