Statewide ★ Transportation Analysis & Research

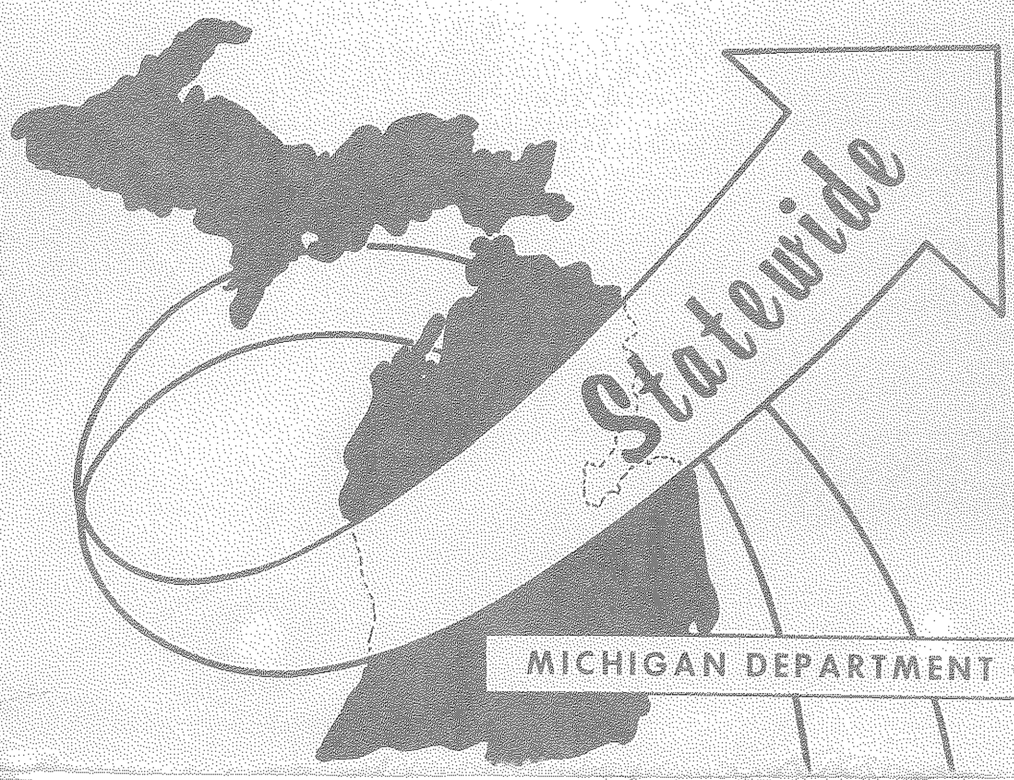
MICHIGAN'S

STATEWIDE TRAFFIC FORECASTING MODEL

VOLUME I

OBJECTIVES & WORK PROGRAM

December, 1970



MICHIGAN DEPARTMENT OF STATE HIGHWAYS

MICHIGAN DEPARTMENT OF STATE HIGHWAYS

In Cooperation With:

U.S. Department of Transportation
Federal Highway Administration

MICHIGAN'S STATEWIDE TRAFFIC FORECASTING MODEL

VOLUME I

OBJECTIVES & WORK PROGRAM

December, 1970

TRANSPORTATION PLANNING DIVISION
STATEWIDE STUDIES UNIT

Supervisor Richard E Esch

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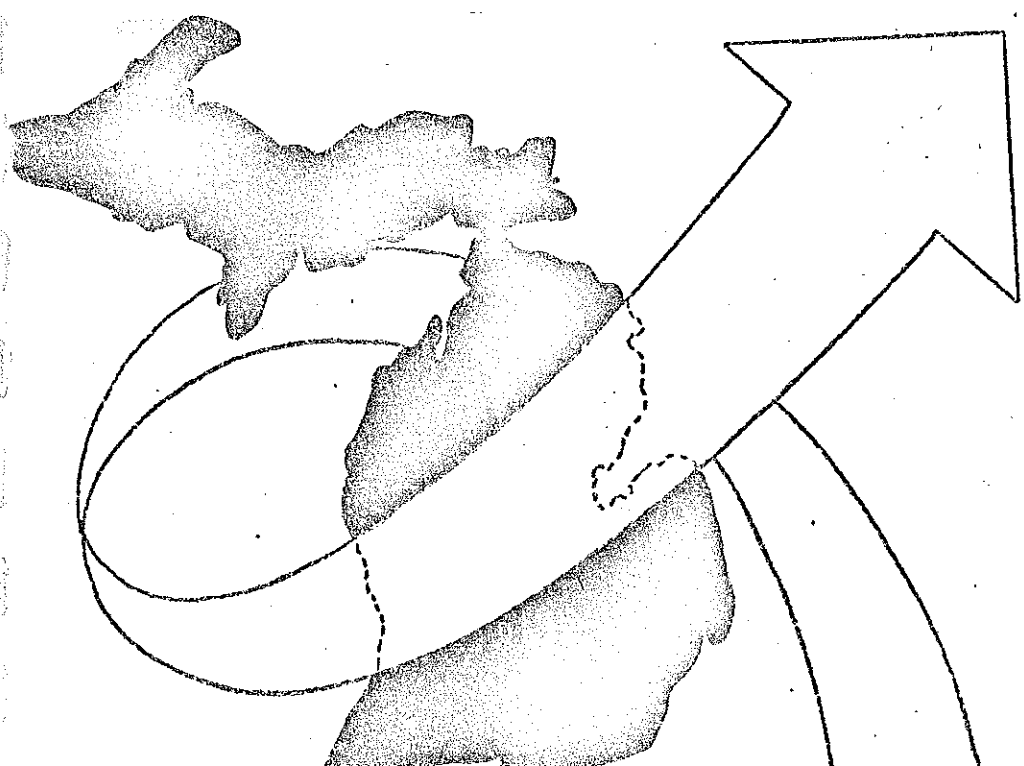


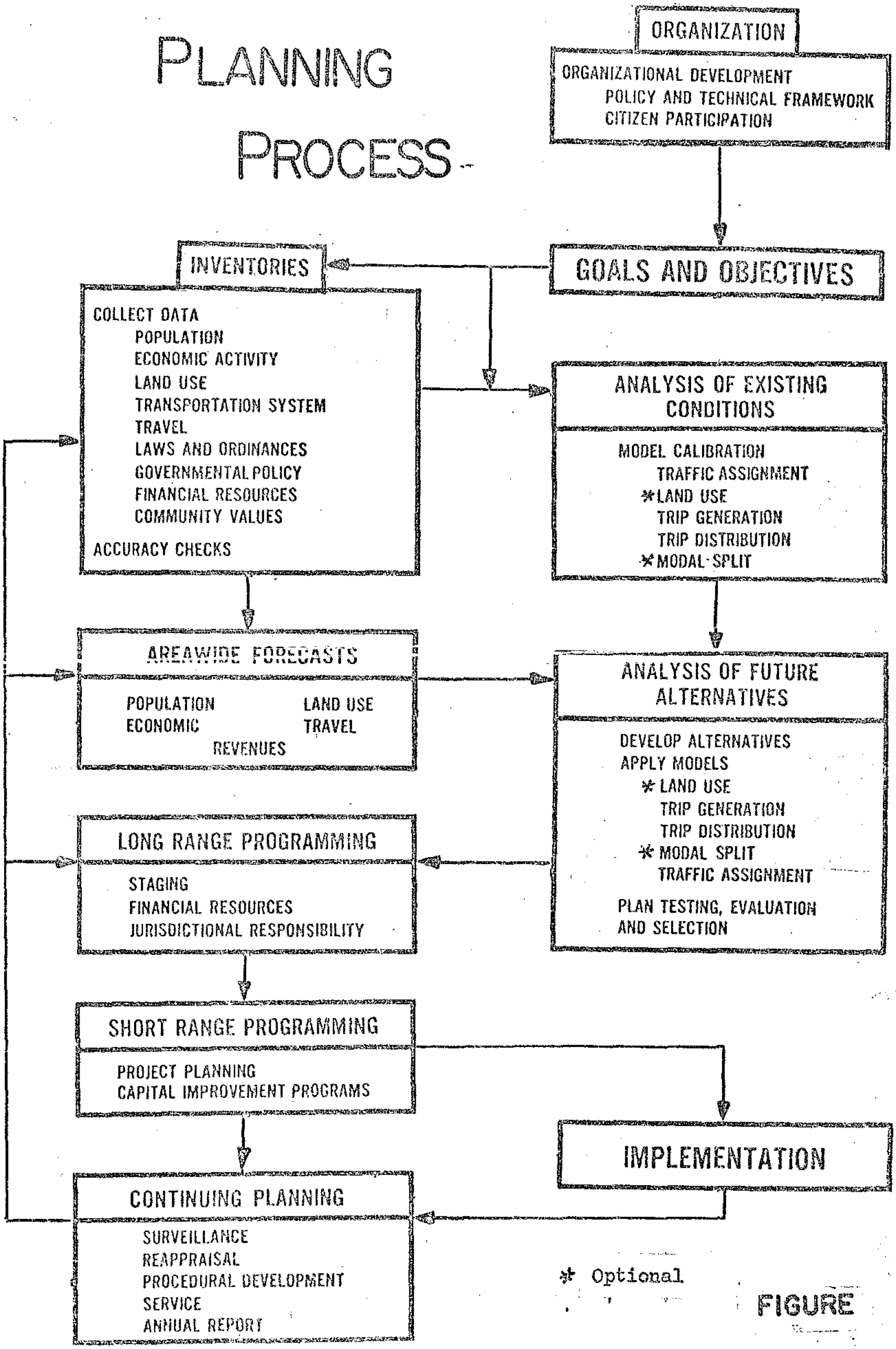
INTRODUCTION

In June, 1970, the Michigan Department of State Highways completed the initial development of a computerized statewide traffic forecasting model.

The department, in conjunction with the Federal Highway Administration and many of the more progressive Highway Departments, early in 1965 recognized the need for rapid development of a statewide traffic forecasting model which is the basis for comprehensive highway planning, design and construction. The diagram in figure 1 is a summary of the Federal Highway Administration's comprehensive transportation planning process. Because of the complexity of the environment, many state highway departments will need to rely heavily on this type of comprehensive planning process when developing a total state trunkline system.

Many states such as New York and Wisconsin have used techniques similar to Michigan's proposed statewide modeling process to successfully accomplish those tasks outlined in red within the transportation planning process diagram. Selected governmental agencies have also used the basic research and development efforts in their statewide modeling program as the initial input to the formulation of a statewide land use model. Statewide land use modeling techniques would be extremely valuable if applied within the framework of the transportation planning program as suggested in the Federal Highway Administration guideline.

TRANSPORTATION PLANNING PROCESS



FIGURE

Other state agencies such as the Department of Natural Resources and the Department of Commerce would also benefit from development of this type. Specific projects within their organizations have an existing need for land use projection data.

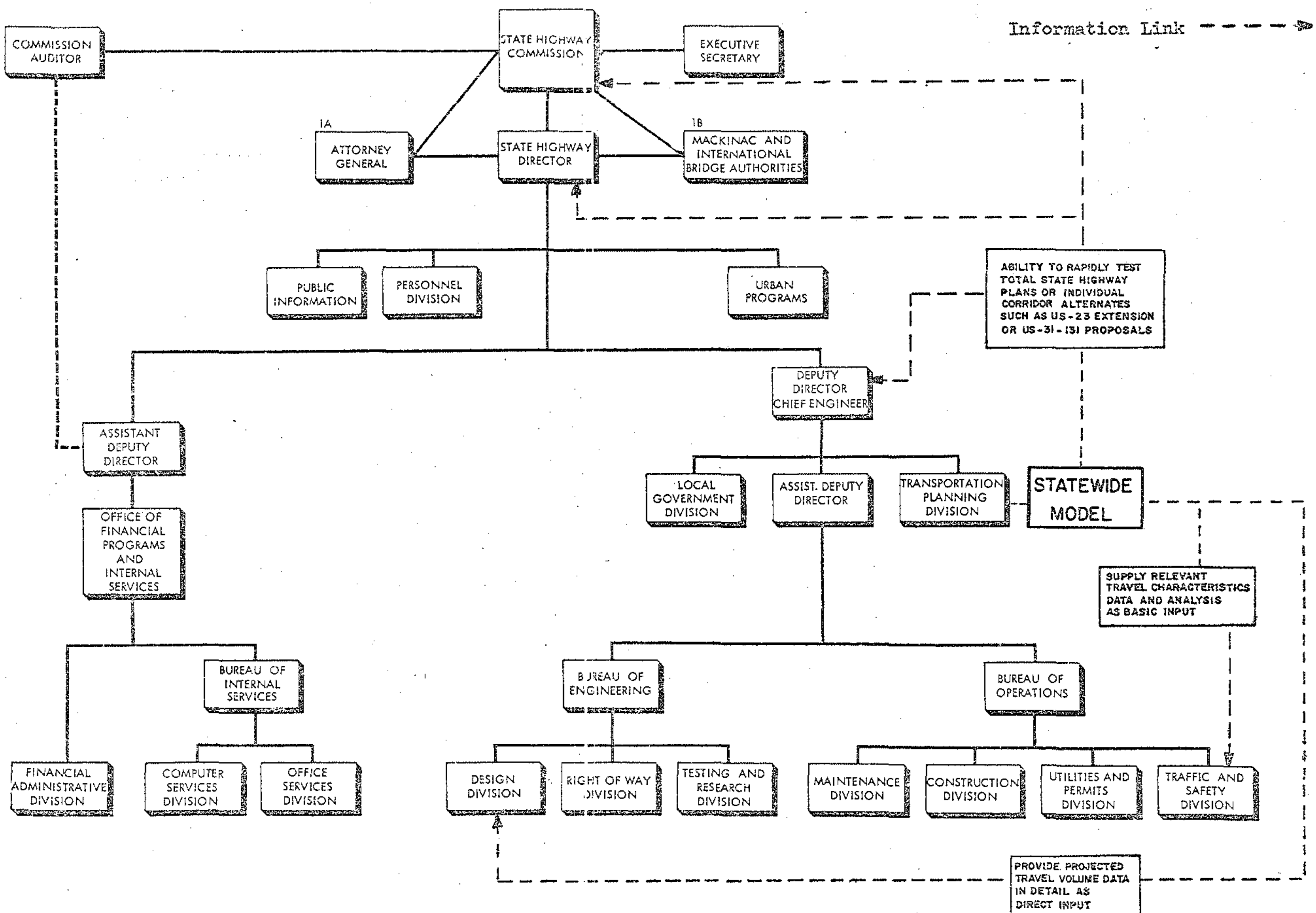
A statewide land use model would ultimately improve the Michigan Department of State Highways planning and construction program by supplying the necessary land use projections required in a comprehensive transportation planning process. This modeling effort would necessarily have to be less complex than similar urban models.

The Michigan Department of State Highways have taken a significant step in the formulation of a comprehensive transportation planning process through the preliminary development of a statewide traffic forecasting model. Creation of a computerized traffic model is critical to the operation of a functional highway construction program. Final calibration of this sophisticated modeling effort will provide members of the commission, legislators and other department administrators with the ability to obtain expedient cost-efficiency analysis of proposed trunkline systems or route location questions related to the development or planning of a total state trunkline system. The calibrated model will also allow any user to test alternate total highways systems, segments of the total system, or specified individual routes. Initial research and development has been conducted so that this same model may be applied at the administrative level as well as in the final highway design stage.

Selected examples of specific model applications at each decision-making level are presented in the figure 2. Model development responsibility is assigned the Statewide Studies Unit within the Transportation Planning Division but as this figure indicates there is unlimited potential use throughout the department.

Model development of this type within the Transportation Planning Division is critical to the division's efficient operation, because of the expanding scale and complexity of the comprehensive highway planning process. The scope of each subsequent transportation planning project, such as the needs and classification studies or the post-1977 bonding program, warrants immediate consideration of some sophisticated computerized technique similar to a statewide model. The Federal Highway Administration has recognized the necessity of developing a statewide traffic forecasting model. These models will be a primary importance in the future highway planning process as the letter on the page following figure 2 indicates.

A very brief resumé of the model's potential application specifically within the Transportation Planning Division appear in figure 3. These comments are the result of a review of existing application of statewide models within other state highway departments and therefore are tested operational uses. Completion of Michigan's statewide model development process would make these same applications available to the Michigan Department of State Highways.



MICHIGAN DEPARTMENT OF STATE HIGHWAYS

FIGURE 2

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
BUREAU OF PUBLIC ROADS
REGION FOUR
Lansing, Michigan
48901

December 29, 1969

IN REPLY REFER TO:

Mr. Henrik E. Stafseth
State Highway Director
Department of State Highways
Lansing, Michigan

Dear Mr. Stafseth:

We are attaching a copy of a field trip report by Messers. Hazen and Dean of our Washington office reviewing the Statewide Traffic Forecasting Model.

The progress on the Statewide Model is satisfactory and we believe it to have one of the highest priorities in the planning program. The quality and interest of those involved in utilizing the best possible procedures was encouraging. One of the deterrents to having a working Statewide Model is the existing staff limitations. We feel that the priority of this item warrants a review, by the department, in terms of increased staffing.

Sincerely yours,

Daniel Watt
Division Engineer

Attachment

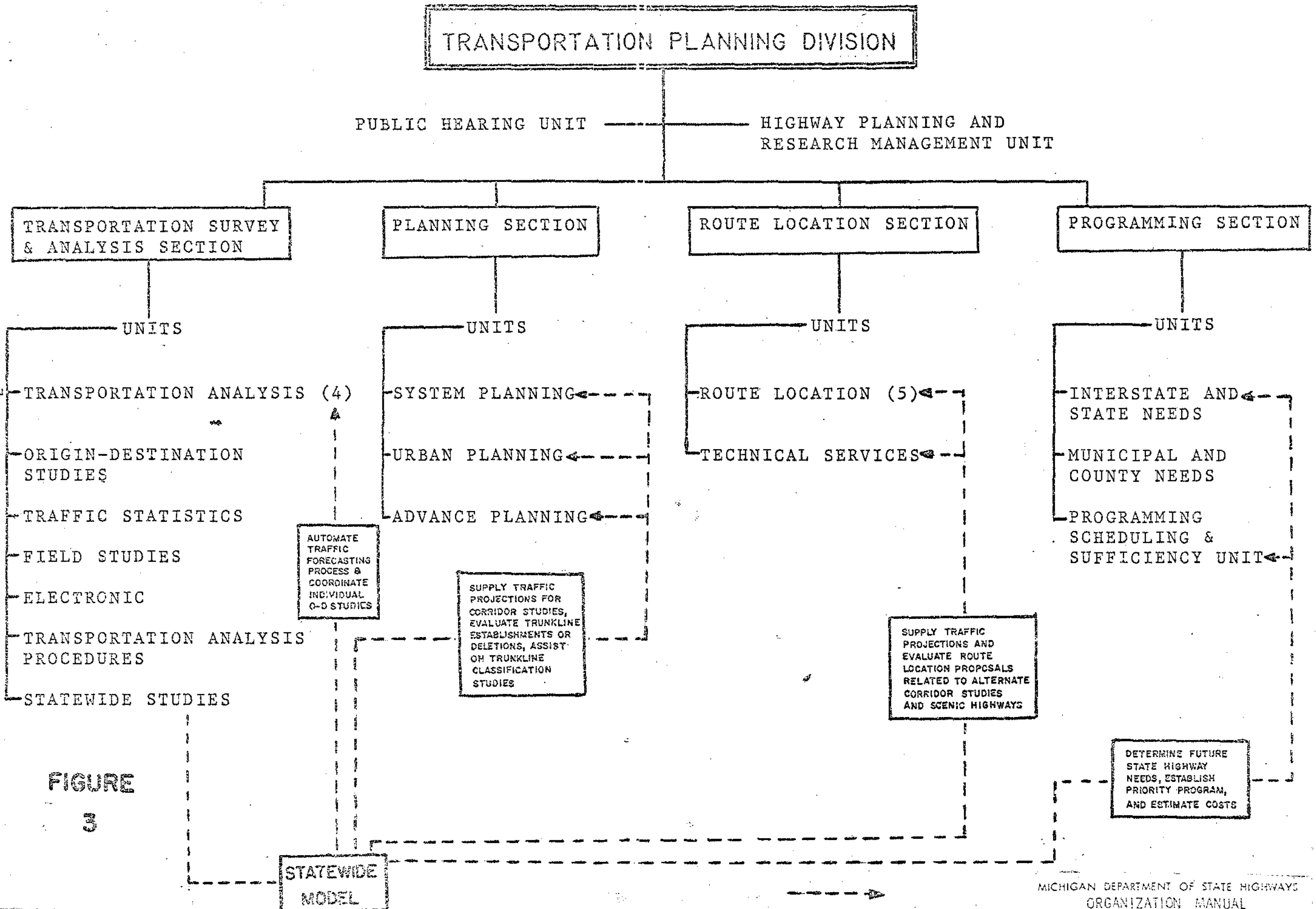

TRANSPORTATION PLANNING DIVISION
PUBLIC HEARING UNIT
HIGHWAY PLANNING AND RESEARCH MANAGEMENT UNIT
TRANSPORTATION SURVEY & ANALYSIS SECTION
PLANNING SECTION
ROUTE LOCATION SECTION
PROGRAMMING SECTION
UNITS
TRANSPORTATION ANALYSIS (4)
ORIGIN-DESTINATION STUDIES
TRAFFIC STATISTICS
FIELD STUDIES
ELECTRONIC
TRANSPORTATION ANALYSIS PROCEDURES
STATEWIDE STUDIES
UNITS
SYSTEM PLANNING
URBAN PLANNING
ADVANCE PLANNING
UNITS
ROUTE LOCATION (5)
TECHNICAL SERVICES
UNITS
INTERSTATE AND STATE NEEDS
MUNICIPAL AND COUNTY NEEDS
PROGRAMMING SCHEDULING & SUFFICIENCY UNIT
AUTOMATE TRAFFIC FORECASTING PROCESS & COORDINATE INDIVIDUAL O-D STUDIES
SUPPLY TRAFFIC PROJECTIONS FOR CORRIDOR STUDIES, EVALUATE TRUNKLINE ESTABLISHMENTS OR DELETIONS, ASSIST ON TRUNKLINE CLASSIFICATION STUDIES
SUPPLY TRAFFIC PROJECTIONS AND EVALUATE ROUTE LOCATION PROPOSALS RELATED TO ALTERNATE CORRIDOR STUDIES AND SCENIC HIGHWAYS
DETERMINE FUTURE STATE HIGHWAY NEEDS, ESTABLISH PRIORITY PROGRAM, AND ESTIMATE COSTS
STATEWIDE MODEL

FIGURE 3

In addition to the suggested applications in figure 3 the model's technical capabilities have been used by several state highways departments as a unifying element within the planning structure. The model also has been used to:

1. Supply for the first time complete detailed analysis of a total highway plan or alternate plans as a single project, rather than the manual segmented techniques presently in use.
2. Act as a binding element between each of the individual urban transportation studies, thereby filling a void that presently exists.

As a refined transportation planning tool, this model will allow the Division to supply both the administration and commissioners with explicit informed answers to questions that arise regarding such subjects as the US-2 "freeway", US-23 extension, scenic highway projects and the "post-1977 bonding program".

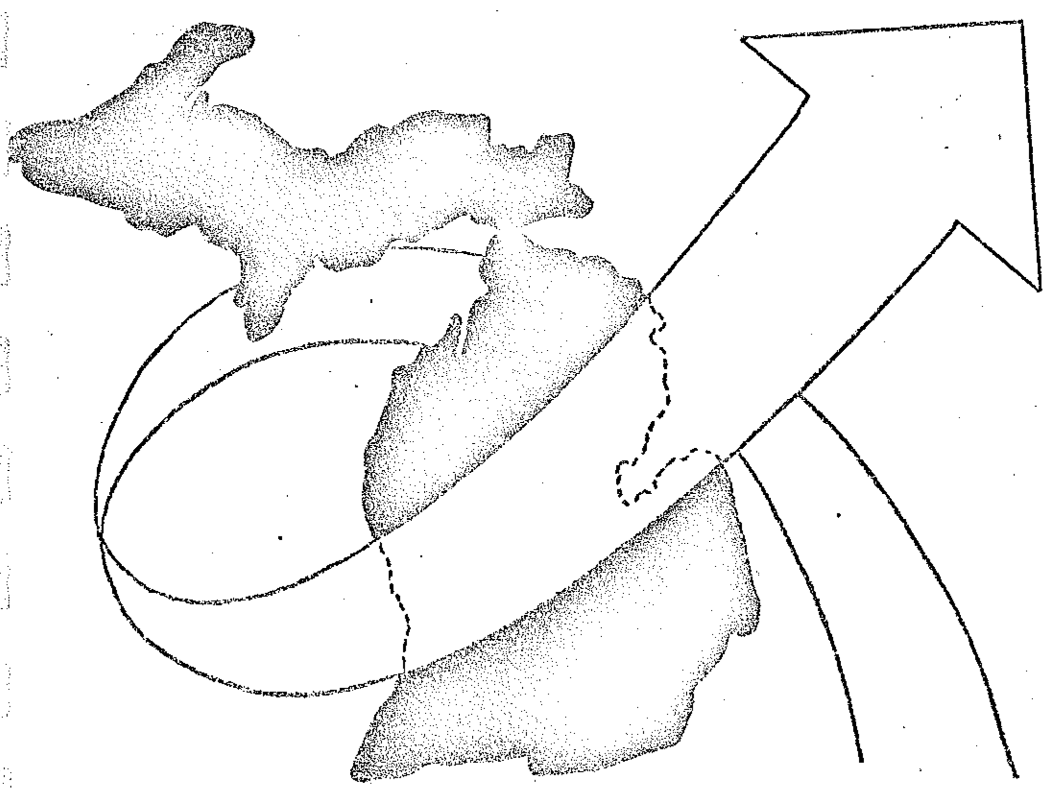
Finally, the two most significant model contributions regardless of the level of application are:

1. The model's ability to eliminate many of the presently subjective decision-making precesses. Decisions based on subjective analysis tend to be only as reliable as the attitude of the individual at the particular moment each decision is made.
2. All analysis phases of this process are computerized. This will allow the user-- whether administrator,

planner or analyst-- to provide intelligible answers to complex individual plans or questions involving the total trunkline system in a matter of days. Presently, the answers to the multitude of questions related to the development of a total trunkline system require months to formulate.

Therefore, the basic purpose of this report is three-fold: (1) to present the proposed model objective, (2) to define the specific work programs involved, and (3) to document the benefits received from an operational forecasting model. Staff requirements and a proposed time schedule have also been discussed in the concluding section of this report. Comments and suggestions from any of those individuals who review this report would sincerely be appreciated as the final product will be useful only if the requirements of the potential user are taken under consideration during this development program.

STATUS REPORT



STATUS REPORT

MICHIGAN STATEWIDE TRAFFIC FORECASTING MODEL

During the past decade travel forecasting procedures have experienced rapid development in urban areas, as the result of the application of computerized traffic forecasting techniques. Many of the original computerized urban traffic modeling efforts were developed because of the complexity of the basic socio-economic data collection process in combination with urban origin-destination surveys.

Several states began to recognize the potential necessity of the application of similiar technology at the statewide level. The size and complexity of many studies such as the highway needs and highway classification projects actually reinforced the need for development of a computerized statewide traffic forecasting model. These studies, as well as the Federal 104 B-5 study, required traffic forecasts for several pre-selected years for the total state trunkline system. With existing techniques, tasks of this scale bordered on the near impossible, especially if the final product was to be reliable. The Michigan Department of State Highways recognized the need for automation and was among the first to begin development of a statewide traffic forecasting model. Arthur D. Little, Incorporated was retained to complete the preliminary model and to develop working procedures early in 1965.

The initial work program was a two-phased project with Phase I being completed by Arthur D. Little, Incorporated. Phase II was to be a detailed refinement of the Phase I network and travel models through the use of additional data collection analysis.

Information obtained from the research and development work in Phase I has resulted in a major change in the work program as originally defined by the State Resource Planning Agency. The proposed work program follows:

PHASE I - Preliminary Network and Travel Model Development

PHASE II - Calibration of 510 Zone System and Conversion of Vacation Model

PHASE III - Peak Hour (DHV) and Vacation Model Development in Conjunction with 2300 Zone System Definition

PHASE IV - Definition of Total Road System as Related to the Development of Cost Efficiency and Highway Programming Model

This work program was developed as a result of the preliminary research completed by Arthur D. Little, Incorporated and a review of the future traffic forecasting needs both within the department and the federal level. Included in the second portion of appendix A is a copy of the original consultants' suggestions as to model improvement at the conclusion of Phase I. These suggestions, along with information gained from analysis of the consultants' traffic assignment plus review by the Federal Highway Administration, were the basis for the final work programs presented in this report. All of the questions discussed in the model improvements section (appendix A) had to be resolved and therefore were the basis for the development of Phase II and Phase III work programs.

The work program has been expanded into a four-phased project because:

1. Model calibration and data update are complex projects by themselves and therefore should be completed independently from detailed model development.

2. Model reliability must be established during Phase II before additional model applications are attempted in Phase III and IV.

3. The vacation model refinement process and development of a peak or design hour volume (DHV) model are similar in data requirements and therefore have been combined as the Phase III portion of the proposed work program.

4. Cost-efficiency and highway needs programming processes are additional model applications. Therefore, Phase IV has been added so that the Department's model will be developed to its fullest potential.

Phase III will deal with the influence weekend travel has on statewide travel patterns. Although Phase IV may not include sophisticated travel models, it should involve a significant proportion of Michigan's total road system, both state and county. Model development will proceed as a four-phased project. The diagram on the following page is a resumé of the present project status as of October, 1970.

From the date the department received the final consultants' report on the preliminary model development in Phase I until late 1969, only two part-time staff positions were allocated to continue this project. Therefore, until

PROJECT STATUS

PHASE I

	1965	1966	1967	1968	1969	1970	1971
Network Model Development	↔	↔					
Travel Model Development	↔	↔					
Define Procedural Guide		↔					

INTERIM

	1967	1968	1969	1970	1971
Conversion of Computer Programs to Operate on Department B-5500 Computer	↔	↔			
Completion of Preliminary Model Analysis	↔	↔			
Preliminary Definition of 2300 Zone System		↔			
Preliminary 1990 Traffic Assignment		↔			

PHASE II

	1965	1966	1967	1968	1969	1970	1971
Network Calibration					↔		
K-Factor Calibration							
Travel Model Update							
Vacation Model Conversion					↔	↔	

late 1969, the equivalent of only one full-time analyst had been assigned to continue refinement of the model.

Beginning in late 1969 and early 1970, two additional analysts were added to the Statewide Studies Unit. With this addition and due consideration for added responsibility, the unit at this time could allocate the time of 2 1/2 staff positions to the model development process. This is somewhat less than the staff requirements suggested in the final staff requirement section of this report. Project funding difficulties also hindered development during this same period and as a result the department has not presently realized the full potential of the model.

PHASE I

OBJECTIVES

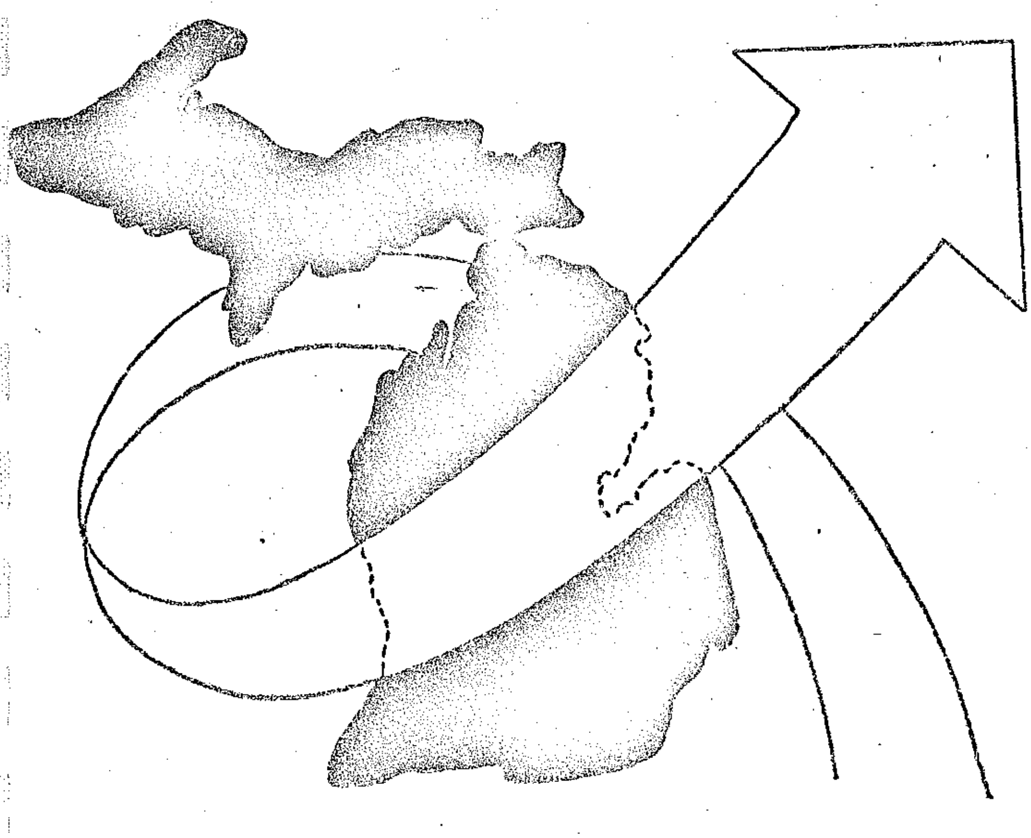
A significant portion of the Phase I work program was accomplished by Arthur D. Little, Incorporated. A summary of the model development techniques are included in this report in the first portion of appendix A. The primary objectives of Phase I were threefold:

1. Definition and development of a preliminary state highway network model.
2. Definition and development of a set of preliminary travel forecasting models.
3. Definition of computer programmer-operator manual. This manual was to provide the information needed to operate the computer programs which form the statewide traffic forecasting model package.

The preliminary state highway network model was to include all state trunklines and only selected county roads. County roads included in the highway network model carried either relatively large traffic volumes or had travel characteristics similar to state trunklines.

The preliminary travel forecasting model development was a two-part process. The primary objective was the development and calibration of a set of trip generation model(s).

PROPOSED WORK PROGRAM DETAILS



Secondly, based on the knowledge gained in trip generation research, three trip distribution models were defined and calibrated. In both situations the model research was based on survey data collected for the following origin-destination studies.

Allegan	Benton Harbor
Alpena	Cadillac
Ann Arbor-Ypsilanti	Detroit
Battle Creek	Monroe
Bay City	Niles

A daily computer program operation procedures manual evolved as a result of the statewide traffic forecasting model development process. This manual was to describe the operational procedures of the Federal Highway Administration traffic assignment system on an IBM 7090 computer. The manual was also planned as a computer program users guide when attempting to operate the preliminary trip operation-distribution forecasting models.

WORK PROGRAM

With the above objectives in mind, a work program was defined to include the following tasks:

1. Selection and definition of the type and number of roads to be included in the highway network model.
2. Definition and development of a statewide zonal system related to the scale of the highway network.

3. Refinement and analysis of trip data base to be used in travel forecasting model development.
4. Calibration of the trip generation model to base data.
5. Calibration of the trip distribution model to base data.
6. Full scale test of both highway and travel models through the application of computerized traffic assignment methods in use in urban areas.

Network selection and definition was to be accomplished using techniques commonly utilized by the Federal Highway Administration as suggested in the 1964 Traffic Assignment Manual. Slight modifications were required due to the size of the statewide highway network. This network definition process resulted in a highway network of approximately 3500 segments or links.

Definition of the zone system involved the division of Michigan's 83 counties into 510 zones. This division resulted in a zonal system of 480 zones for the state and 30 zones for Ontario and the 4 surrounding states.

Before travel model development could begin, the survey data for each of the origin-destination studies was adjusted to a base year. This adjustment process was required because the original surveys were taken over a period of time that differed as much as 5 years. This time span resulted in significant variations in preliminary travel summary statistics.

The travel analysis involved such summaries as total trips by study area, average trip lengths by purpose, and other related trip statistics. These summaries supplied the basic answers to questions which had to be resolved before trip generation and trip distribution model calibration could be initiated.

Trip generation and distribution model development involved determining exactly what types of models would be required to accurately forecast future travel. Calibration of the final models required the statistical fitting of each model to its related survey data from the ten origin-destination studies.

The final task in the work program was to be accomplished using traffic assignment techniques defined in a Federal Highway Administration's manual entitled Traffic Assignment Manual, published in June of 1964.

OUTPUT FOR DEPARTMENT USE

As a result of the completion of the work program for Phase I in the development of a statewide traffic forecasting model, the following data are available for department use:

1. A computerized model of the state highway system which might be used as a base for other tasks within the department such as the trunkline data file. The Department of Natural Resources is

presently using the preliminary highway model as a basic input in the development of modeling efforts within their organization.

2. A set of actual highway travel times between each statewide zone and all others is another basic output. This will be used within the Transportation Planning Division in an attempt to better understand the cause and effect of travel within the State of Michigan. The actual distance between each zone and all others on the highway system may be determined using the techniques in the Federal Highway Administration's Traffic Assignment Manual mentioned previously.
3. The trip generation and distribution models will supply the user with the preliminary trip interchange between all Michigan zones for any year required--both present and future. This is only preliminary travel data used primarily to test the feasibility of developing a statewide traffic forecasting model. This data is useful in initial model development phase but should not be used as a basis for final highway planning and design.
4. If an agency desired to know the actual shortest highway path or route from any particular zone or city to all other zones in the model, this could be obtained either as a computer listing or a graphic plot. These paths are often referred to as "trees".

BENEFITS TO THE DEPARTMENT

The primary benefit to the department as the result of Phase I was the development and application of computerized techniques for forecasting traffic at the statewide level. The application of these urban area techniques at the statewide level will now allow the department to obtain future travel data very rapidly compared to manual techniques used in the past. However, the preliminary statewide traffic forecasting model will have to be calibrated during Phase II before the forecast results may be reliable enough to be used to plan and design Michigan highways. After calibration the department would have the ability to evaluate any proposed future trunkline plan, for any pre-selected time period. The computerized modeling techniques would allow this analysis to be completed in one or two man-weeks. This has required as much as one-half to three-quarters of a man-year when done manually.

Because the department's staff was involved in the basic work program, future model calibration and development may be accomplished within the department during Phase II. This will result in an experienced staff to operate the model at the date of completion of calibration.

Phase I set out to determine the feasibility of developing an operational statewide traffic forecasting model. As a result of Phase I, the department has a preliminary highway network model and a preliminary trip generation and distribution model plus a set of work procedures. These preliminary models will now have to be calibrated or refined before becoming useful when planning or designing Michigan's future highway system.

In the interim between Phase I and Phase II the following tasks were completed.

1. Completion of preliminary model analysis.
2. Preliminary definition of 2300 zone system.
3. Creation of a 1990 trip table and traffic assignment.
4. Conversion of computer programs to operate on Department's computer.

A flow chart and time schedule of the interim work program follow this section. Using the traffic assignment technique suggested by the Federal Highway Administration, the 1990 trip table was assigned to the existing 1965 state highway network. This 1990 traffic assignment or forecast for the state trunkline system was completed by applying the results of preliminary trip generation-distribution models. Therefore, it seemed necessary to apply a simplified method of determining how reliable the final travel forecasts were under these conditions.

To accomplish this reliability check, trend lines were developed at all permanent traffic recorder stations which had sufficient trend data available. The results of this simplified reliability check appear in Appendix B. The preliminary check indicates the statewide traffic forecasting model is supplying relatively reliable future travel volumes for the total state trunkline system. Some local problems exist in the more populace regions but future model refinement will improve this situation.

PHASE I

WORK PROGRAM FLOW CHART

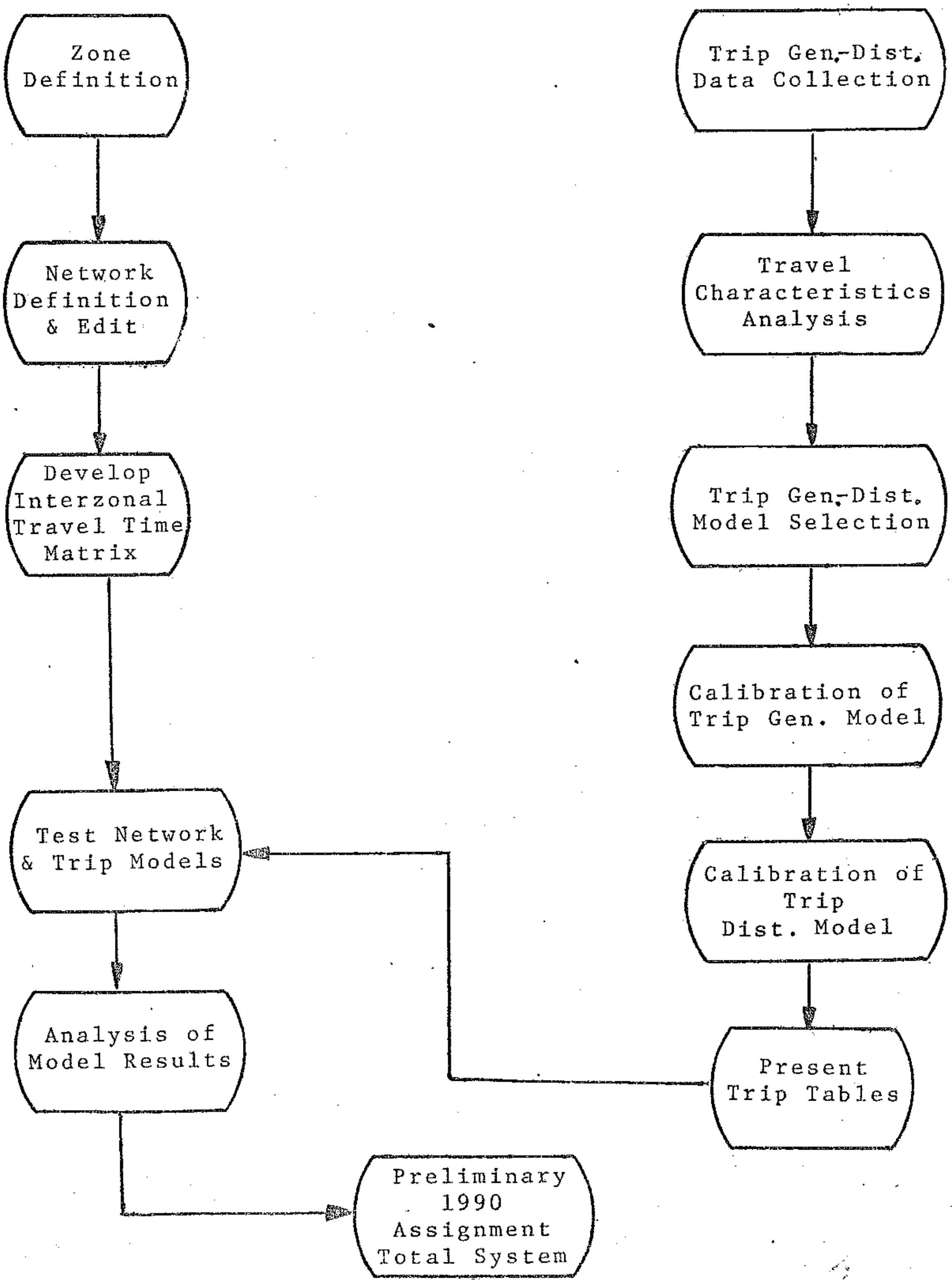
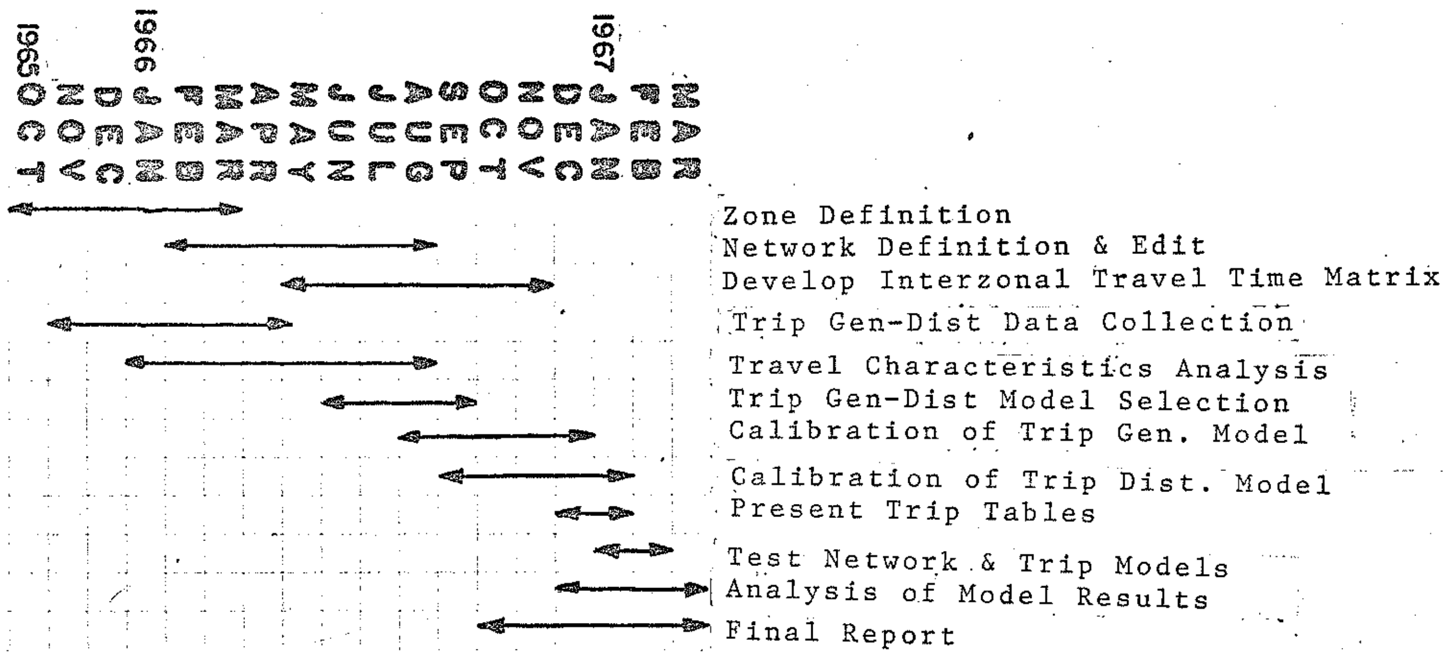


FIGURE 4

PHASE I

WORK PROGRAM TIME SCHEDULE



INTERIM

BETWEEN PHASE I PHASE II

WORK PROGRAM FLOW CHART

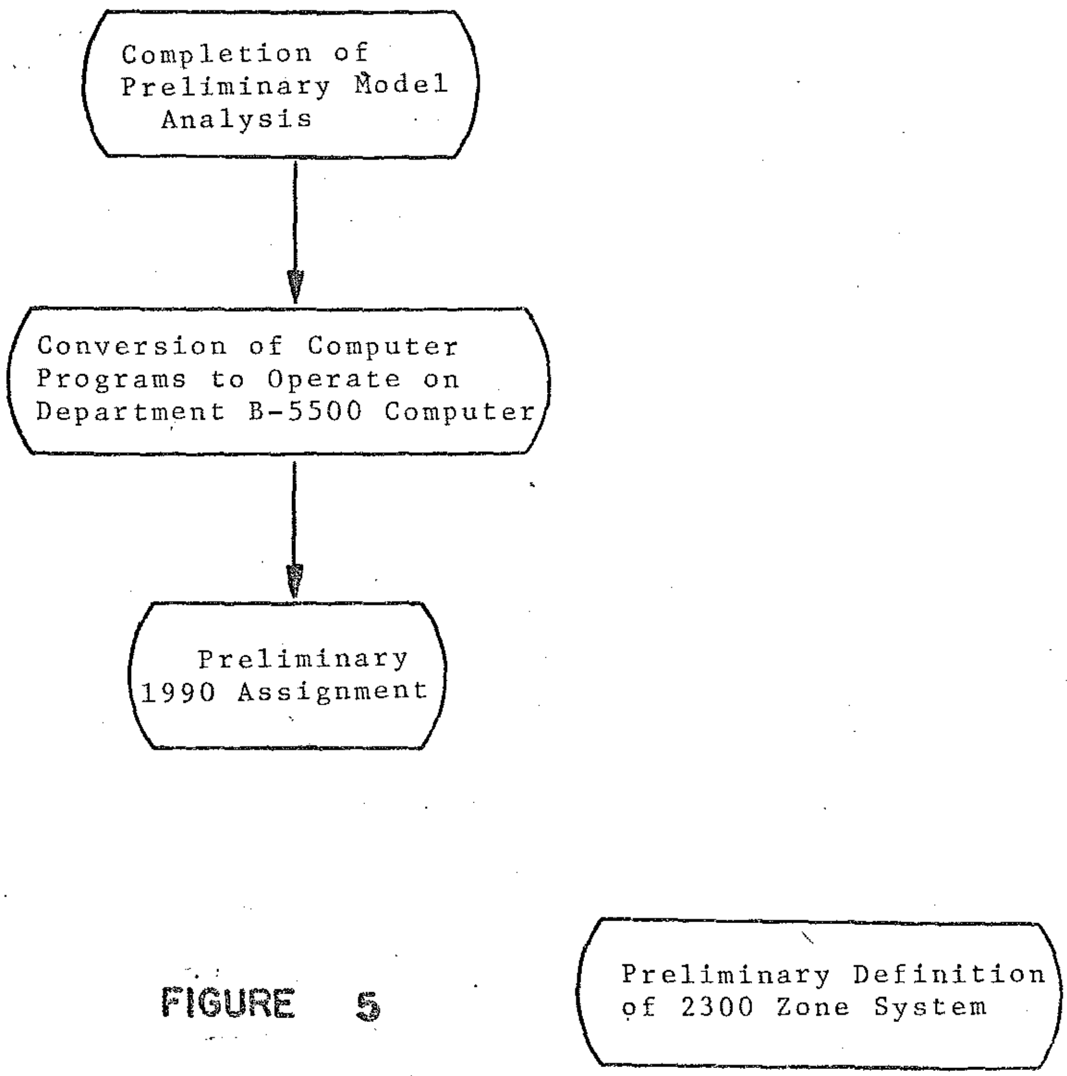


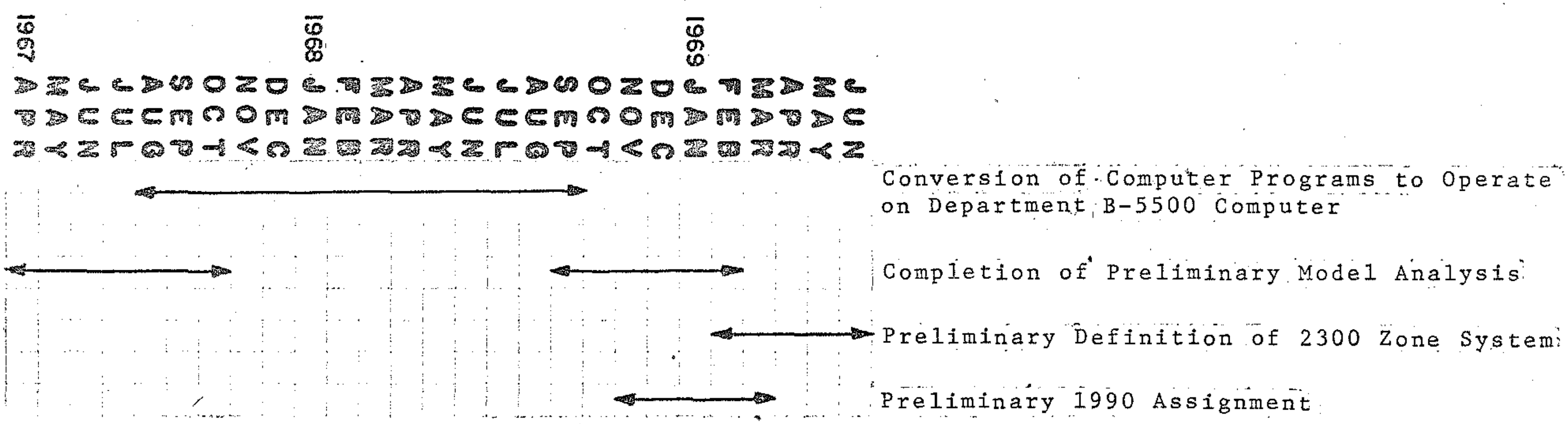
FIGURE 5

INTERIM

BETWEEN

PHASE I PHASE II

WORK PROGRAM TIME SCHEDULE



PHASE

II

PHASE II

OBJECTIVES

Calibration of the preliminary highway and travel forecasting models is the basic objective of Phase II. This calibration process is a refinement process which is required if the preliminary models are to become reliable daily traffic forecasting tools within the department. The final product of Phase II will be used within the department to supply future traffic volumes for any segment of a state trunkline for any predetermined year.

A secondary objective of Phase II is the proposed update of the original travel survey data base which is to be used to develop the preliminary travel forecasting models. This will involve the detailed analysis of travel survey data from 25 additional origin-destination studies completed since Phase I. Because of the origin-destination travel survey data base update, calibration of the preliminary travel forecasting models is a two-part process. This two-part process will be defined in detail in the work program for Phase II.

A tertiary objective of Phase II is the conversion and development of a vacation travel forecasting model which will operate on the department's B-5500 computer. The original preliminary travel forecasting models were converted in the interim between Phase I and Phase II but time was not available to convert the vacation model.

The final objective of Phase II will be the completion of a 1990 traffic forecast for the proposed 1990 State Trunkline System. A 1990 traffic forecast could be completed both before and after updating the travel data survey base as well as after conversion of the vacation model. Time and staff conditions will determine the feasibility of completing 1990 forecasts during the Phase II work program. The most desirable 1990 forecast would be one completed after the travel data base update. This type of 1990 forecast would take advantage of the additional travel data and, therefore, would supply more reliable model results.

WORK PROGRAM

The Phase II work program has been separated into three basic sections as follows:

SECTION A Calibration of the preliminary highway network model.

SECTION B Calibration of the preliminary travel forecasting models.

SECTION C Conversion and development of an operational vacation travel forecasting model on the department's B-5500 computer.

As mentioned, the secondary objective of updating the origin-destination travel survey data base requires that section B of the work program be subdivided into two parts. The actual calibration process technique will depend on the availability of staff at the time calibration is being completed. A technique similar to K-factoring used in gravity model development would require fewer personnel than updating the travel data base. This K-factor technique is a process whereby parameters other than travel time are considered during model calibration. The final calibration results would be less reliable with this K-factor technique. If staff is available during Phase II then model calibration will be completed by updating the travel data base, otherwise, this travel data base update must necessarily take place during a later Phase in the model development process. The details of the actual work program follow and take into consideration both possibilities.

WORK PROGRAM PHASE II - SECTION A

(1) Detailed analysis of Phase I traffic assignment and network.

(2) Correction of network errors and omissions.

(3) Testing of updated network.

(4) Calibration of updated network "trees".

WORK PROGRAM PHASE II - SECTION B, PART 1

(Assuming no O & D travel survey data update)

(1) Detailed analysis of the results of the preliminary travel forecasting models.

(2) Review of the results of the analysis of the traffic assignments from Phase I.

(3) Development of the trip generation-distribution model K-factors similar to gravity model K-factors.

(4) Testing of the calibrated trip generation-distribution models' zonal outputs.

(5) Testing of the calibrated network and trip generation-distribution model by completing a present traffic assignment.

(6) Completion of a 1990 traffic forecast-- Optional.

WORK PROGRAM II - SECTION B, PART 2

(Assuming O & D travel survey data update)

(1) Collection and reformatting of survey data for the 25 additional origin-destination studies completed since Phase I.

(2) Development of a Michigan statewide travel data bank based on the analysis of the survey data from approximately 40 cities.

(3) Development of a Michigan statewide socio-economic data bank as a result of data requirements in the model update process.

WORK PROGRAM II - SECTION B, PART 2 (contd)

(4) Analysis of the travel data trip characteristics in preparation for development of updated travel forecasting models.

(5) Calibration of final trip generation-distribution models to existing travel survey data base.

(6) Modification of preliminary travel forecasting model computer programs to accept new models.

(7) Completion of a present traffic assignment using updated models plus calibrated highway network.

(8) Calibration of state highway network using updated travel forecasting models.

(9) Completion of a 1990 traffic forecast-- Optional.

WORK PROGRAM PHASE II - SECTION C

(1) Analysis and review of preliminary vacation travel forecasting model.

(2) Conversion of original computer program to operate on the B-5500.

(3) Full scale test of preliminary vacation travel forecasting model using actual population data.

(4) Completion of present traffic assignment using the vacation model and the calibrated travel forecasting models.

(5) Completion of a 1990 traffic forecast using all travel models.

Primary input to the Phase II work program was the preliminary highway network model and the preliminary travel forecasting models developed in Phase I. The 1965 traffic assignment completed during Phase I also will be used as a basic input.

Insignificant time was spent on network development because most of the network model techniques applied during Phase I were procedures which had already been tested by the Federal Highway Administration. No time was allocated for network model corrections during Phase I. Network calibration is therefore a necessary part of the Phase II work program.

Section A of the Phase II work program will allow time for updating and calibration of the preliminary highway network model. This initial network calibration will allow for a rapid and accurate calibration of the travel forecasting model suggested in Section B of the Phase II work program.

Two separate approaches are being taken when calibrating the preliminary travel forecasting models during Phase II. Part 1 assumes no origin-destination survey data update will be completed. Model calibration will consist of detailed accuracy checks on an individual zonal basis, as well as after the traffic assignment stage, similar to the Phase I accuracy checks. As a result of the network calibration and travel forecasting model analysis, K-factors similar in concept to those used in the urban traffic forecasting gravity model calibration process will be developed. This K-factor model calibration technique often is necessarily repetitive before the travel models are finally calibrated. Calibration of both network and travel models will require several present traffic assignments. The traffic assignment techniques are similar to those suggested by the Federal Highway Administration in their June 1964 Traffic Assignment Manual.

Part 2 of Section B of the Phase II work program assumes a major update of the origin-destination travel survey data bank. This model data base update will unquestionably increase the reliability of the travel forecasting models' capacity to determine future travel. This travel data base would then include survey data from 25 additional origin-destination studies completed since 1965, plus the travel data from the original 10 origin-destination studies used in Phase I. The list of additional origin-destination study data is presently quite extensive and includes survey data from the following cities:

Lansing	Holland
Sault Ste. Marie	Port Huron
Kalamazoo	Petosky
Adrian	Big Rapids
Jackson	Mt. Pleasant
Iron Mt.	Sturgis

Muskegon	Midland
Grand Rapids	Marquette
Saginaw	Flint
(Detroit Update) TALUS	Traverse City

This additional travel survey data will be utilized when completing the calibration of the preliminary travel forecasting model.

The use of this additional data will involve the completion of four basic work tasks.

1. Data assembling and reformatting.
2. Travel characteristics analysis as input to travel model.
3. Calibration or fitting of trip generation models to existing survey data.
4. Calibration or fitting of trip distribution models to exiting survey data.

These tasks involve the analysis of an estimated 1,100,000 trip records-- an increase of 750,000 trip records since Phase I. Completion of this update of the travel forecasting model through the use of additional origin-destination data will eliminate the tendency of total dependence on K-factors in model calibration process except for selected circumstances.

Presently, the staff is attempting to accomplish the basic objective of Phase II by relying primarily on K-factor calibration techniques. As time and staff allow, progress is also being made in updating the travel data base. The travel data update approach is the best lasting approach to travel model calibration, but it is naturally time consuming because of the sheer size of the data base.

A preliminary vacation model was defined during Phase I for use on an IBM-7090 computer. During Phase II this vacation model has been converted to operate on the department's B-5500. Testing of the operation of this model will be completed during Phase II along with minor K-factoring similar to the techniques used to calibrate the general travel forecasting model. This portion of Phase II should be completed by September, 1970.

If time allows, a 1990 traffic assignment will be completed at the end of the Phase II work program. If insufficient time is available, this task will be accomplished only once after calibration of the travel forecasting model and the conversion of the vacation model.

Based on present staff conditions in the Statewide Studies Unit and related model demands, the work program for Phase II is being accomplished as follows:

1. Priority one has been set on network calibration and analysis, as this is necessary to both portions of the proposed Phase II work program.
2. Priority two has been set on the portion of the work program where the use of additional origin-destination data would be used in the travel

forecasting model calibration. This would allow for the development of more reliable and lasting results.

3. Priority three has been set on that portion of the work program which would depend on K-factors to calibrate the travel forecasting models. This is rapidly becoming priority two because staff limitations will not permit the analysis on the additional survey data to be completed within a reasonable period of time. The K-factor technique will expedite model calibration and permit the department to use model results at an eariler date.

Based on existing staff conditions, calibration of the highway network model was completed in October, 1970. Calibration of the travel forecasting model using K-factor techniques could possibly be completed by the end of the first quarter of 1971. Because the two-part work program is being completed simultaneously, updating of the travel forecasting model may be completed late in 1971.

OUTPUT FOR DEPARTMENT USE

The significant change in outputs for departmental use centers on the reliability of the actual traffic forecasting results. A list of the outputs follows:

1. A calibrated computerized model of the state trunkline system, which uses a nodal concept, could be the basis for accident location records, thereby serving a dual purpose. (See Appendix C)
2. A listing of the actual highway travel time or distance between each statewide zone and all others would be available. It is also possible to build a matrix which will supply travel costs from any zone to each of the other zones.
3. Vehicle travel between every zone for any desired year, both present and future, will be available from the calibrated trip generation-distribution models.
4. Preliminary vacation travel between all zones will be available for any desired year as a result of the completion of the vacation model.
5. As with Phase I, the actual highway path from any zone to all others is available as a result of the "tree" building program.
6. As a result of the Phase II work program, an additional development which might be used benefically by the department is the fact that the complete state trunkline system has been given grid coordinates. This will allow the user to automatically plot travel data such as traffic volumes, speeds, and distances in a graphic manner. These plotting techniques, based

on present schedules, should be available by the first quarter of 1971. Modification of this original plotting package might easily allow additional user information to be graphically plotted. This could include travel data, log information and accident statistics.

7. A preliminary socio-economic data bank for the State of Michigan, with update potential, will be available as a result of the trip generation-distribution update process.
8. Present and future traffic volumes could be obtained for any segment of state trunkline for any selected year or any proposed system or alternate system.
9. Vehicle mile forecasts by trunkline type with summaries by county could be obtained.
10. Both present and future trip length statistics for any segment of road included in the highway network model.
11. Travel analysis listing by trip purpose for any portion of the state trunkline system is an option if specified by the user.

BENEFITS TO THE DEPARTMENT

Completion of research and development work initiated in Phase II would allow the Michigan Department of State

Highways' administrators and commission members to arrive at informed decisions on such projects as the "US-2 Freeway" in the Upper Peninsula, the "I-75 Saginaw Bridge" and other critical tasks such as the "post-1977" Arterial Highway System for Michigan. The model would allow the department to determine the best possible future arterial trunkline system by rapidly testing several alternate systems. The statewide traffic forecasting model would allow the department to plan for future needs as the projected date when various routes will require improvement may also be predetermined. Projected estimated costs or budgets on a yearly basis could also be made available although this task has been left until Phase IV.

Each of these projects is an extremely complex task and because of this the present decision-making process is hindered under certain circumstances. The model will improve the above situation by allowing the administrator and legislator alike to test many alternate plans and proposals in very rapid sequence, finally selecting the most reliable proposal. Once a plan or program has been selected this same model, because of the completeness of initial development work, will also be able to supply details required to select the most appropriate corridor and complete final design.

Presently all traffic forecasts in rural areas as well as some of the urban areas are completed using manual techniques. These techniques are reliable but often very time consuming. In recent years, many projects such as the Federal Needs Study and Classification Study require traffic forecasts, both present and future, for the total state trunkline system. Within the department, on many occasions detailed alternate corridor analysis related to travel volumes should be completed in order to supply the department with sufficient data to select the best alternate. The US-23 extension north of Standish is just such a situation. Manually these tasks now require many man-months to complete. Often the completion dates for many of these projects necessarily have to be extended. Under certain circumstances data reliability is sacrificed because of the complexity and existing manual nature of these tasks. With the calibration of a statewide traffic forecasting model, many of these tasks previously done manually can be defined in terms of man-weeks because the travel forecasting model will make use of automated computerized traffic forecasting techniques. The level of accuracy of the final results is greatly improved because of powerful features of the computer which will allow the department's staff to complete a more detailed analysis for each project. As another specific example, upwards of one man-year's time was spent on the travel forecasting portion of the Federal Highway Administration 104 B-5 Study. This same project could have been completed with the model in a period of two to four man-weeks. Also in addition to fulfilling the Federal Highway Administration requirement for completing this study in relation to the Interstate System, the department would also have available a forecast of all state routes.

Presently, a vehicle mile forecast on state trunklines is the result of a manual task separate from, although interrelated to, the traffic forecasting process which necessarily involves man-weeks to complete. With a calibrated statewide traffic forecasting model, vehicle miles by various defined systems would be an automatic output requiring only two or three man-days to complete. Vehicle mile forecasts using Phase II modeling would initially include only state trunkline miles.

To date, any travel characteristics analysis used in highway planning is a manual task involving the analysis of rural origin-destination data. Under certain conditions, man-months can be spent in the thorough analysis of a specific trunkline's travel characteristics-- such as trip length frequency distributions and trip purpose summaries. With a calibrated statewide model this same analysis could be completed in two or three man-days. Future plotting capabilities of the statewide model would allow highway staff to automatically plot the necessary statistics and charts required to make final planning decisions under multiple highway environmental conditions. Plotting capability of the model might also allow for rapid presentation and analysis of final data. The model could also provide future travel characteristics for the same route if the department so desired, which is presently not possible manually.

With existing manual methods it is not possible for Route Location to analyze the total effect on the state trunkline system from alternate route locations. The statewide model would have the capability of determining the proposed route's effect in the immediate area as well as the entire state. If deemed necessary, cost benefit analysis studies could be a basic output from the statewide modeling process, thereby supplying actual dollar and cents measurements of road improvements. Additional computer programming would be necessary to obtain this last capability.

The previous discussion is only a very brief resumé of the vast potential of a computerized statewide traffic forecasting model. The actual potential of a computerized statewide traffic forecasting model cannot be underestimated by those persons delegated with the responsibility to develop and maintain Michigan's state trunkline system. The Federal Government has recognized this potential but this same priority must be considered within the department's structure if the past four year's of model development is to result in an effective statewide highway planning tool.

A flow chart of the Phase II work program is provided in figure 6 followed by a detailed time schedule. This time schedule is based on additional personnel as suggested in the staff requirement section of this report.

PHASE II

WORK PROGRAM FLOW CHART

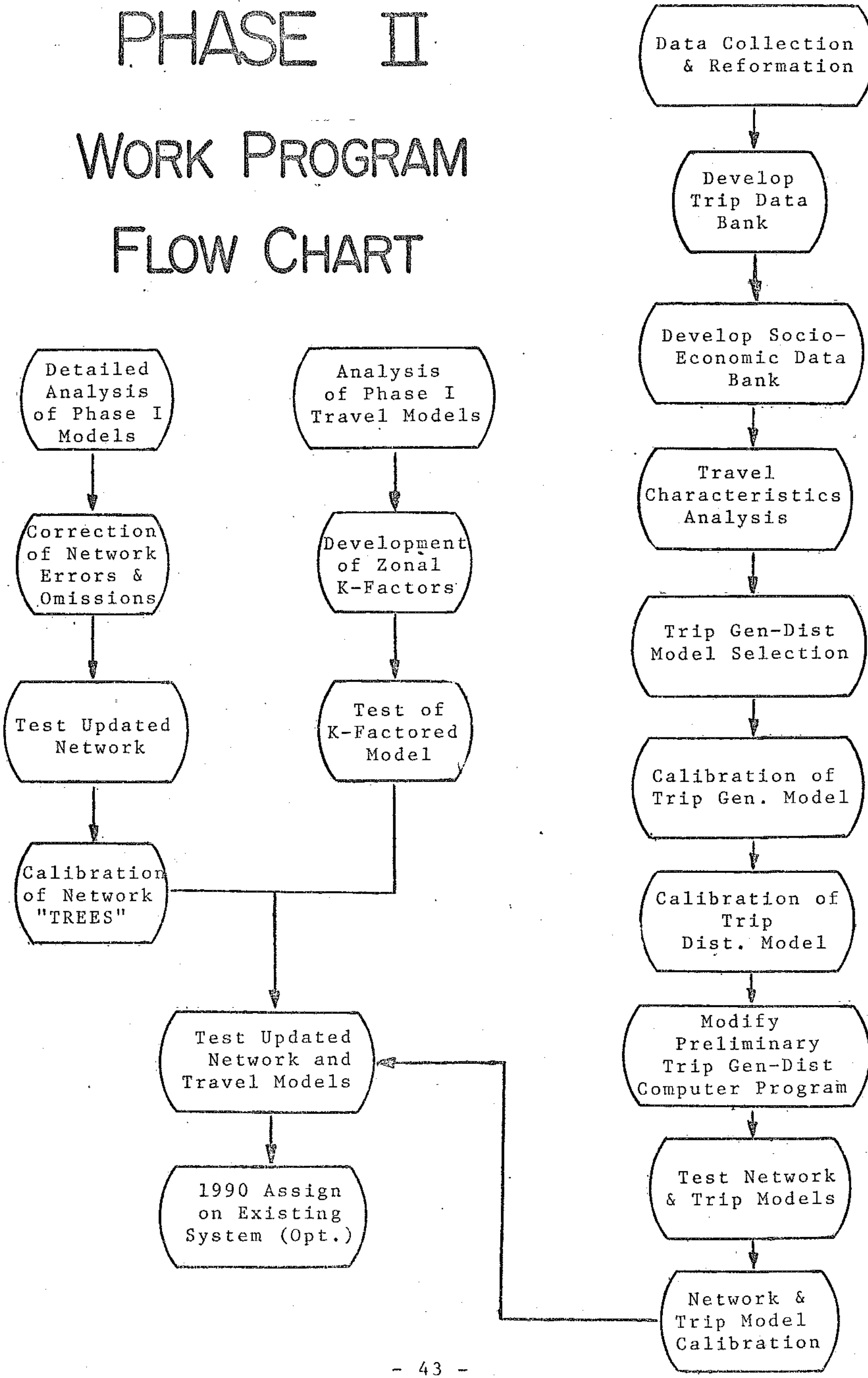


FIGURE 6

CONTINUED

PHASE II

WORK PROGRAM FLOW CHART

CONTINUED

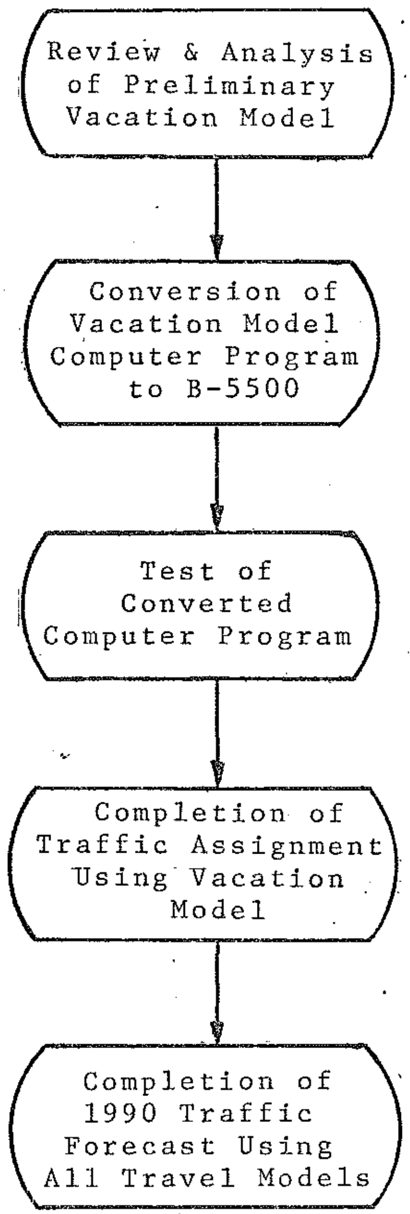


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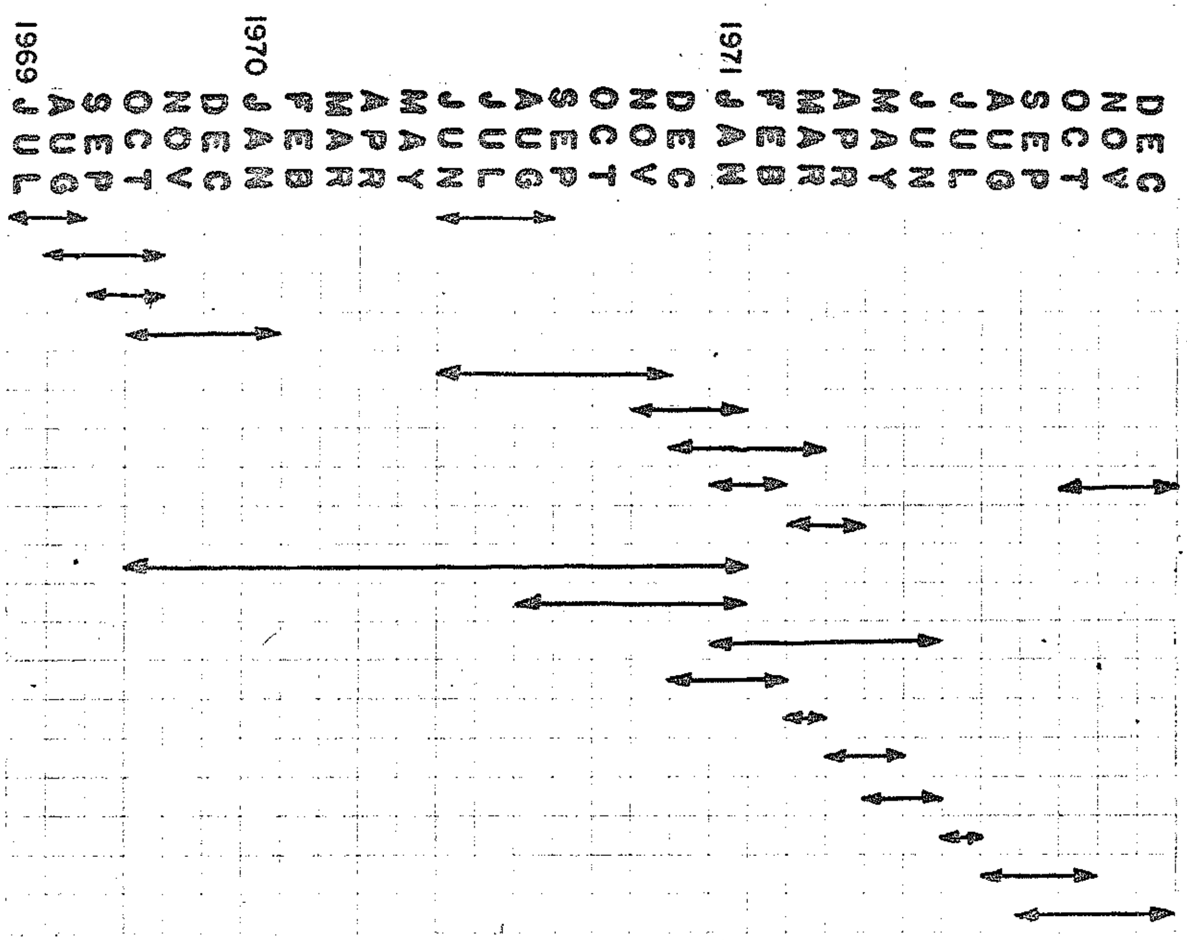
FIGURE 6

PHASE II

WORK PROGRAM TIME SCHEDULE



Detailed Analysis of Phase I Models
Correction of Network Errors & Omissions
Test Updated Network

Calibration of Network "TREES"
Analysis of Phase I Travel Models
Development of Zonal K-Factors

Test of K-Factored Model
Test Updated Network and Travel Models
1990 Assign on Existing System (Opt.)

Data Collection & Reformation
Develop Trip Data Bank
Develop Socio-Economic Data Bank

Travel Characteristics Analysis
Trip Gen-Dist Model Selection
Calibration of Trip Gen. Model

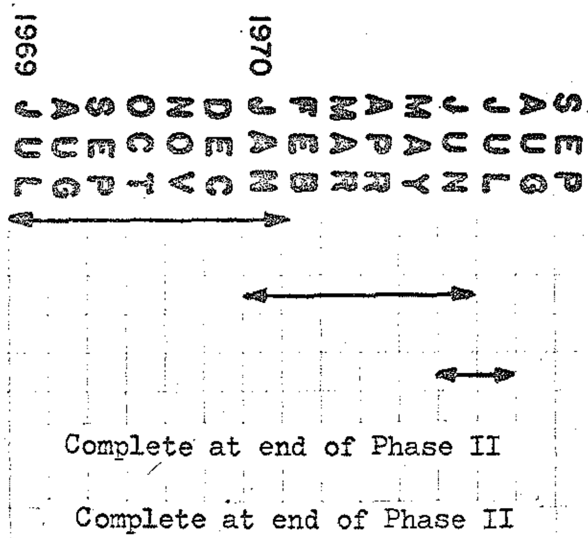
Calibration of Trip Dist. Model
Modify Pre. Trip Gen-Dist Computer Program
Test Network & Trip Models
Network & Trip Model Calibration

CONTINUED

PHASE II

WORK PROGRAM TIME SCHEDULE

CONTINUED



Review & Analysis of Preliminary Vacation Model

Conversion of Vacation Model Computer Program to B-5500

Test of Converted Computer Program

Completion of Traffic Assignment Using Vacation Model

Completion of 1990 Traffic Forecast Using All Travel Models

PHASE

III

PHASE III

OBJECTIVES

As a result of Phase I and II, the department will have the capability to forecast both present and future average daily traffic volumes for any or all segments of the state trunkline system. These traffic volumes are commonly referred to as AADT or annual average daily traffic. The primary objective of Phase III is the development of peak hour or design hour volume model (DHV). This model, in combination with the highway model and the AADT travel forecasting models from Phase I and II, would supply the department with all the necessary present-future travel data required to plan, design, and construct Michigan's future state trunkline system. Development of a peak hour model (DHV model) may necessitate the collection of additional travel survey data on weekend travel, as a significant percentage of peak hour traffic occurs between Friday noon and Monday noon.

A secondary objective of Phase III would be the refinement of the preliminary vacation model converted in Phase II. Analysis completed during Phase I suggests that the primary element in studying vacation travel resides in the vacation destinations rather than origin-destination data normally applied in travel forecasting model development processes. This same conclusion was arrived at in a separate survey completed by the Michigan Department of Natural Resources. Therefore the refinement of the vacation model during Phase III may also require additional data collection. This data collection process can possibly be combined with the data collection process required to develop the DHV model, thus resulting in a significant savings in data collection costs. Both the peak hour and vacation model will deal with the topic of weekend travel influences on statewide travel patterns.

A final objective of Phase III will be the improvement of the travel forecasting model's sensitivity by increasing the number of zones from 510 to 2300. Preliminary research between Phase I and Phase II indicated that a finer level of detail would be necessary if the model was to be useful throughout the highway department. The 2300 zone system will allow the model to more accurately forecast actual turns on and off of state trunklines as well as the more detailed volume fluctuations along these routes. This will involve refinement of the highway network along with modification of the calibrated travel forecasting models. As a result of this network refinement process, the model would have the capability of accurately forecasting future trunkline traffic volumes within most of the major urban areas. The actual highway network model at this point should include upwards of 35 percent of the total state road system.

WORK PROGRAM

The work program for Phase III is proposed as a three-part process. Depending on staff conditions, all three parts could be completed simultaneously, as they are relatively independent research and development projects.

The proposed work program details follows:

SECTION A

1. Definition of design hour volume (DHV) model objectives and methods of development.
2. Determination of data requirements based on model's defined objectives.
3. Definition of data collection and analysis methods.
4. Design hour model research and development.
5. Full scale test of design hour model on a present and future highway network.
6. Analysis and calibration of design hour model.

SECTION B

1. Analysis of preliminary vacation model assignment from Phase II.
2. Determination of data weaknesses and definition of data collection methods.
3. Collection of additional data for use in vacation model calibration.
4. Update trip and socio-economic data banks from Phase II.
5. Calibration of vacation travel forecasting model individually and in conjunction with the general travel forecasting models.

SECTION C

1. Addition to data bank of travel survey data collected since start of Phase II.

2. Development and definition of detailed zone and network model.

3. Refinement of travel survey data bank.

4. Development of refined trip generation-distribution model.

5. Calibration of detailed network and travel forecasting model.

In the final design of the state trunkline system, it is the DHV value which becomes pertinent to the actual number of lanes and the geometric design of each intersection. This type of design hour volume data can be obtained using available information from the Phase II traffic assignment outputs but this process would necessarily be a manual task involving many subjective decisions. Completion of Section A of Phase III work program will automate this DHV process through the use of computer techniques similar to those developed to supply the department with projected annual average daily traffic.

Refinement of the vacation model converted in Phase II was left to Phase III because additional data collection, as suggested in the original consultants' report, might possibly be required. The time and staff were not available during Phase II to define these data collection techniques. During Phase III the reliability of the vacation model is significantly more critical to the success of a statewide modeling effort because the design hour volume model will be more closely related to recreational travel patterns and weekend travel.

Therefore, refinement of the vacation travel model will significantly improve the accuracy of the final DHV model or models.

Improvement of the travel forecasting model's sensitivity will allow the department to include a significant proportion of the Federal Aid Highway System in the modeling process. This will allow the model to supply detailed turning movement data for most state trunkline and major county road intersections. This network model refinement process will also result in more accurate simulation of AADT volume increases and decreases along each segment of state highway.

Most of the work described above is tentatively scheduled to start sometime in late 1971 or early 1972, based on existing staff within the Statewide Studies Unit. The chart at the conclusion of this portion of the report supplies a detailed time schedule for this phase of the work program.

OUTPUT FOR DEPARTMENT USE

Assuming positive results from the proposed modeling efforts related to development of a DHV model and refinement of the vacation model, the department should be able to use the results of this statewide travel forecasting model as direct input into the process of planning and designing Michigan's state trunkline system. Specific outputs for department use are outlined below:

1. Vacation travel between all zones or areas within

the state and each of the contiguous states.

2. Travel within Michigan on all state trunklines by trip purpose for any pre-selected year plus travel pattern analysis.

3. Design hour volumes (DHV) for all segments of state trunkline for any design year specified.

4. Due to refinement of network model, the travel forecasting process may be expanded to include AADT forecasts for certain segments of the Federal Aid System.

5. Detailed turning movement data, both present and future, at most major intersections involving state trunklines and county roads.

6. Improved traffic forecasts on state trunklines within urban areas which may serve as a basic input to the urban forecasting process.

As the model reaches this stage in development, many of the outputs from the statewide travel model forecasting process could be used as direct input to the highway planning or design process.

BENEFITS TO THE DEPARTMENT

Presently, the department has no comprehensive means of surveying the effects of vacation travel on the state trunkline system. Only in small segments has any attempt been made to analyze the effect of vacation travel. As the demand for recreation facilities increases in the near future, the department will have the need for some comprehensive vacation travel forecasting tool if the planning and design of the state trunkline system is to effectively consider vacation travel.

The design hour model will allow the department to eliminate the manual process of forecasting DHV values. As with Phase II, clearly the most significant benefit to this department is the elimination of another subjective technique which presently is done manually. This manual DHV process is reliable but often is too time consuming, thus, final DHV forecast reliability is sometimes sacrificed in order to meet project deadlines. As the department continues to receive requests for such projects as the Federal needs studies, the department will have to rely on some sophisticated computerized technique to meet the deadlines set for such studies. The use of the proposed modeling techniques developed in all phases of this work program will provide the department as well as the Federal Highway Administration with reliable future travel data.

As an example, let us suppose the department was requested or had need to determine the 1990 DHV values for the total state trunkline system. Presently, this is a manual process which would require upwards of six to eight man-months to develop. With the development of a calibrated DHV model, this project could be completed in a matter of one or two man-weeks. The savings is obviously quite significant. Because the system of models is automated, it will allow for the analysis of several alternate highway systems at one time if desired.

The model at the completion of this Phase would be developed to the extent that it could reliably evaluate the appropriateness of the functional and administrative classification of many of the roads in the state. This would allow the department to rapidly update and frequently reclassify selected road systems within the state.

The basic outputs from Phase I-III would supply the necessary AADT and DHV data required to plan, design and construct additions to Michigan's state trunkline system. Phase IV could result in the development of optional features which would allow the department to fully utilize the potential of initial travel forecasting models.

PHASE III

WORK PROGRAM FLOW CHART

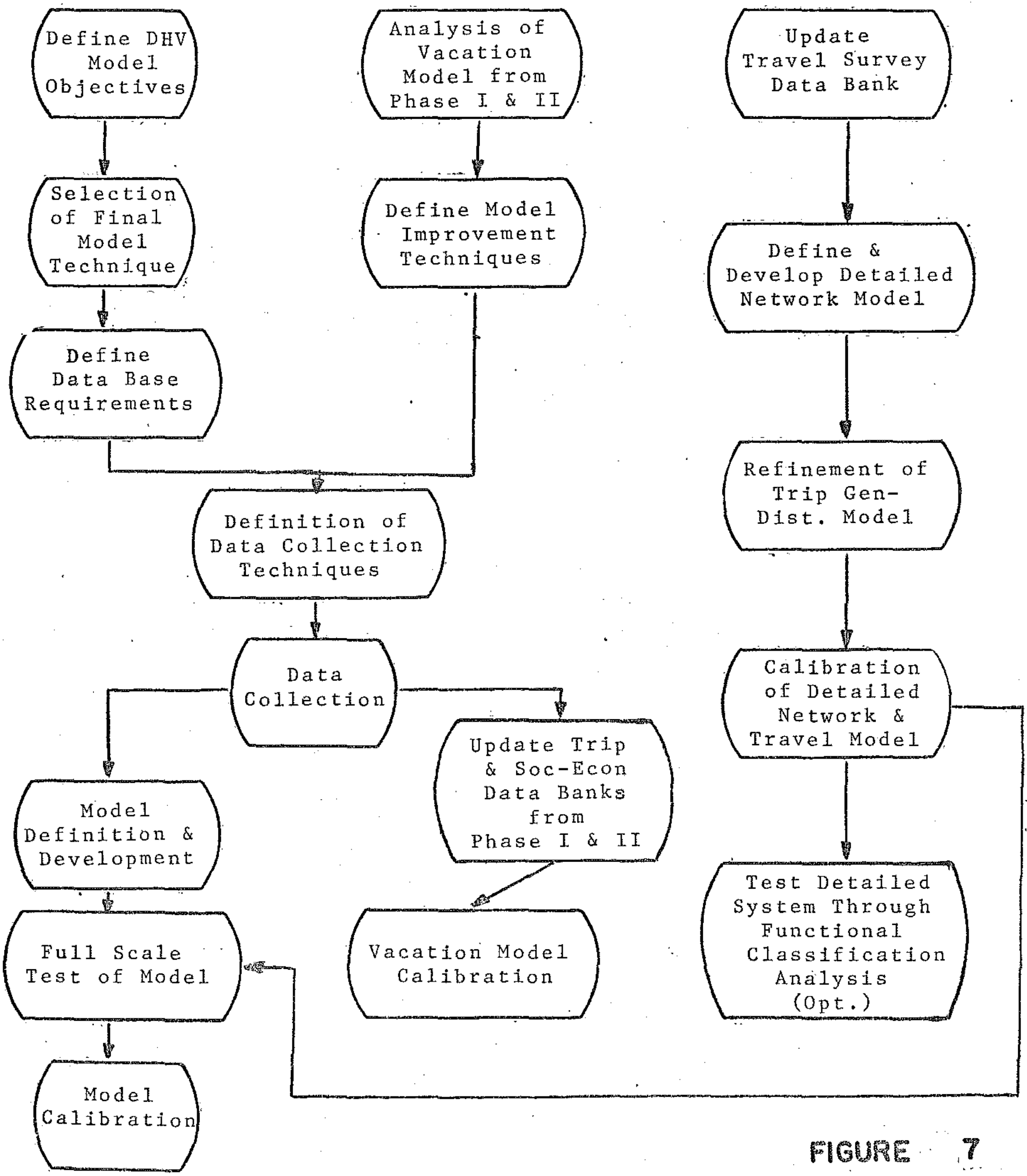
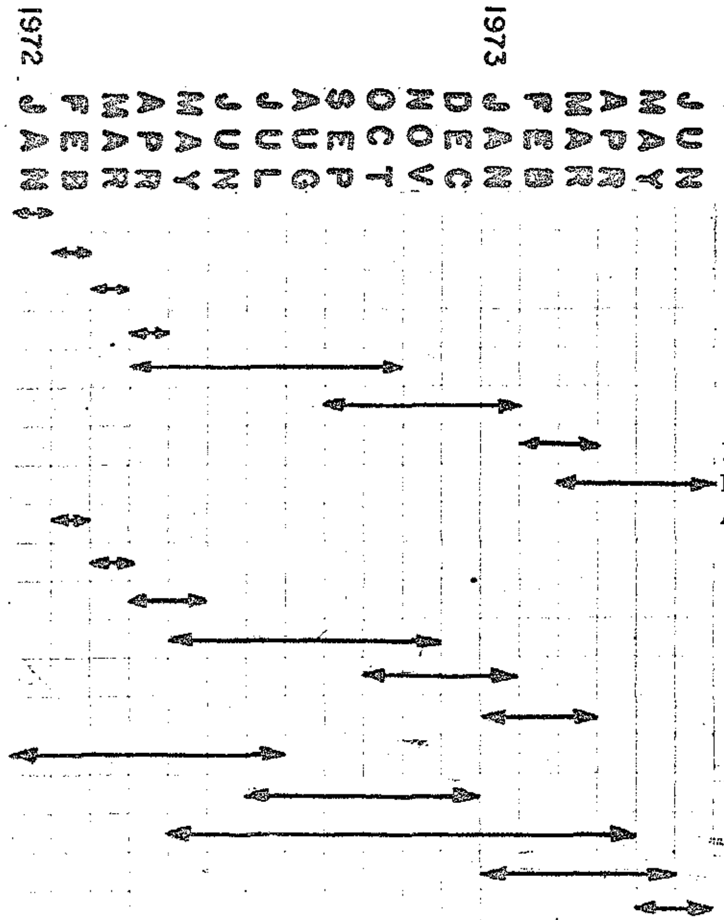


FIGURE 7

PHASE III

WORK PROGRAM TIME SCHEDULE



Define DHV Model Objectives
Selection of Final Model Technique
Define Data Base Requirements

Definition of Data Collection Techniques.
Data Collection
Model Definition & Development

Full Scale Test of Model
Model Calibration
Analysis of Vacation Model from Phase I & II

Define Model Improvement Techniques
Definition of Data Collection Techniques
Data Collection

Update Trip & Soc-Econ Data Banks from Phase I & II
Vacation Model Calibration
Update Travel Survey Data Bank

Define & Develop Detailed Network Model
Refinement of Trip Gen-Dist Model

Calibration of Detailed Network & Travel Model
Test Detailed System Through Functional Classification Analysis (Op

PHASE

IV

PHASE IV

OBJECTIVES

With the completion of Phase I, II and III, the Michigan Department of State Highways will have a statewide travel forecasting model which would supply reliable AADT and DHV data for any selected year for any or all segments of the state trunkline system. The models will also allow the department staff to accurately compare alternate systems. The outputs from the statewide travel forecasting model could be designed as direct input when planning and designing any segment of the state trunkline system.

The basic modeling effort, as directly related to the traffic forecasting process, has now been completed. The actual potential of the model has been only partially developed at this point. Several of the potential uses of this model have been selected for specific development during Phase IV so the true potential of this forecasting model may be recognized.

As a result of highway network development, approximately 30 to 35 percent of Michigan's total road network would be included in the model. Many of the state federal needs studies deal with Federal Aid Secondary routes as well as Federal Aid Primary routes. The model could supply much needed data in this area. Therefore, the initial objective of Phase IV will be an attempt to incorporate a significant proportion of Michigan total road mileage with the possible exception of city local streets.

In past years, the department has not been able to deal with cost-efficiency analysis in an effective manner when dealing with alternate corridor route location and planning studies. Because of the basic nature of the model development process, cost-efficiency techniques may rapidly be adapted to function as part of the model's basic output. This will allow the department's engineering staff to quickly determine the functional cost of one alternate route versus another. This cost-efficiency technique may also be used to determine which one of many suggested total state trunkline plans will best supply Michigan's future highway needs.

The final objective of Phase IV would be the development of the techniques whereby the department would have the capability to determine highway needs well in advance of trunkline deficiencies. Use of the statewide traffic forecasting model's capabilities would allow the department to test present and proposed state trunkline plans and alternates in five-year increments. This would allow the department to begin to automate a significant proportion of the programming of highway needs. With a little extra effort, actual programming of highway funds in this area could become automated. The following work program has been suggested in order to accomplish the above objectives. Because many of the objectives discussed earlier in the section have been discussed very briefly, the

Phase IV work program is not as detailed as the three previous work programs. Much of what is learned by completion of Phase II & III may lead to slight modification of the Phase IV work program.

WORK PROGRAM

The Phase IV work program is a three-part process. There is some possibility of completing selected portions of this program simultaneously. The proposed work program details are as follows:

A. Total highway network --

1. Review of existing data availability as a possible input in the development of a computerized road network for all Michigan roads.
2. Determine potential uses of a total road network if the network is simulated by computer techniques similar to the network finalized in Phase II.
3. Definition of total road network based on results of first two steps in work program.
4. Review possibility of incorporating some method of travel forecast modeling within the forecast of the complete county road network. Actual model development and calibration could be completed as a Phase V project if preliminary testing proved promising.

B. Development of cost-efficiency techniques related to highway planning and design --

1. Selection of the type of cost-efficiency analysis technique as a result of the specific needs within the department.
2. Review of existing data availability in relation to cost-efficiency analysis techniques selected in step one.
3. Definition of data collection methods and collection of data.
4. Development and definition of computer programs necessary to apply cost-efficiency analysis programs to solve department needs.
5. Full scale test of programs on a sample highway network route location problem.
6. Definition and development of daily work procedures so that the cost-efficiency programs developed may be used as a daily tool in the decision-making process.

C. Development of automatic highway needs and programming techniques using statewide model as a base --

1. Review of existing techniques used in programming highway funds related to future highway needs.
2. Determination of specific programming processes which might benefit through the use of statewide traffic forecasting modeling techniques.
3. Definition and development of specific computer programs which will use data from the statewide

traffic forecasting model to supply the necessary answers required by department users.

OUTPUT FOR DEPARTMENT USE

Because of the general nature of the proposed work program, only selected comments can be made in regard to the actual form or type of output available at the completion of Phase IV. An attempt has been made to list possible outputs. These listings were the result of statewide modeling efforts completed in other states and therefore should be very similar to outputs from the Michigan model.

1. AADT and DHV data should be available for selected portions of the Federal Aid System in addition to all state trunklines.
2. Highway user cost and benefits should be available by various road type or classification or even selected links of the total system. The data would also be available for selected alternate systems by predetermined categories.
3. The needs and programming techniques developed are quite significant and only a few of the various outputs are mentioned in this report.
   a. Potential deficiences of existing and committed highway system. This data may be displayed graphically or detailed volumes and traffic statistics could be obtained on a link by link basis.

b. Determination of future highway needs. This data can also be graphically presented.

c. Testing of alternate plans and the comparison of vehicles miles and cost-efficiency statistics. This data may again be graphically presented, or a detailed listing would also be available for final analysis.

BENEFITS TO THE DEPARTMENT

Cost-effectiveness analysis is a method of evaluating alternate plans for accomplishing a specific objective. First, the cost and expected benefit of each proposal are estimated. The proposals are then compared on the basis of their cost-effectiveness ratios. This method of analysis is often used by the Federal Government and could prove to be effective if applied by the department when planning and designing highways, particularly when alternate plans need to be evaluated either from the viewpoint of the legislator or the commission.

The complexity of highway planning design should lead to the development of analysis techniques designed to systematically examine the consequences of decisions so that making a decision is simpler and more scientific.

Cost-effectiveness analysis is an important method for clarifying the consequences of decisions. It has been widely used in the Department of Defense and in our space program for a number of years. There is no basic reason why this technique cannot be used to great advantage by the Michigan Department of State Highways. In addition, it has been theorized that future subsidies from Federal Aid programs will require an application of more sophisticated cost-effectiveness analysis techniques.

Often the department has only a limited amount of money available to satisfy an almost unlimited number of competing projects. Thus, the problem becomes one of allocating available funds among the various programs and activities that must be, or should be carried out. For a single goal - completing the INTERSTATE system, for example - a basic strategy might be: (1) allotting a fixed amount of money and then (2) choosing those projects that will bring the maximum benefit for that amount of money. The Phase IV modeling efforts will supply this information.

Cost-effectiveness analysis would increase the reliability of the final decision. Costs are normally stated in dollars -- although in some instances it may be wise to state the cost of any activity in terms of resources such as men or time, or even accident costs. Benefits could also be measured in various ways, but it is usually desirable to convert benefits to dollars. This has the advantage of simplifying both the analysis and the presentation of results to the decision-maker. Assigning dollar values to benefits in some cases may seem arbitrary, but if all the proposals are treated in the same manner, the comparisons will be valid and the analysis will serve its purpose.

The basic supposition is that future departmental decisions will involve many complex factors and a new technique is needed to provide for a rigorous evaluation of the various factors as they interrelate in the alternatives. The continued development of the statewide traffic forecasting model will allow the department to reach informed decisions.

Only two processes have been selected for detailed study in Phase IV, but it should again be noted that many of the techniques developed during the statewide modeling process could serve dual purposes. As an example, the node numbering system used in the network model has been used by several states as a method of filing highway link data such as accident reports. Appendix C is a copy of a report prepared by the staff of the Maine State Highway Commission which discusses their use of this technique.

Finally, the department systems section is presently undertaking a survey of the highway link data system. The final product of the analysis task is to be a coordinated data system for use within the department. As a result of the work completed in Phase I and portions of Phase II, specific techniques developed for the statewide traffic forecasting model could also serve a dual purpose -- as a base for the highway data system currently being developed by the systems unit. A year and a half of research was recently completed on this same topic by the Federal Highway Administration in most of the states in the union. The results of their research may be reviewed in Appendix D. It should be noted that their analysis results in four major conclusions.

One: Grid coordinates for any system selected should be available in order to rapidly present data.

This technique will presently be available with the existing state highway network model. The Statewide Studies Unit has also defined and developed a refined data plotting package which very probably could be used by other divisions within the department.

Two: They also recognized the fact that some type of reference system was required to interrelate the various divisions of data. The results of their analysis indicated that the most favorable system was the reference post system.

The reference post system is another term used to define the nodal identification system used in the statewide highway network model. This reference post or nodal system is presently available for both a coarse and fine state highway network. This would fulfill the requirements of the second point.

Three: As part of a coordinated highway data system, some means of data location-identification technique is a necessary prerequisite. The results of the Federal Highway Administration research states that most favorable location-identification system could be either of the reference post systems mentioned in Appendix D.

As previously mentioned, the statewide model presently uses this technique. It is therefore possible that the statewide model nodal or reference post concept could serve dual purpose efficiently.

Four: The Federal Highway Administration's final conclusion states that in order to develop a coordinated highway data system, many computer programs would have to be written.

During the last four years the statewide model has used computer programs or defined computer programs which operate on the nodal or reference post concept. In the last year the department, with the assistance of Alan M. Vorhees & Associates, developed a total transportation planning package of computer programs which also operate in this nodal concept. Many of these programs were designed to obtain various types of data and summary information. It is quite possible that only slight modifications to selected summary programs within this package would allow the department to rapidly and efficiently develop a coordinated data system.

As a final comment, the results of the trip generation-distribution update in Phase II will supply the preliminary area data base suggested in this report. A flow chart and time schedule for Phase IV appear at the conclusion of this portion of the report.

PHASE IV

WORK PROGRAM FLOW CHART

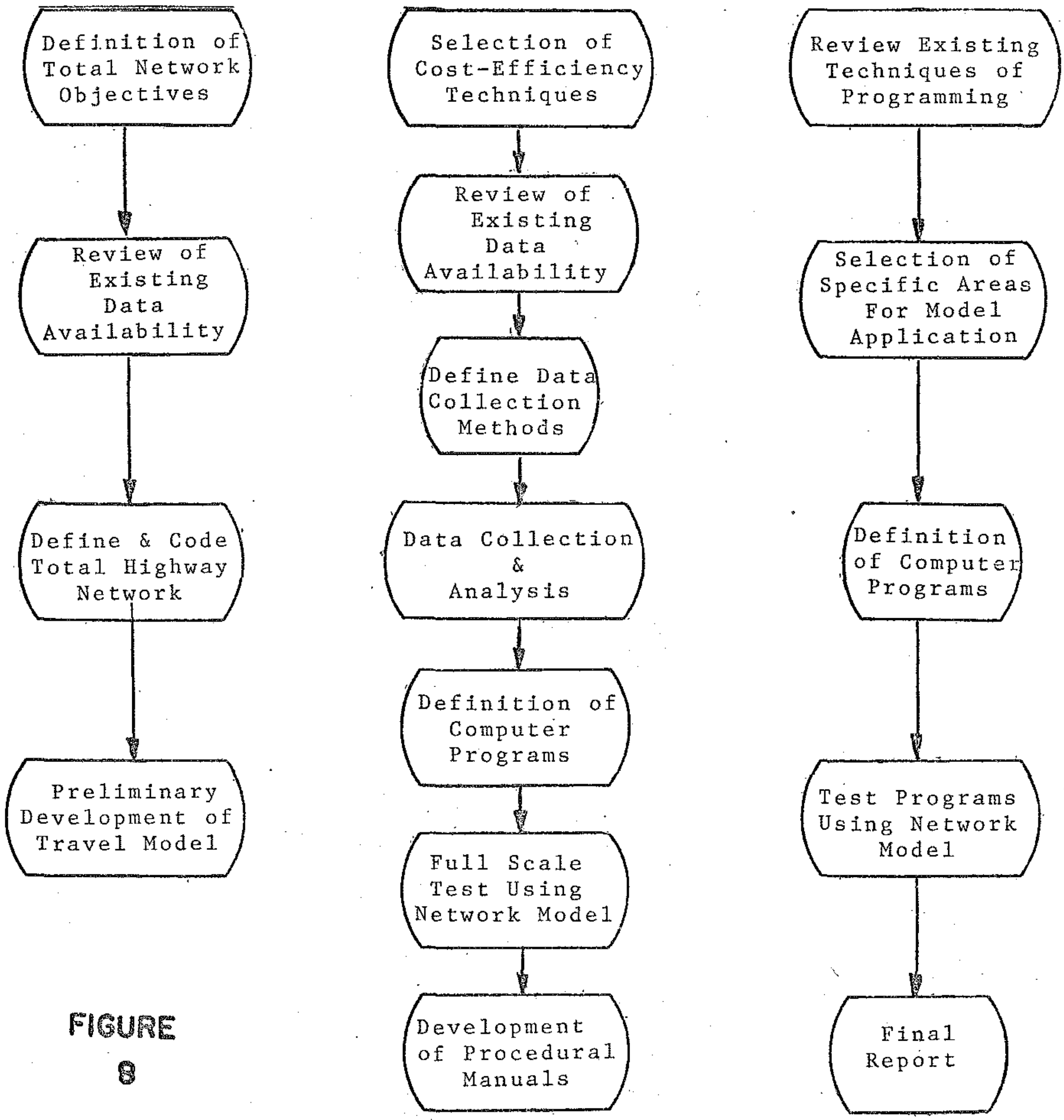
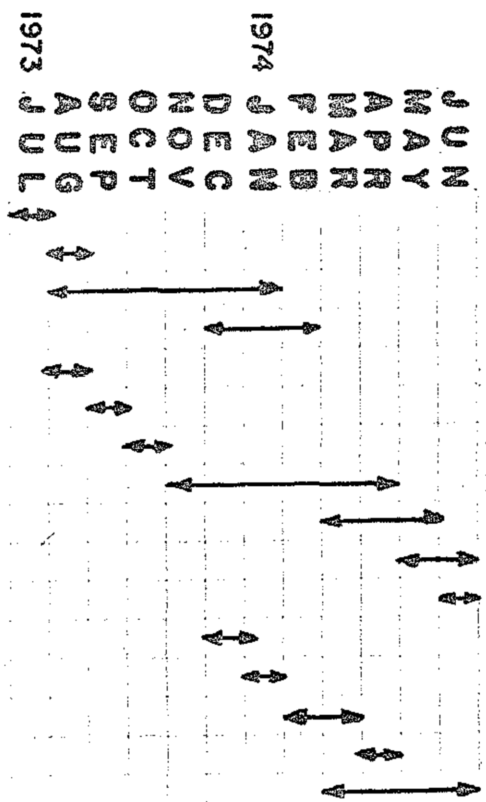


FIGURE 8

PHASE IV

WORK PROGRAM TIME SCHEDULE



Definition of Total Network Objectives
Review of Existing Data Availability
Define & Code Total Highway Network

Preliminary Development of Travel Model
Selection of Cost-Efficiency Techniques
Review of Existing Data Availability

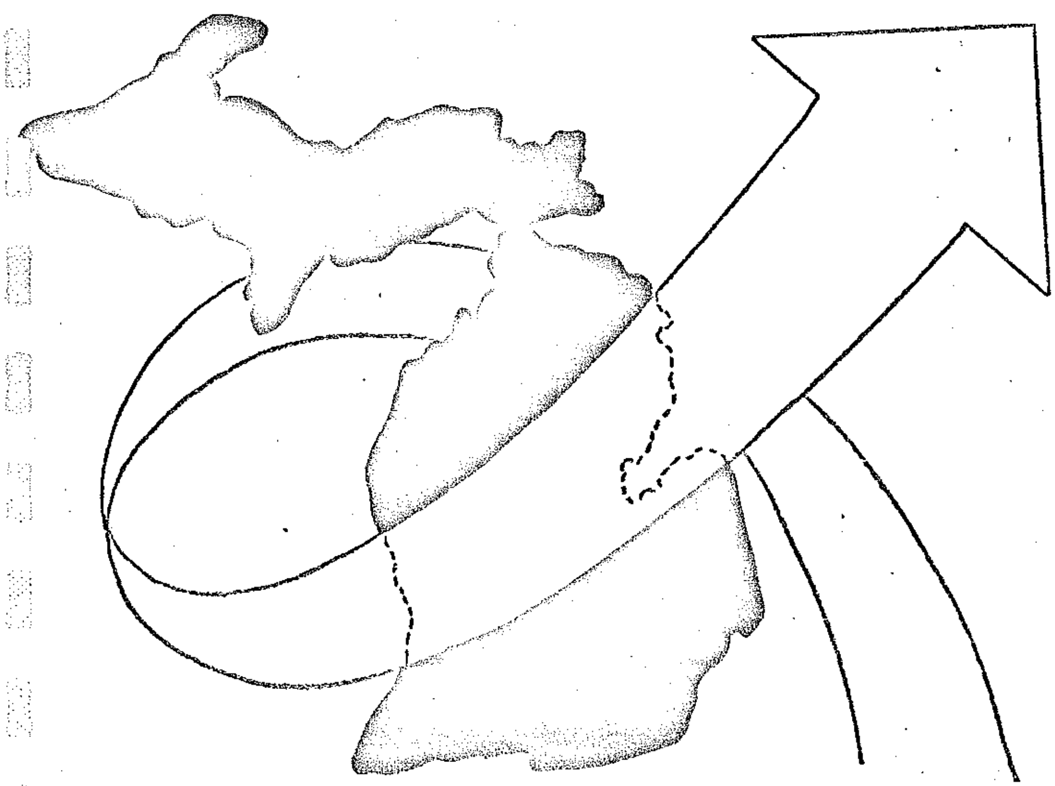
Define Data Collection Methods
Data Collection & Analysis
Definition of Computer Programs

Full Scale Test Using Network Model
Development of Procedural Manuals
Review Existing Techniques of Programming

Selection of Specific Areas for Model Application
Definition of Computer Programs
Test Programs Using Network Model
Final Report

TIME SCHEDULE

STAFF REQUIREMENTS



TIME SCHEDULE - STAFF REQUIREMENTS

Development of a computerized statewide traffic forecast model does require definition of new techniques and innovation on the part of the staff assigned a project of this scope. Only a few states presently have operational statewide traffic forecasting models, therefore, the supply of personnel possessing experience in this area is extremely limited. As there are so few sources to refer to for development assistance, the staff assigned this project necessarily has to be composed of well-trained professional individuals. The diagram on the following page briefly presents a summary of the primary skills required to complete development of this modeling effort. This summary is based on a review of the experiences of other states which have completed similar projects and suggestions from the Federal Highway Administration. The Federal Highway Administration's letter following figure 2 presents their suggestions regarding staffing of this model project.

A thesis reviewing the "state of the art" in the statewide traffic forecasting model area was published in June, 1970 by Phil Hazen, Federal Highway Administration Engineer, to fulfill his Master of Civil Engineering Degree at Northwestern University. Included in his analysis was a chart defining the various classes of statewide models. A copy of this chart has been presented following the general staff requirement diagram.

GENERAL STAFF REQUIREMENTS *

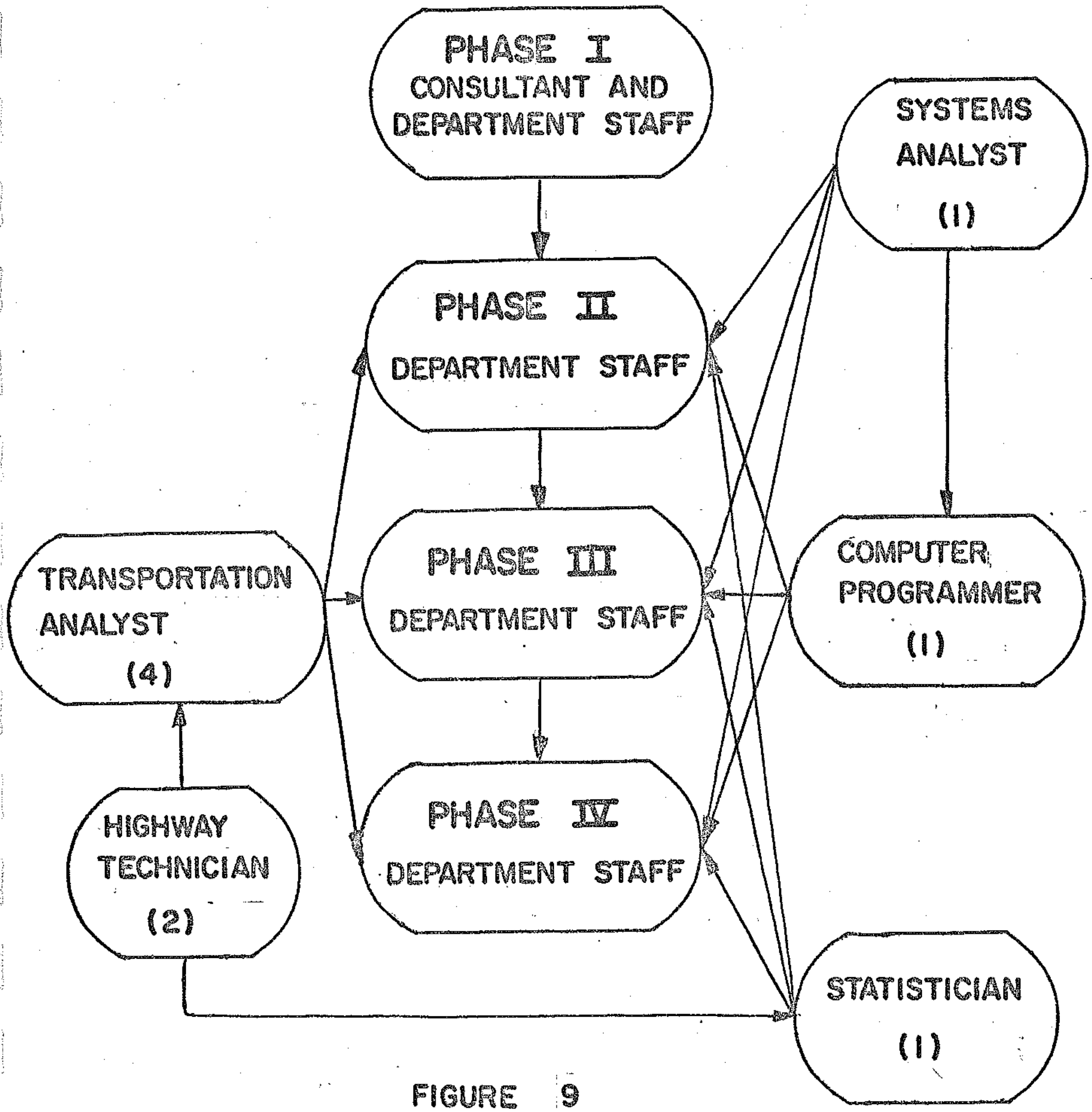


FIGURE 9

*Based on review of statewide modeling projects in the following states:
Pennsylvania, Iowa, Connecticut, Wisconsin, Rhode Island and Illinois.

Classes of Statewide Transportation Studies

Statewide Traffic Model $100,000 or less 6 - 18 months	To do system simulation using the computer in order to better understand how the system operates. Results will be used for functional classification and general planning purposes.	Zones and network will be selected and coded using standard procedures, Models for trip generation and distribution will be kept simple: Usually, no trip purpose breakdown, usually, one but not more than three independent socio-economic variables, and minimum O-D data would be utilized.
Statewide Transportation Study (Highway) $100,000 - $500,000 (Usually over $200,000)	To develop an intermediate priced traffic model based on O-D sample design - To obtain good information on trip generation and trip length; To evaluate alternative highway networks - To develop a State highway plan.	O-D sampling for internal trips accomplished by multiple-screenline roadside interviewing, stratified, cluster sample of homes, telephone interviewing or comparable procedure. Models developed by trip purpose, usually: Auto (3-5) and Truck (1-2). Comparisons and calibration made against ADT volumes. Development of alternatives will include functional classification, scheme development and testing.
Comprehensive Statewide Transportation Study $500,000 - $1,500,000 24 - 48 months 10 - 25 personnel	To develop on a statewide or regional basis the comprehensive transportation planning process - To simulate person movements by mode of transportation - To evaluate alternate modes and networks - To develop a State transportation plan.	Elements and Procedures would be similar to the Comprehensive Urban Transportation Studies. Interviews would be sufficient to develop a trip table of interzonal person movements. Studies would include an Economic Base Model, and Land Use Model. Within budget limitations, goods movements would be obtained and projected.
Integrated Statewide Transportation Study Over $1,500,000 36 - 60 months 15 - 50 personnel	To apply the latest techniques in systems analysis and operations research to statewide transportation planning - To study the complete system of person and goods movement from origin to destination - To evaluate alternate sets of policies in regard to the transportation system - To develop a State transportation program	The procedures would incorporate the latest techniques in systems analysis and operations research. Detailed person and goods movement from origin to destination would be studies with emphasis on transfer and terminal points. The models would be iterative with a feedback to account for results of different transportation policies.

As a result of the technical review by the Federal Highway Administration, it was determined that the Michigan model should logically fall in the second class. A study of this size involves a period of 8 to 25 man-years and a budget of $100,000 to $500,000. Michigan presently has spent $150,000 and 5 part-time man-years.

Presently this project has been assigned the following staff:

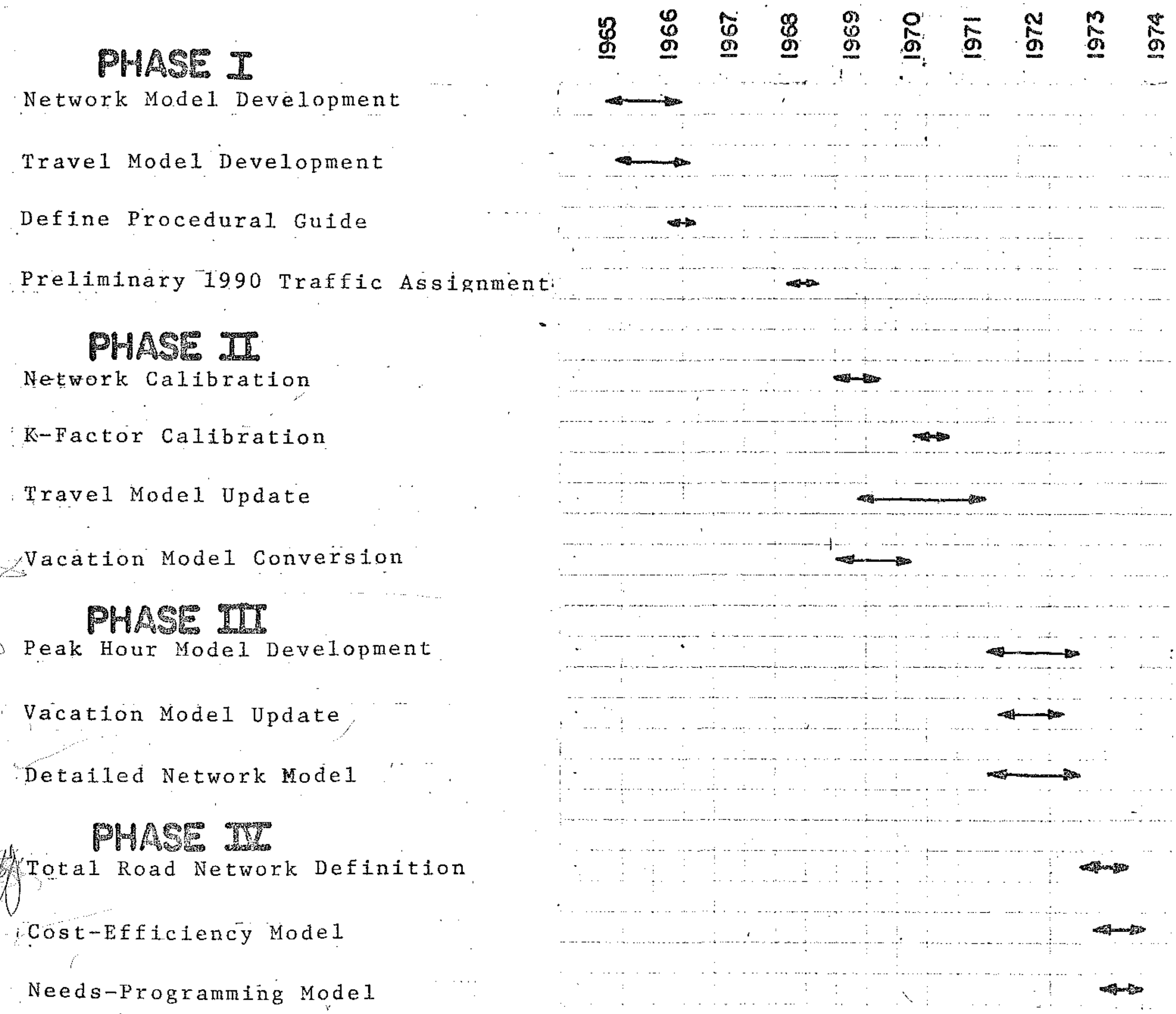
Transportation	- 2 1/2 Positions
Statistician - Part Time	- 10 Hours per Month
Highway Technician	- 2 Half Time Positions

The proposed time schedule at the conclusion of this section is based on the assumption that as of July 1, 1971, the existing staff can be reinforced to more closely reflect the staff requirement summarized in the previous staff requirement diagram. This is the time schedule for the entire four phases of this model development project.

Any change in existing priority or staff conditions would significantly alter proposed completion dates.

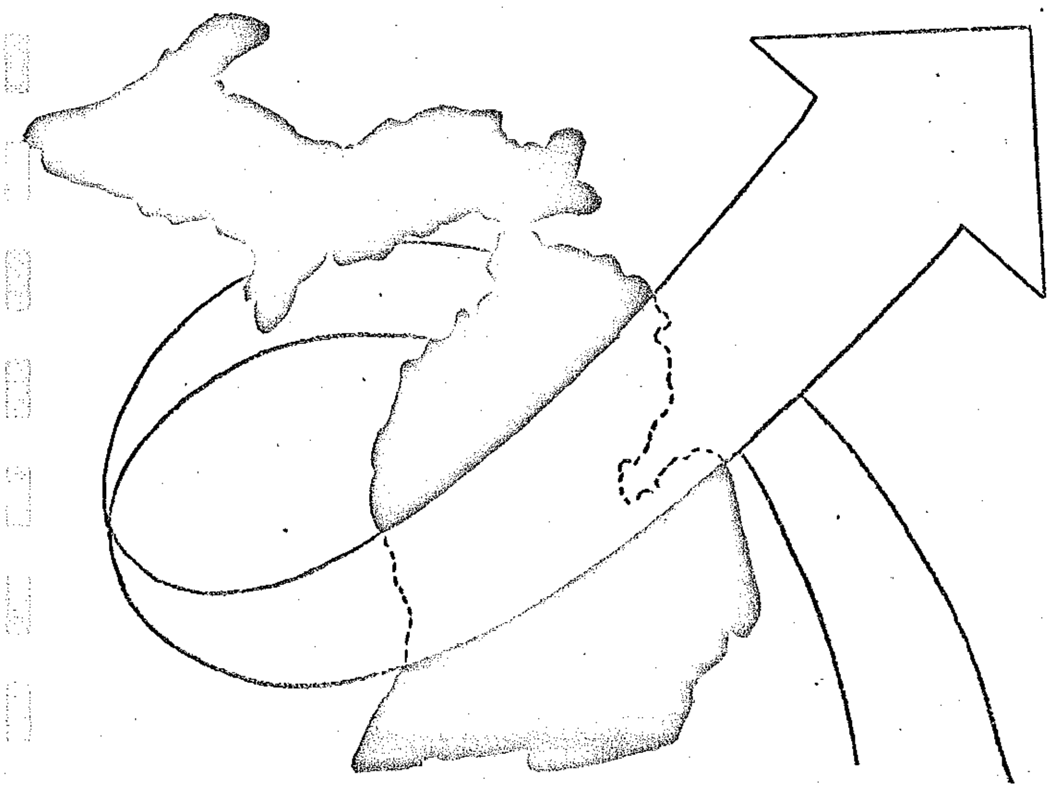
TIME SCHEDULE *

(ALL PHASES)



*Based on review of statewide modeling projects in the following states:
Pennsylvania, Iowa, Connecticut, Wisconsin, Rhode Island and Illinois.

MODEL OUTPUT AVAILABILITY SCHEDULE

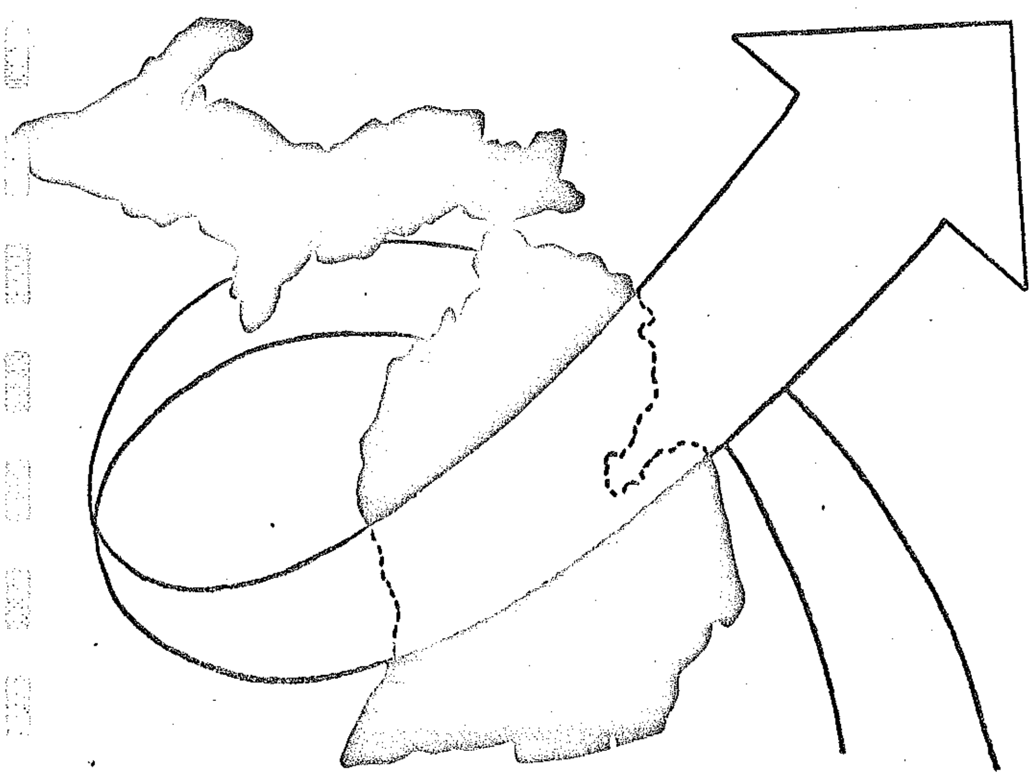


PROPOSED MODEL
OUTPUT DATA AVAILABILITY
DATES

	OUTPUT	DATE AVAILABLE
1.	Preliminary 510 Zone Computerized State Highway Network	August, 1966
2.	Preliminary 510 Zone Travel Time Matrix for all Sub Zones in Michigan	October, 1966
3.	Preliminary Trip Generation Model	November, 1966
4.	Preliminary Trip District Model	December, 1966
5.	Final Report on Phase I Model	March, 1967
6.	Preliminary 1990 Assignment on Existing Trunkline System	March, 1969
7.	Calibrated 510 Zone Highway Network Model	January, 1970
8.	Calibrated 510 Zone Travel Time or District Matrix	February, 1970
9.	Preliminary Vacation Travel Trip Table-510 Zone System	August, 1970
10.	Calibrated Trip Generation Model Using K-Factors	February, 1971
11.	Statewide Trip Data Bank - 510 Zone System	February, 1971
12.	Calibrated Trip Distribution Model Using K-Factors	March, 1971
13.	Statewide Travel Characteristic Summary	March, 1971

OUTPUT		DATE AVAILABLE
14.	Calibrated 1990 Assignment Using K-Factored Models	May, 1971
15.	Calibrated Trip Generation Model Using Updated Data Bank	June, 1971
16.	Statewide Socio-Economic Data Bank-510 Zone System	July, 1971
17.	Calibrated Trip Distribution Model Using Update Data Bank	August, 1971
18.	Calibrated 1990 Assignment Using Updated Trip Generation-Distribution Models & Vacation Model	December, 1971
19.	Phase II Final Reports	March, 1972
20.	Calibrated 2300 Zone Highway Network	December, 1972
21.	2300 Zone Time or Distance Matrix	January, 1973
22.	Statewide Socio-Economic Data Bank - Updated to 1970	February, 1973
23.	Calibrated Vacation Travel Trip Tables - 510 Zone System	April, 1973
24.	Calibrated Design Hour Volume Model Data	June, 1973
25.	Calibrated 2300 Zone Trip Tables	June, 1973
26.	Statewide Weekend Travel Data Bank	August, 1973
27.	Phase III Final Reports	August, 1973
28.	Total Road System Network Model	February, 1974
29.	Cost-Efficiency Analysis Listings	May, 1974
30.	Highway Programming Model Listings	May, 1974
31.	Procedural Manual on Cost-Efficiency Technique	June, 1974
32.	Procedural Manual On Highway Programming Model Technique	June, 1974
33.	Phase IV Final Report	August, 1974

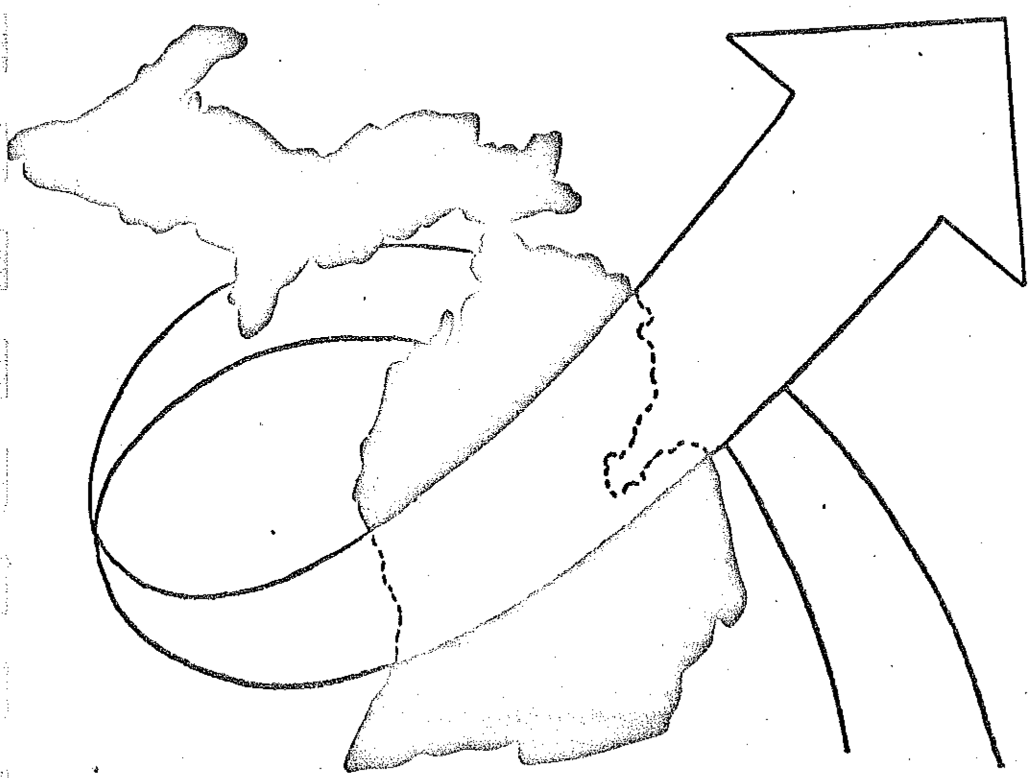
APPENDIX A



APPENDIX A

This appendix is composed of two sub sections from the consultant's Phase I final report. The first section is a summary of the consultants development techniques. The second section includes a review of possible model improvements. Most of the suggested model improvements will be considered during the Phase II and Phase III work program. If additional Phase I model development details are required they may be obtained by referring to the final report entitled A Computer Model for Determining Future Highway Requirements of the State Of Michigan Volume I and Volume II, prepared by Arthur D. Little, Incorporated C-67672-2, December, 1966.

APPENDIX B



SECTION I

Parts A-G

I. INTRODUCTION AND SUMMARY

The Resources Development Planning Program for the State of Michigan requires, as a major component, a plan concerning the various transportation systems that will be needed by the state for the target years of 1980 and 2000. Arthur D. Little, Inc., has been assisting several of the state departments which are responsible for this transportation plan in a two-phase study under contract number Michigan P-52-(4A). This report is submitted in partial fulfillment of this contract, and is concerned only with highway planning. Volume I of the report will provide material on: the background studies we have conducted; a description of the computer model which has been developed; an evaluation of the performance of this model; a review of lessons learned in the process; and suggested steps which might be taken to improve and provide growth for the resulting model. Volume II will provide a user manual describing the various steps necessary to employ the model for the determination of highway requirements at future times, or for evaluation of the desirability of one or more specific highway links.

In the remainder of this section, we will summarize the contents of both volumes, and provide references to more detailed descriptions of the work.

A. BACKGROUND AND HISTORY

In July, 1964, Arthur D. Little commenced its first-phase study of transportation requirements for the State of Michigan, submitting a report on the results in September, 1964. The Highway portion of this first-phase study was essentially a reconnaissance, concerned with the availability of suitable data and techniques for the development of a computer model for estimating future highway requirements. During this reconnaissance we tested specific samples of machine-readable data collected in a series of Mississippi Valley Multiple Screen Line Surveys and a series of Metropolitan Area Origin-Destination Studies. The tests of these samples indicated that the data was generally "clean" and consistent, although a variety of problems existed because the data collected for different surveys employed different coding systems, and different degrees of detail in tabulating origins and destinations.

During this period we also surveyed available analysis techniques and computational procedures, to determine whether any major barriers existed to the employment of a network model for evaluating highway requirements. At the end of this Phase I study we noted that although "there were still many problems to be encountered before an operating program can be put to use, we have found no reason to believe that the proposed approach is in any way impractical. As we have noted previously, it is not possible to guarantee success in advance of actual trials of the analytical procedure; the eventual test will be the degree to which derived density data and actual observations are in agreement. However, we consider the value of the end product to be so great in comparison with the risk involved that we continue to recommend this approach." Accordingly, a decision was reached to proceed further in the development of a highway requirements computer model.

The only technical change in the proposed program at this stage was a change in emphasis: whereas the original intent was the design of a research tool to determine future highway requirements, it became apparent that the same techniques could be of value as a routine working tool for the Highway Department. Effective use of such a tool is dependent on simplicity, economy and opportunities for continuity in employment, so these factors have received increased attention in our work.

Other changes in the original program were made necessary by the very limited availability of funds. The most significant of these was to impose an increased burden on the State Highway Department for conducting the major work in two areas: the edit and preparation of input data and the documentation of the final program. This split in labor was logical, since the Highway Department had been involved in the collection of all the data used as inputs, and was, therefore, in a relatively good position to perform the necessary review and changes of format; it was also possible in this process for the Highway Department to obtain data tabulations of interest to them for purposes other than the study. In a similar vein, the preparation of documentation by Highway Department personnel is a step which ensures that they have thorough acquaintance with the programs involved, and will, therefore, be able to make effective use of the programs in the future.

A more detailed history of the Phase II work is provided in Section V of this volume. We have also attempted there to provide a summary of the difficulties encountered in the project, and the lessons learned in the process. We believe these difficulties are characteristic of the type of work undertaken. Unfortunately, however, they are seldom reported formally and in detail, we believe there is value in indicating the specific problems which caused most difficulty, so that future workers in this field can benefit from our experience.

B. PURPOSE AND SCOPE OF STUDY

The major purpose of our work for the Highway Department has been the development of:

- A computer program for relating economic and/or population data to origin/destination movements;
- a computer program for converting this origin/destination data into highway sector density data, by means of a network model, so that;
- as an end product, there can be produced a complete set of working procedures which can be applied by Highway Department personnel on a routine basis both for forecasting future traffic loads and for evaluating the effects of specific proposed changes in one or more highway sectors.

In meeting these purposes, we have been guided by three general policies:

1. Building on Past Efforts in this Field

A number of network models had already been developed for performing tasks similar to ours. Related "gravity" models to produce origin/destination data had also been employed previously, although principally for the determination of metropolitan area road requirements. Rather than develop our own model ab initio, we concentrated on modifying an existing model developed by the Bureau of Public Roads, so as to make it more suitable for the needs of the State of Michigan. The BPR model was chosen from among the available alternatives because of our belief that it was the model most likely to be "maintained" and modernized in a fashion which would make it available to the State of Michigan in the future, in spite of changes in computer equipment and other factors which tend to make models become obsolescent with time.

2. Simplicity of Usage

Network models are relatively complex, and require a large base of data and input control for employment. Most of these models have required and undergone elaborate tune-up procedures before being put to use. We have attempted to keep our model as simple as possible, in the belief that this will encourage effective usage. The simplicity has been acquired at some sacrifice in potential accuracy; however, we believe that the accuracy of all such models is limited (especially when the problem of forecasting more complex demographic characteristics is considered) and that intelligent model employment rather than the seeking after a high degree of accuracy is the key to deriving utility.

3. Growth Potential

Since it is apparent that both the data sources currently available and the techniques currently employed pose important limits on the general accuracy of the model, we have attempted to make it as easy as possible to incorporate additions and changes which will update components of the model as new information becomes available. The use of network models for highway requirements analysis is still in its infancy; we have preferred, therefore, to develop a model which can be improved over time rather than to develop a closed model where future growth might be limited. Specific areas for potential growth are described in Section V.

C. GENERAL BASIS OF THE MODEL

Models concerned with social interactions over a distance have been under study for several decades, and the use of these techniques for studying highway linkages was suggested relatively early in their history. In practice, the first employment of network models was in the study of urban rather than inter-urban transportation. In many respects the analysis of state highway links via a network model is simpler than that of studying equivalent linkages within a single city, since many of the detailed structure elements employed in the latter are not necessary for study of a state highway program. However, the basic heritage of our model lies in urban transportation rather than inter-urban studies.

All network models for the study of transportation links are based on a set of important assumptions and principles. The main ones are:

1. The overall area of study can be divided into a set of well-defined and meaningful nodes or zones.

a. The definition of nodes or zones is usually based on a set of geographic boundaries which are also related to the physical and demographic patterns of the area under study. Within a city, where network models had their first employment, homogeneity is an extremely important factor in zone definition. Cities are relatively inhomogeneous, in that there tend to be separate, very different shopping and industrial areas, as well as residential areas, and these must be distinquished in urban models. For State Highway planning, however, where entire towns or cities are usually considered as single zones or nodes, this problem of inhomogeneity is less apt to arise.

b. The meaningfulness of a set of zone definitions depends primarily on two factors, First, the zone sizes must be significantly smaller than the distances of travel which are under study; otherwise, there will be severe edge effects and loss of ability to capture detail. Secondly, it is important to be able to forecast with relative ease and accuracy the economic and demographic characteristics used to determine the movements to and from a given zone or node.

2. Population and economic factors can be used to measure the extent to which each zone or node will generate potential automobile traffic--traveling out of this zone to other zones or nodes--and will attract automobile traffic which originates outside its boundary. Because of the relatively inhomogeneous internal structure of individual cities, the attraction and production characteristics of urban zones are quire different and are kept separate. In a state-wide model, however, where we are dealing with relatively homogeneous zones, these two factors become indistinguishable, in most cases of importance, and tend to merge into a single measure of traffic movement potential.

3. Time, distance, or some cost factor incorporating the two serves as a measurable deterrence to movement. It is assumed here that individual drivers will have to make a series of choices among destinations to which they can go, and that these choices will be made on the basis of some combination of the relative attractions of destinations and of the costs of going to them. Thus, deterrence serves to perform an allocation in a rational and determinable manner of the destinations to which traffic leaving a given zone will go. The deterrence is not based solely on distance; the quality and capacity of roads as they influence both travel times and costs, and aesthetic values

encountered during a trip, will influence the allocation. In general, however, aesthetic values do not seem important except on vacation travel, since quality of roads and aesthetic values tend to be so tightly correlated that the two can be subsumed in a single measure.

4. A network model can be used to unite the factors described in 2 and 3 above, by allocating traffic to individual highway links. The same model, with modifications, can be used to distribute travel among a series of roads or road combinations between one node and another in cases where the cost factors are not significantly different. This step is necessary to perform redistribution which takes into account the effects of overloads on highways.

5. The detailed output of the network model can lead to road density statistics, which in turn can be used to evaluate the effectiveness of developing new networks or of undertaking some degrees of modification of an existing network.

One extremely important factor should be noted in the above set of principles and assumptions, and this is the intensive "feedback" that arises between items 2 and 3. In making this pair of assumptions we are tacitly assuming that there is a basic social pattern or structure which relates the size and wealth of a city to its surrounding environment. Each city, in a sense, must both influence and be influenced by the patterns of increase or decrease in neighboring cities, and its growth therefore depends on the demography of its surroundings. We are, therefore, assuming a type of fundamental social structure which governs the rise and fall of cities as places to live and work, in terms of a combination of the opportunities, economic structure, and resources of a given city and of the distribution of other cities which surround it. This is a relatively subtle point which has not received suitable study in either this or any other network analysis of which we are aware.

D. SPECIFIC BASIS OF THE MICHIGAN HIGHWAY NETWORK MODEL

The specific application of the principles described above was made in the following manner.

1. Zone Definitions

With the exception of the city of Detroit, the zones in our model are based on individual townships (or cities) or combinations of townships. The use of townships provides a logical basis, since census data is available and forecasts of future population for the State of Michigan have been constructed on this basis. Further, individual townships are sufficiently large throughout the state to provide the degree of homogeneity sought in the state-wide transportation model. For the city of Detroit, an arbitrary division was made so that this metropolitan area is divided into three zones.

2. Population and Economic Factors

Early in our work it was established that car ownership throughout the State of Michigan at any given time appears to depend almost solely on population. Correlations between county car and truck ownership data and county population , were consistently .98 or higher. Other data indicate that total motor vehicle travel (i.e., urban plus inter-urban) is quite constant, and independent of location of auto registration. Accordingly, in the interests of simplicity, only population is employed to measure total motor vehicle travel during a given period.

To take account of the time dependent effects of economic factors, highway conditions, etc., on the per capita level of car ownership, an additional item is necessary. For this purpose, we have used the ratio of the forecast vehicle miles per capita traveled during the year under study to vehicle miles per capita traveled during the base year of 1960. The Michigan Highway Department has already made estimates of the values necessary to derive this ratio, so the information is on hand for use in the program.

The population of a zone is not by itself adequate to specify the traffic generation characteristics of that zone. This can be seen by considering the effect of city size on the extent to which inhabitants will travel by car outside the boundaries of that city. A small city is apt to lack many facilities desirable to its inhabitants, such as good shopping, adequate sources of employment, nearby recreatonal facilities, etc. Accordingly, a significant fraction of the total automobile traffic of cars owned by residents of a small city are apt to pass through the zone boundary in search of these facilities. As the city grows, however, its sources of internal attraction will increase, and a smaller fraction of automobile travel by inhabitants will pass through the zonal boundary. On the other hand, a city surrounded by other nearby cities will tend to generate more interzonal traffic than one which is isolated by large distances from other cities; it is more difficult to travel to the desired facility in the latter case, so more of the travel will be oriented inwards.

A number of studies of this subject have led to a variety of possible models. After a series of investigations we have determined that an adequate measure of interzonal traffic generation can be based on a combination of the internal zone population plus a function of the external population within a limited distance of the center of the zone--of the order of 30 minutes driving time. A regression analysis has been performed leading to the equation:

$$N = 1.04\, P_c^{0.89} \left(\frac{P_c + P_e}{P}\right)^{0.19}, \text{ general trips*}$$

$$N = 0.062\, P_c^{0.89} \left(\frac{P_c + P_e}{P}\right)^{0.11}, \text{ heavy truck trips}$$

P_c = Zone population

P_e = Population in external ring

N = Interzonal trips generated in each direction (inbound and outbound)

*General traffic includes all trip purposes, other than vacations, made by automobiles and light trucks.

The results indicate that these models account for 99% of the variance in general trips and 95% of the variance in heavy truck trips (which are less important) observed in the nine cities for which we have O/D data and in Detroit.

3. Deterrence Function

For a deterrence function we have employed time of travel rather than distance. The times of movement on individual highway links have been estimated by the Michigan State Highway Department and take into account the quality and capacities of roads as well as the distance traveled on the links.

In early work on the gravity model, a single exponent of distance was employed for deterrence, and for urban and some inter-urban studies. This led to a deterrence function proportional to time or distance approximately cubed. Data indicate that this simple relationship is inadequate both for very close and very large distances, where there is a tendency for deterrence to fall off more slowly than in inverse cube. We have derived separate deterrence curves from O/D data for individual purposes of travel of: (a) general traffic, (b) heavy truck traffic, and (c) vacation. For all of these except the case of vacation, we have developed sets of quadratic equations which describe deterrence as a function of distance. The procedure for this is relatively simple, and leads to a far more accurate model than one based on a single exponent.

4. Network Model

For our network model we have employed, as previously indicated, the Bureau of Public Roads Network Model. We have made slight modifications to this model in the process whereby vehicles are assigned to roads.

This model makes use of the zone to zone trip table supplied by the traffic generation and gravity models and assigns these trips to the highway links forming the minimum travel time paths between the corresponding zone pairs. With approximately 500 zones, there are of the order of 250,000 zone pairs and associated minimum travel time paths. When several assignments are made in an iterative process, with link travel times adjusted each time to account for link congestion found in previous assignments, even more paths will result.

It is clearly impossible to check all of the minimum travel time paths. We have, however, plotted a representative sample of these paths. From this inspection we can note in general that these paths look reasonable. Paths between distant zones tend to lie along major freeways where appropriate. In general, the paths computed correspond very closely to those which one would tend to select from reading a road map and trying to balance direct routing (minimum distance) against the desire to travel on faster highways which avoid congested areas.

5. Link Density

Since it is not practical to check accurately the density on all of the links (approximately 2,100) which unite the various zones considered in our analysis, we have concentrated attention on a specific set of links where there is reason to believe that accurate measures of traffic counts have been taken in the past. These are links on which permanent traffic recording stations are located. We have used the average daily traffic for the year as the indicator to which we wish to calibrate our model.

E. MODEL LIMITATIONS

The accuracy and validity of the model we have developed is limited by a number of factors.

1. Data Limitations

Although a large amount of traffic data have been collected in the State of Michigan, a relatively small portion of it has been oriented towards measurements which have proven useful in our work. The earliest decision which was necessary concerned whether to base the model primarily on Mississippi Valley Screen Data or on Metropolitan Area External Origin/Destination Data. Although these two types of data are in many respects complementary, they are very difficult to combine in developing a single model. The Mississippi Valley data gives great detail on passages along certain links, but provides very little information about car movements outside an origin or destination which do not travel on these specific links. The external O/D data for metropolitan areas furnishes detailed information on all traffic entering or leaving the zone in question, but say little concerning the highways over which this traffic travels. In theory, a model could be based on either set of data, but not easily on a combination of the two.

After examination of the data we determined that the metropolitan area data was the superior set on which to base our model. The screen line data were not available on a sufficient number of links in a well planned manner to permit the type of analysis that would be needed for constructing a model. Further, the analysis of the link data provided by the Mississippi Screen Lines is a far more complex process, and is less easily adapted to existing network computer programs, than is metropolitan O/D data.

However, the metropolitan data itself suffers some deficiencies. First, the available data on external trips to and from Detroit are inadequate and treat the city as a whole, rather than splitting it into zones as is necessary for use in a network model. Second, there is very limited data on small towns and rural areas. The latter bias shows up from the fact that for all but one of the nine cities on which external O/D data were available, the attraction of traffic to these cities was greater than the production of internally registered traffic taking trips out of the cities. If this characteristic was applied to the whole State of Michigan, it would lead to an impossible and unbalanced situation.

We must conclude, therefore, that our results are based on biased data, and suffer potential inaccuracy because of the fact that the necessary O/D data is not available for a sufficiently broad sample of zones.

2. Tune-up Procedures

By the application of sufficiently elaborate tune-up procedures, it would be possible to develop a model which would fit almost perfectly actual observations of critical link densities. We have not followed this process, however, because we believe such models provide a form of "false accuracy." By having a sufficient number of constants and other parameters, which can be adjusted to fit observations, it is always possible to achieve any desired level of accuracy in describing past situations. The presence of these constants, however, will usually have a very unsatisfactory influence on the accuracy of link densities forecast by the model for future time periods unless there is a firm physical understanding as to why they arise and have a specified value. Accordingly, we have used a relatively crude tune-up procedure, and--as a result--have significant errors in the resulting link densities. We believe our procedure is the more sound, however, since there is no "false accuracy" present, and the few parameters that we do employ can be forecast for future conditions with relative accuracy and confidence.

3. Forecasting of Inputs

The major errors in the application of the model will probably arise in the area of forecasting of inputs. This is always a difficult process, and efforts to minimize the difficulties and errors of these forecasts have been responsible for much of the relative simplicity we have incorporated in the model.

F. MODEL PERFORMANCE

The Michigan Highway Computer Model has been completed and is available as a working tool to assist both long-range planning and the development of more immediate decisions concerning highway transportation requirements for the state. Limited error checking of model assignments on a set of links having permanent traffic recorder stations has indicated that in its present form the model is biased towards over-assignment by approximately 57%. A simple scaling adjustment can be used to compensate for this bias, resulting in an average assignment error of approximately 40% over link volumes ranging from under 1000 ADT to 30,000 ADT.

The present model represents completion of the first development stage, and its performance is remarkably good when compared with models of similarly complex processes in their early stages of development. As is common with newly developed models, however, significant improvements can be made both through a number of adjustments and improvements of an immediate nature, particularly with respect to the zone structure and link network that are employed, as well as through longer term improvements requiring more extensive analysis.

G. MODEL USAGE

Ease of employment of the model and ability to incorporate improvements are closely related, since both characteristics are favored by a modular system. The use of the Michigan Highway Network Model requires three major steps:

input preparation, computer runs, and output analysis. These steps are described briefly below.

1. Input Preparation

The basic inputs required for model operation include:

a. Population Forecasts

Forecasts of population for a target year must be made for each zone in the network. A machine readable tape containing such forecasts on a township basis for the two basic target dates, 1980 and 2000, as well as for 1965, 1970, and 1975, and a program to convert this data to forecasts by in-state zones has been prepared by the State of Michigan. Interpolation between these dates can be employed if other target years are desired; otherwise, these inputs are available without further human intervention. Manual preparation of population forecasts for out-of-state zones (which are few) is required.

b. Vehicle Miles Per Capita Growth Rate

The Highway Department of the State of Michigan has already prepared estimates of future total vehicle miles for the state for years in the future up to 1990. In conjunction with state-wide population figures, these can be applied to provide the growth factor estimate, relative to the base year of 1960, as required for the model.

c. Vacation Trip Destinations Allocation

Because vacation travel does not follow the same pattern as other traffic movements, it is necessary to allocate expected vacation destinations among the various zones in the state. For the present model, we have made use of data from a sampling of Michigan and out-of-state vacationers, and have used Mackinac Bridge data to convert these figures into an estimate of total vacation travel. As further vacationer samples are taken, the inputs we have employed can be altered and specific changes in vacation patterns--such as unusually large growth in some counties which provide special facilities--can be incorporated.

d. Vacation Growth Rate

We anticipate that automobile travel for vacation purposes will probably grow more rapidly than overall movements. Separate estimates of the growth rate of vacation travel can be incorporated-if desired-- to take this factor into account.

e. Link Data

Finally, data on any new links or changes in the existing network must be incorporated. Links are specified in terms of the distance and travel time or speed between the two nodes that they connect (bearing in mind that one or both nodes may not have any population and, therefore, lack any traffic generation characteristics). The links must also be characterized in terms of their capacity, since this factor is employed in route allocation.

When the above data are available, the inputs have been adequately specified for the conduct of a computer run.

2. Computer Runs

The computer runs take place in what amount to three steps:

a. BPR Run

The Bureau of Public Roads network model is employed to develop data on the external population around individual zones and on the interzonal travel times, so that traffic generation characteristics for each zone can be computed.

b. Trip Distribution Model

The trip distribution model takes data developed by the BPR network and then: develops the traffic generation characteristics of each zone; employs a gravity model to determine travel (for each trip purpose) from each zone to each of the other zones; and finally, constructs a consolidated interzonal trip table. The first trip table may be adjusted by an iterative process to obtain an improved fit to the input data.

c. BPR Model

The BPR model is then run a second time, employing the trip table produced by the trip distribution model. In this step, the BPR model determines specific routes which will be followed in making zone to zone trips, computes traffic densities on all links, and performs certain re-allocations of traffic in cases where one or more sets of links are overloaded and alternate routes, which could lead to shorter trip times under these traffic conditions, are available.

3. Output Analysis

A relatively wide range of output formats are available from the final BPR program. The output desired for a specific run will depend on the purpose of that run, and on the analyses which must be conducted thereafter. Since there will be of the order of 2,100 individual links forming approximately 250,000 paths, it is obvious that this analysis must be narrowly oriented if the user is not to be overwhelmed by output data. Tabulations can be developed indicating the most critical links in the system, or a specific family of links or paths can be examined in detail, without the full data developed by the computer being displayed. We anticipate that the most useful outputs will be determined over a period of time, as experience with the model is gained.

There are a variety of forms in which the network model can be improved as further data and experience are gained. In general we do not anticipate that the fundamental network structure of the BPR model will require significant alternation. However, as further metropolitan O/D data is collected within Michigan (or adjacent states with similar socio-economic conditions) it may prove worthwhile modifying the traffic generation functions, especially for heavy trucks--and these in turn may lead to an alteration of the exact equations used for the deterrence functions in the gravity model. In the area of vacation travel, data currently is very limited and some specific components--such as out-of-state travelers passing through Michigan on vacation--could well receive specific attention. In general, however, all of these sub-models can be altered significantly without influencing the main structure of the package of programs.

In the area of output we anticipate that considerable growth is possible. As understanding is developed of the uses to which the model can be put, and of the post-analysis steps required for these purposes, it should be possible to develop a post-processor which performs a major portion of the post-run analysis. In this manner, the burden of using the model can be eased and the results of computer runs can more quickly and effectively be applied.

SECTION II

V-C

IMPROVEMENTS POSSIBLE WITH EXISTING DATA

a. Improvements to Computer Programs

The efficiency of computer operation can be increased through a number of modifications to the computer programs. ADL-Time Convert and ADL-Time Add can be integrated into a single program. Also ADL-Trip Convert can be modified. At present separate runs must be made to produce a major or minor trip table in the BPR format from a Fortran format trip table for each trip purpose. With three trip purposes, this requires six runs. In addition, PR-152 must be run to merge the trip tables. Through modification, ADL-Trip Convert can be programmed to read in all three Fortran trip tables simultaneously, merge them, and generate both the minor and major trip tables in a single run.

It has also been noted that many of the control options in ADL-Trips and ADL-Vacation are exercised through simple modifications to the programs themselves. Once experience has been gained in their use and the options of real interest have been noted, it would be worthwhile to modify these programs so that these options can be specified by means of control cards. This would eliminate the need for continual program modification and program compilation.

b. Improvements to Link Network

It is clear that some, although by no means all, of the discrepancies observed between volumes assigned by the model and volumes actually observed are due to inconsistencies in the highway network rather than in the model itself. Virtually all traffic studies employing network models have found that significant improvements can be obtained by making adjustments to the network once preliminary assignments have been made. Such adjustments include modifications of link speeds and alterations in the placement and length of pseudo links.

In making such adjustments it is important to differentiate between those that can be made in the absence of actual ADT data and those that require such data. To the extent possible, adjustments should be made without recourse to actual ADT data, for such data is not available for the purpose of adjusting proposed future networks.

It is quite likely that worthwhile improvements can be made merely by analyzing the assignments made by the model. The assigned volumes, including those on pseudo links, should be noted on a network map. The map should then be examined for link volumes that are unusually large or small relative to neighboring link volumes or volumes on parallel routes. Similarly, sudden discontinuities in link volume should be noted. Such an analysis may reveal that the speeds listed for the links on one route may be too high relative to those on a parallel route, resulting in an excessive diversion of traffic to the faster one. Large discontinuities may reveal that additional pseudo links from a particular zone are required.

If many of the links in a particular area are heavily overloaded, it may well be that too few of the highways in the area have been included in the network. If accurate assignments are required in that area, more of these highways should be included in the network. If, as in the Detroit area, the primary purpose is to provide a mechanism for routing trips from Detroit to other areas and for permitting other trips to pass through the Detroit area, proper behavior may possibly be achieved by increasing the capacities listed for these overloaded links.

Out-of-state links and pseudo links connecting out-of-state zones to border nodes should also be given attention. In the present network, it appears that some of the out-of-state zones should have additional pseudo links. Also, it appears that the highway around the western side of Lake Michigan channels too much traffic through Menominee County at its northern end. Additional highways leading from Gogebic, Iron, and Dickinson counties toward the Chicago area would eliminate the diversion through Menominee County of traffic between the western tip of the upper peninsula and southwestern Michigan.

As a final note, the Mackinac Bridge deserves special attention. The toll on this bridge no doubt deters much of the potential local traffic across this link. This can be seen from the fact that approximately 90% of the traffic across the bridge in the summer is for the purpose of vacation. In the present network, there is no deterrent simulating the bridge toll and the assigned volume on the bridge is much greater than that observed. Experiments should be conducted to determine the bridge travel time that will serve as an appropriate deterrent. In this regard, it may be necessary to represent the bridge by several links in series since no link can have a travel time in excess of 31.5 minutes.

c. Correlations Between Trip Tables and O-D Data

As mentioned earlier, time was not available to correlate the rows in the trip table corresponding to the nine O-D study cities with the O-D data itself. Such as analysis would be useful in determing the accuracy of the trip table entries.

d. Analysis of Link Growth Ratios

Significant errors between assigned volumes and observed ADT's have been noted on many of the links. It may well be, however, that on many of these links such a disparity would be consistent from year to year. Perhaps a link having an assigned volume 25% of actual for 1960 would have an assigned volume close to 25% of actual for the year 1975. In other words, perhaps the relative change in assigned volume from year to year would be much more accurate than the actual value of the assigned volume in any one year.

In order to establish the degree to which this phenomenon may exist, it would be useful to perform assignments for time periods such as 1950, 1955, 1960 and 1965. In order to avoid the need for establishing separate link networks for each time period, the analysis could be restricted to links not likely to have been affected by highway system improvements over the time periods considered. On the links selected, an analysis should be performed to determine how well relative changes in assigned volumes correspond to relative changes in observed volumes.

e. Evaluation of Double Smoothing

As discussed in Section II B-3, a technique for producing a second smoothing of the entries in the trip tables for general and heavy truck trips has been developed. Analysis of trip table summaries indicates that this process may well produce more accurate trip tables. No traffic assignments have been made using such trip tables, however. It would be useful to do so in order to determine whether or not this process is worthwhile.

f. Development of Improved Measures of Value

The present statewide highway model produces a set of traffic volumes assigned to the various links in the system together with related summary statistics.

Various measures of value or effectiveness must be applied to these results as an aid in determining the relative desirability of alternative proposed highway systems. At the outset of this project, we intended to develop a number of such measures and to develop a computer program for their application. Unfortunately, time was not available for performing this task. Such an undertaking would form a very worthwhile future program. Some preliminary thoughts on this subject are described in Working Memorandum MLE-3, dated December 17, 1965.

IMPROVEMENTS REQUIRING NEW DATA

a. Inclusion of Additional O-D Data in Trip Distribution

Data from a number of external origin-destination studies have become available in the last few months, and additional studies are under way. It would be useful to add this data to the data base employed in the development of the trip distribution models and to determine whether such data would produce any significant changes to the model.

A serious deficiency of all this data, however, is that they focus only on traffic to and from urban centers. We have no data on trips between rural areas. In the internal trip analysis conducted in urban studies, interview data on a sample basis are obtained to describe trips between all zone pairs. A corresponding interview program on a statewide basis would be most useful, and the feasibility of such a study, focusing especially on rural areas, should be examined.

b. Use of Additional Demographic Data for Forecasting Trip Distribution

The present rip distribution models for general trips and heavy truck trips use only population to characterize the individual zones. Additional kinds of demographic data might prove useful in increasing the accuracy of these models, especially that for heavy trucks. The census data tape obtained from the Federal Highway Administration and converted to a data file for the Michigan zones would provide a useful source of such data. Extensions of the model should be approached conservatively, however, for the use of additional types of demographic data will increase the problem of making forecasts for future time periods.

c. Improvement of the Vacation Trip Model

The present vacation model is very crude. Suggested areas of improvement are listed in the final model report. As alluded to there, any meaningful effort to develop an effective vacation model will require very serious and extensive study in which adequate consideration is given to the different kinds of vacation travel that exist, to measures of vacation attraction, and to effective mechanisms for obtaining meaningful data.

d. Analysis of Travel by Time of Day, Day of Week, and Season

The present trip distribution models estimate average daily trips only. The data used in the development of these models, however, was all taken on summer weekdays, and there is some question as to whether the trip estimates are in fact representative of year round ADT rather than summer weekday ADT.

A more serious limitation is that the models do not have the capability of estimating the traffic to be expected on weekends, at various hours of the day, or during different seasons of the year. Although O-D data can be scaled to convert the number of trips observed on a particular day to those observed on the average day throughout the year, this scaling does not account for variations in the mix of trip purposes which in turn have different trip lengths. Hence, such scaling is not likely to provide very accurate results.

A useful program of major dimensions would be to analyze the manner in which trips of different purposes vary by hour of day, day of week, and season. The development of trip distribution models for these different purposes, and the use of scaling coefficients to represent the trip purpose mix for selected time periods, would permit the development of a model which could estimate seasonal, daily, and hourly traffic densities.

If such a study were undertaken, considerable effort would need to be expended in determining the different trip purposes to be employed. For example, work trips of a commuting nature have an entirely different time pattern than work trips involving salesmen making business calls. Similarly, skiing trips have an entirely different seasonal pattern than hunting trips--both of which could be classified as vacation or recreational.

The development of such models would constitute a project of considerable size and duration. A feasibility study would be worthwhile before embarking on such a program.

e. Analysis of the Rural-Urban Interface

The purpose of the statewide traffic model is to estimate traffic volumes on major highways outside urban areas. Such a model cannot contain the detail necessary to accurately estimate traffic patterns within urban areas; urban models are needed for this purpose. On the other hand, the urban areas cannot be ignored in the statewide model, because they are the source of much of the traffic on the highways in rural areas and because much of the statewide traffic passes through urban areas. In our analysis of the traffic assigned to links within the Detroit Metropolitan area, we found substantial problems.

It would be most worthwhile to perform a study of this problem and to develop a more effective means of characterizing urban areas in the statewide model. At the same time, it might prove useful to determine how the statewide model could provide data characterizing external traffic movements for use in urban traffic models.

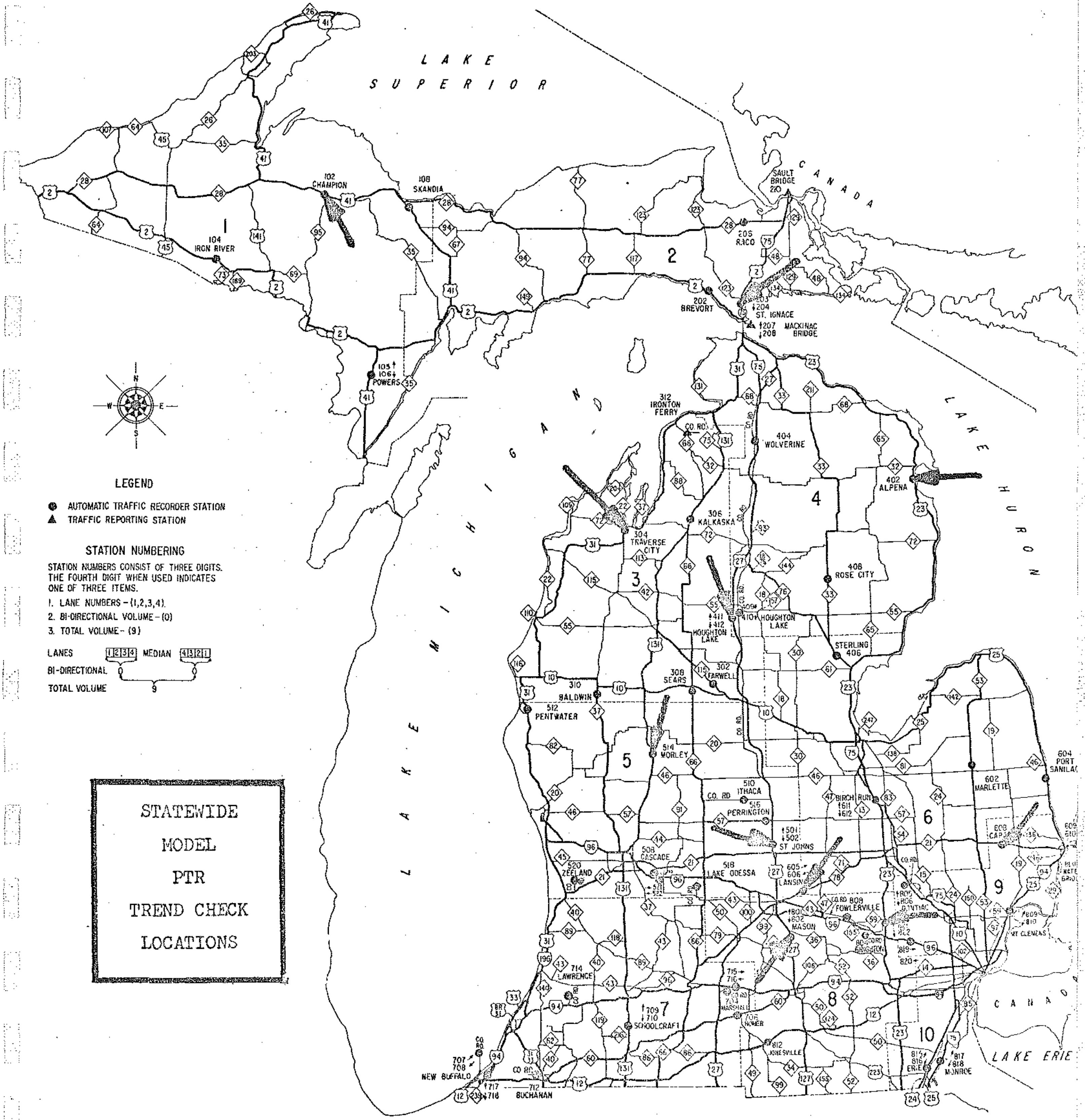
NOTE:

Data presented in this appendix are the results of a preliminary 1990 traffic forecast for the complete state trunkline system as it existed in 1965. These graphs indicated what traffic volumes would occur on the present highway system assuming no changes or additions to the highway system. Only the preliminary trip forecasting models were used to obtained these results.

The traffic volume trends at selected permanent traffic recorder stations has been plotted on each of the following graphs. Appling more simplified techniques of projecting trend data, the user might obtain a trend line similar to the dotted lines on each graph. The future forecast for any specific route might be determined by obtaining the fore-casted traffic volume from this trend line for the year 1990 on the X-axis of these graphs. These values are represented by the diamond on each graph. The projected traffic volume from the preliminary traffic forecasting model has also been entered on these graphs and appears as a star. Note that with the exception of St. Ignace and Houghton Lake graphs the model's results compare favorably with projected trend lines. These are only a few selected stations throughout the state but the results are encouraging and completion of the model calibration process during Phase II should led to a reliable statewide traffic forecasting model for the State of Michigan.

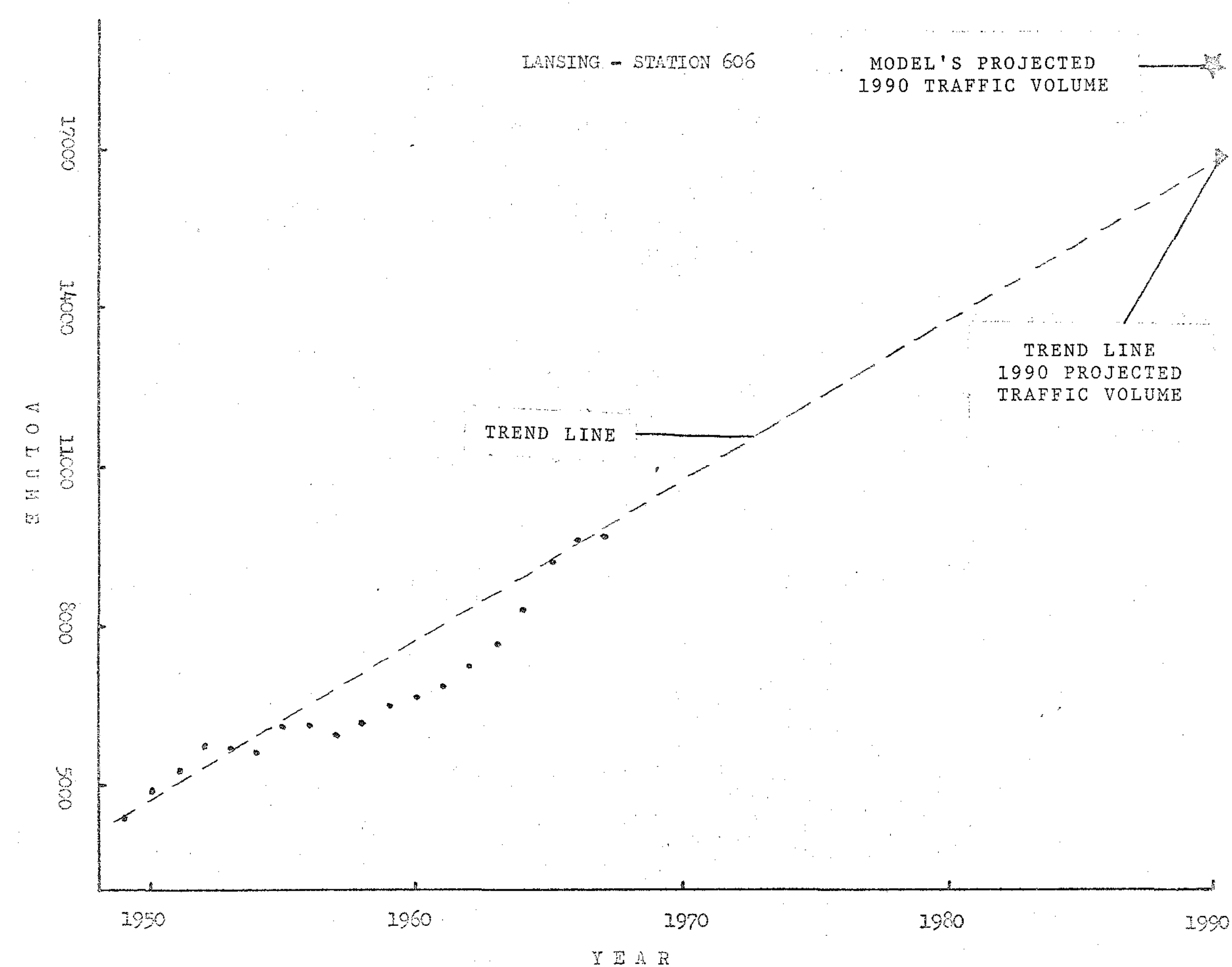
CONTINUOUS AUTOMATIC TRAFFIC RECORDER STATIONS

STATEWIDE TRAFFIC SURVEY



MICHIGAN DEPARTMENT OF STATE HIGHWAYS

TRAFFIC DIVISION — SEPT 1967



STATE OF MICHIGAN
DEPARTMENT OF STATE HIGHWAYS
TRANSPORTATION PLANNING DIVISION

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LANSING

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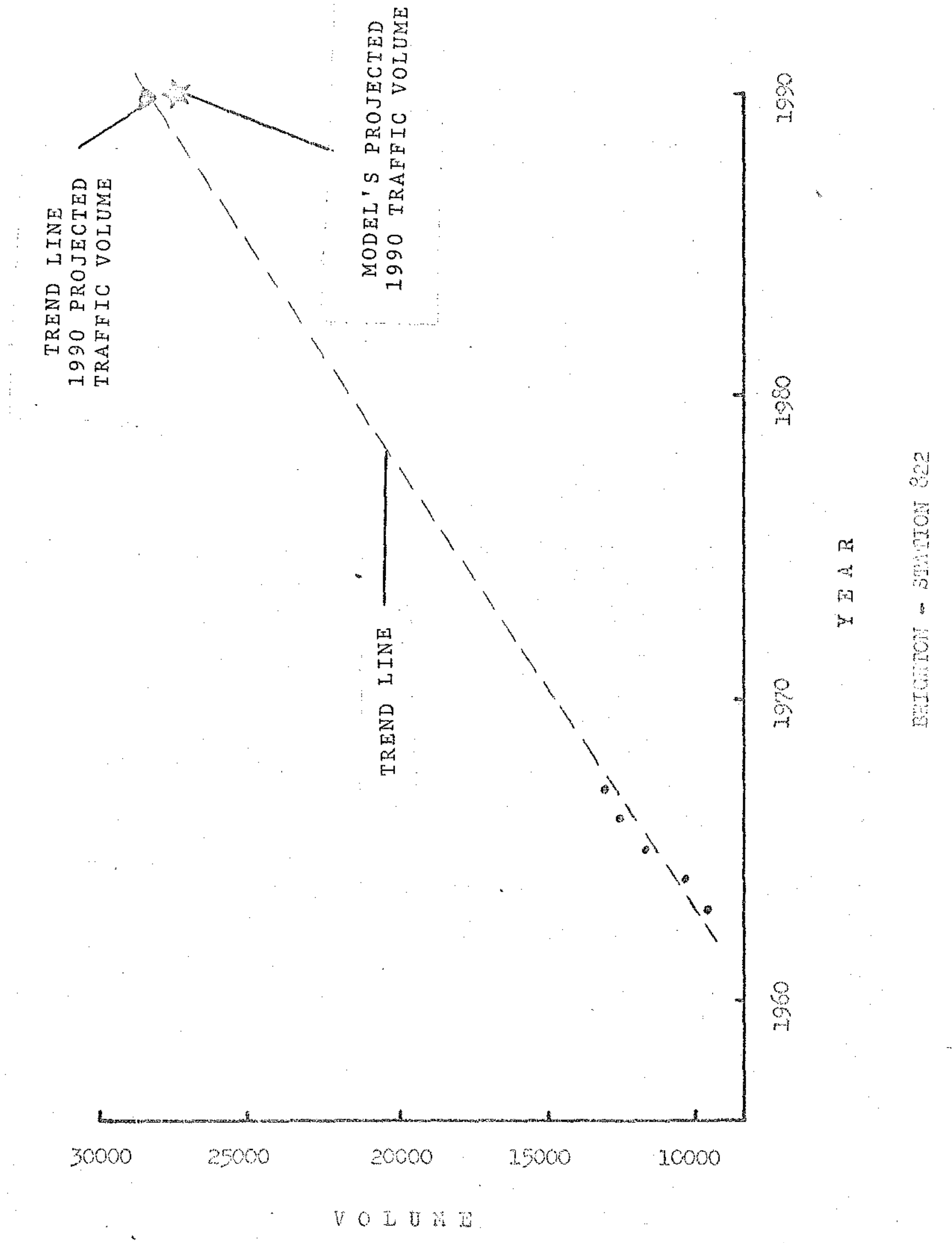

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FORM 1751

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STATE OF MICHIGAN
DEPARTMENT OF STATE HIGHWAYS
TRANSPORTATION
PLANNING DIVISION

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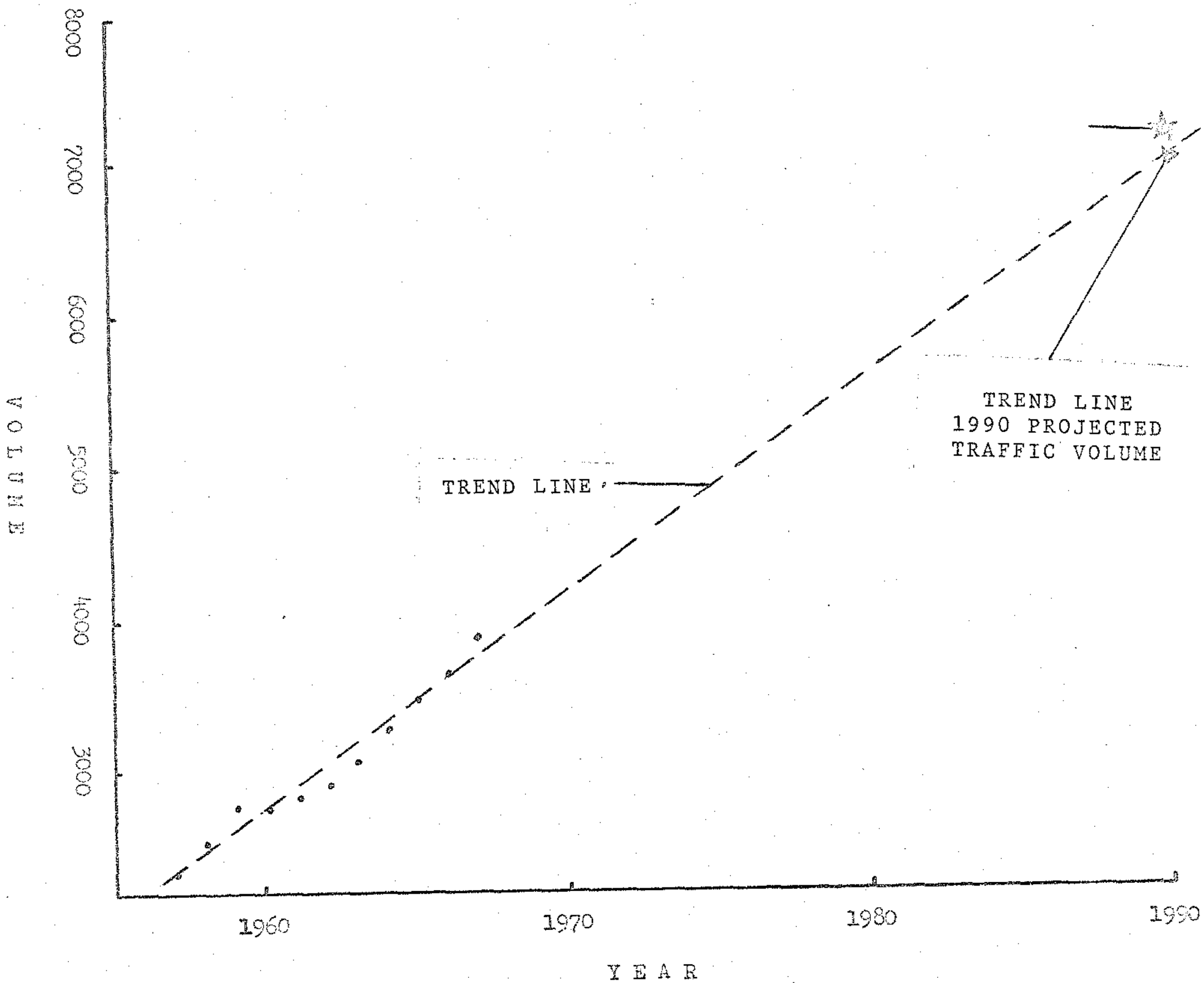
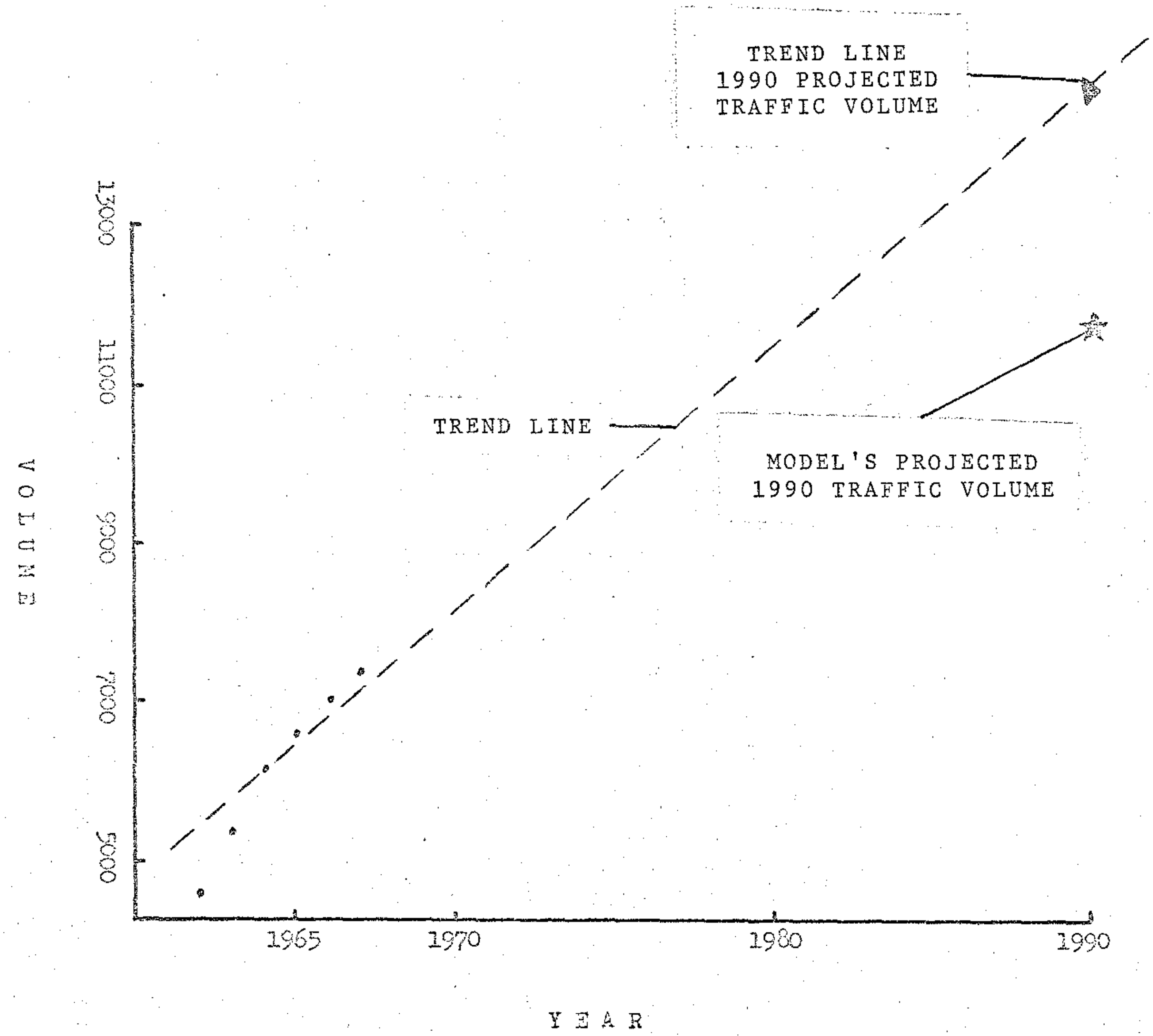
MORLEY



MORLEY – STATION 514



HOUGHTON LAKE - STATION 412

STATE OF MICHIGAN
DEPARTMENT OF STATE HIGHWAYS
TRANSPORTATION
PLANNING DIVISION

TAR. NO.	TAR. BY
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HOUGHTON LAKE

FORM 1751

EDCO 197M 10-68

STATE OF MICHIGAN
DEPARTMENT OF STATE HIGHWAYS

TRANSPORTATION
PLANNING DIVISION

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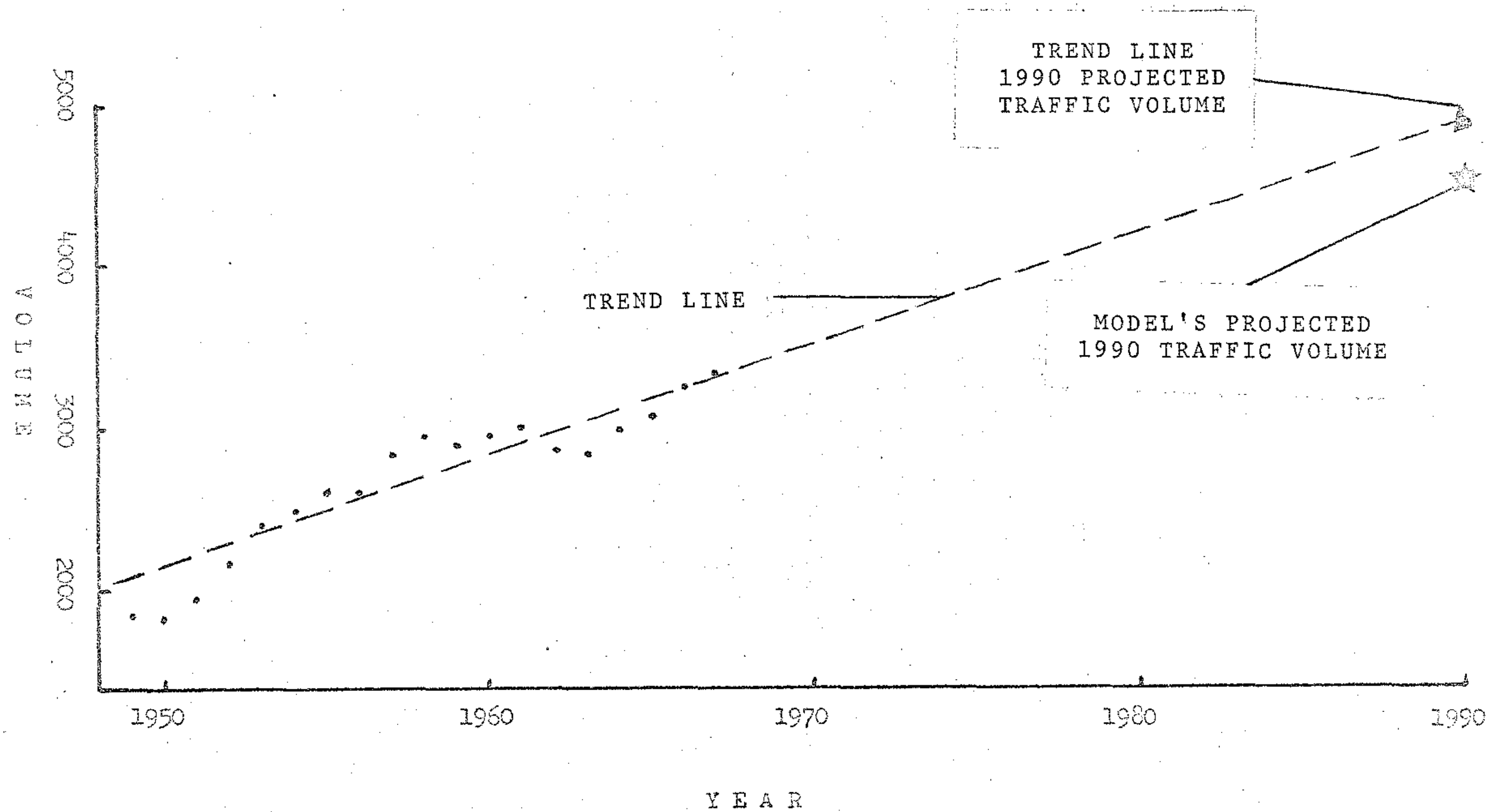
ALPENA



ALPENA - STATION 402

STATE OF MICHIGAN
DEPARTMENT OF STATE HIGHWAYS
TRANSPORTATION
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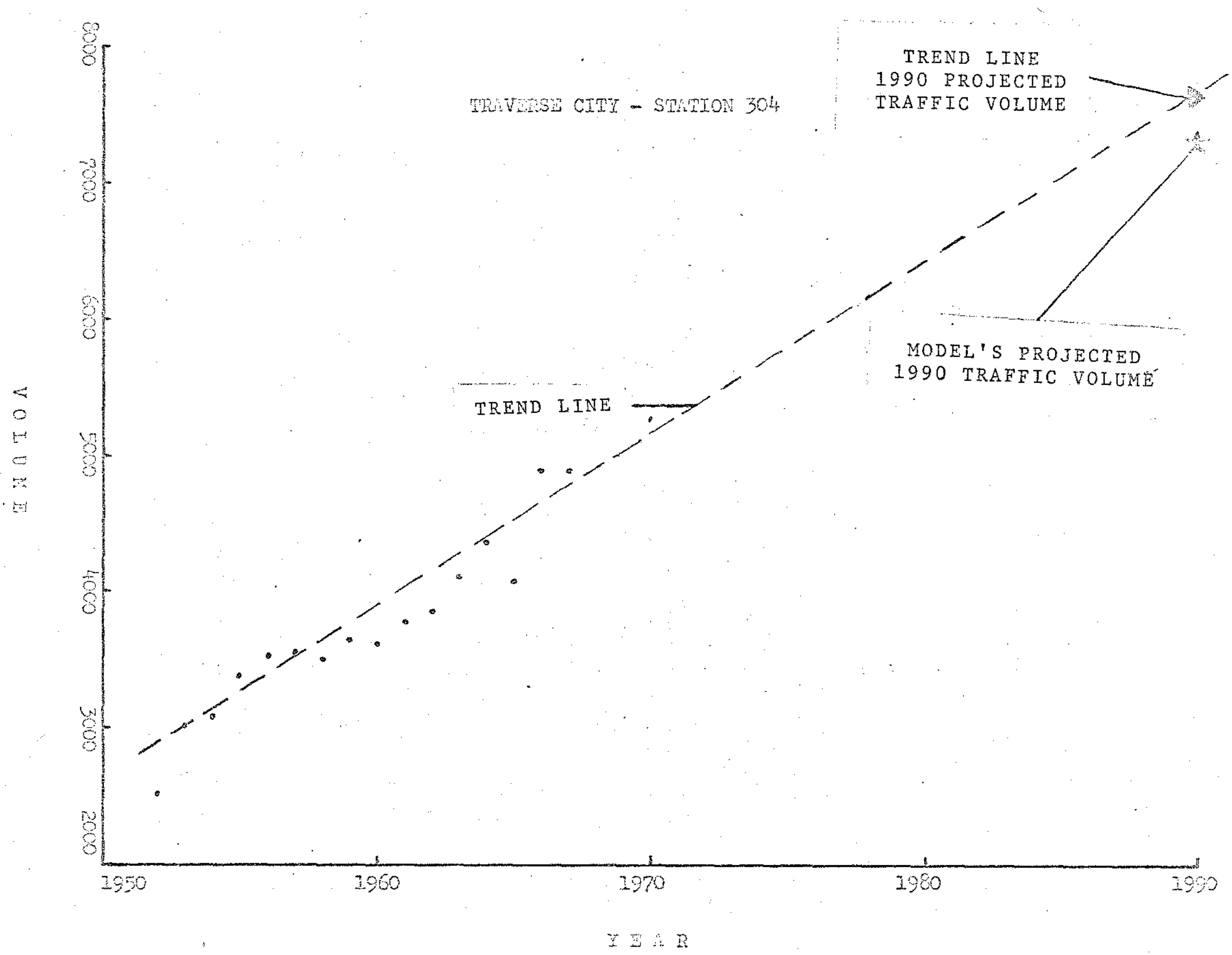
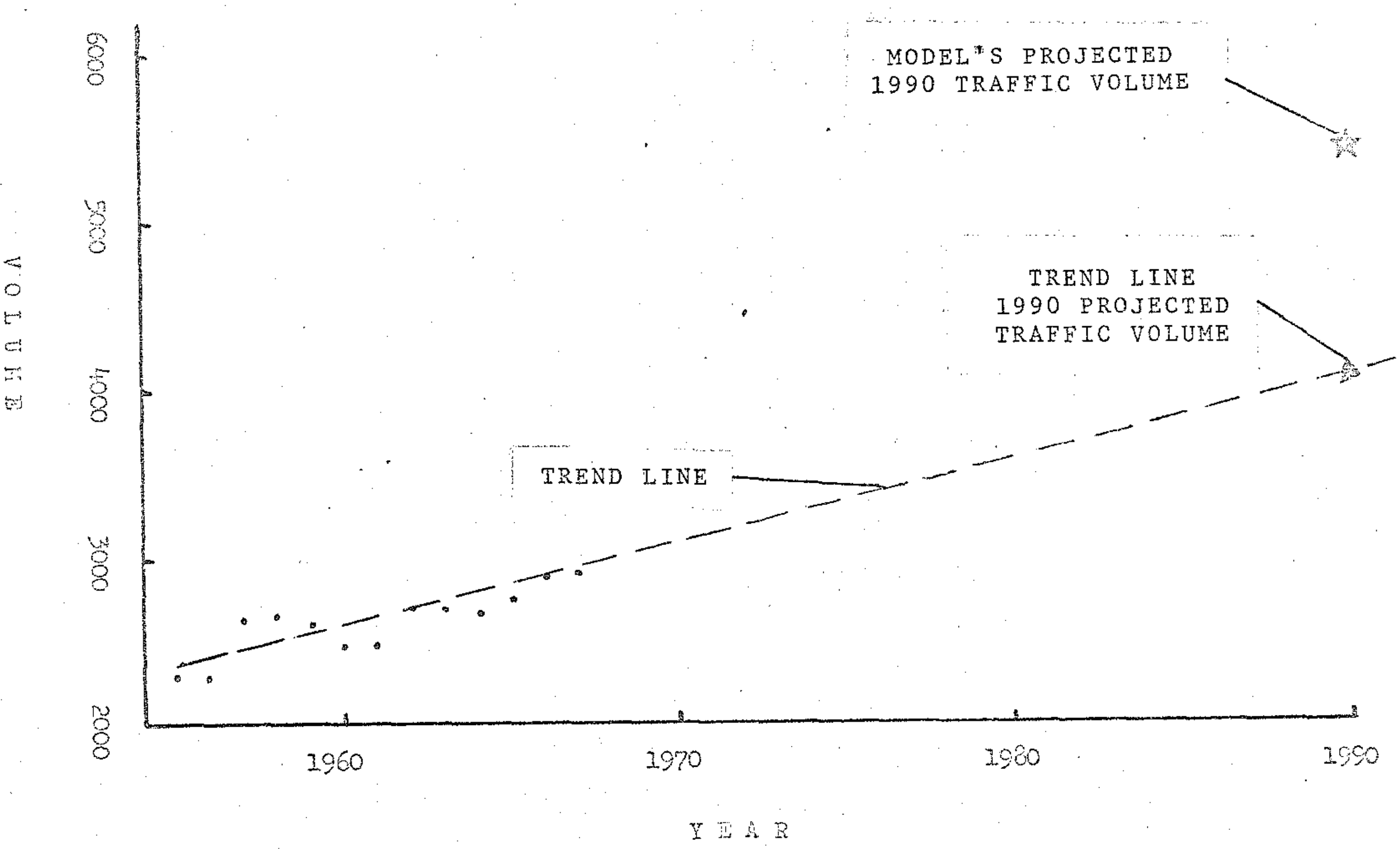
TRAVERSE CITY





ST. IGNACE - STATION 204

STATE OF MICHIGAN
DEPARTMENT OF STATE HIGHWAYS
TRANSPORTATION
PLANNING DIVISION

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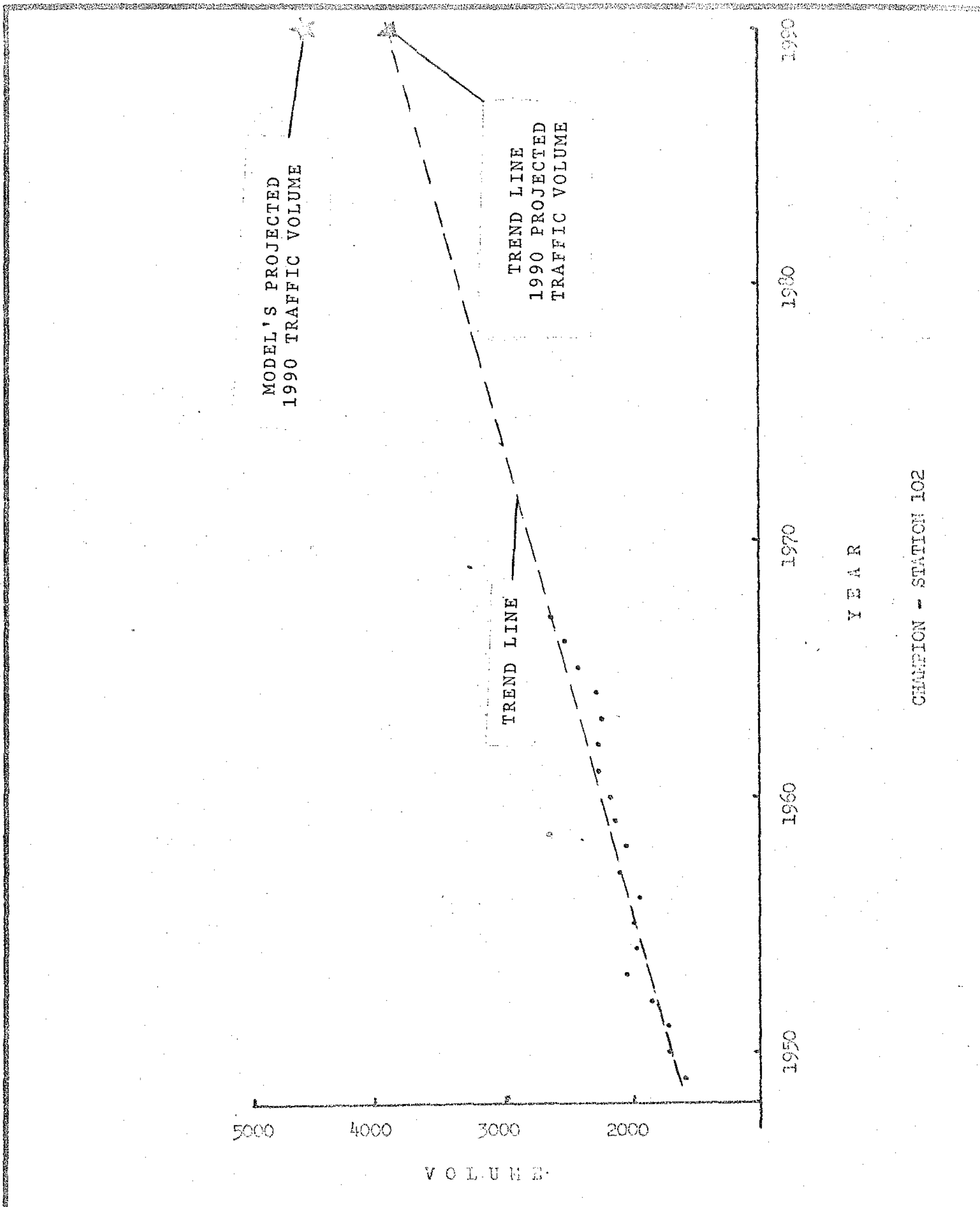
ST. IGNACE

FORM 1751



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FORM 1751

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STATE OF MICHIGAN
DEPARTMENT OF STATE HIGHWAYS

TRANSPORTATION
PLANNING DIVISION

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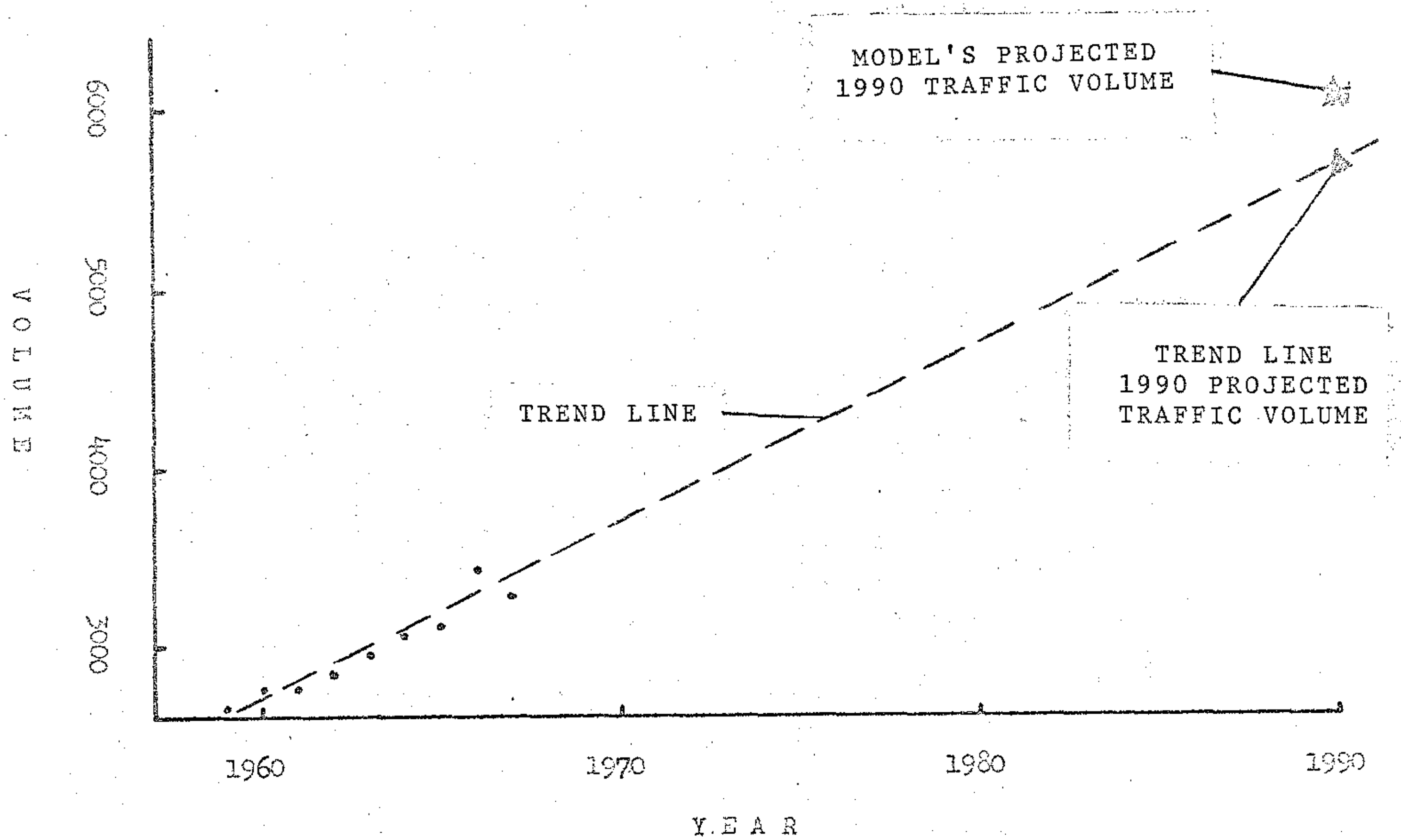
CAPAC



CAPAC - STATION 608

STATE OF MICHIGAN
DEPARTMENT OF STATE HIGHWAYS
TRANSPORTATION
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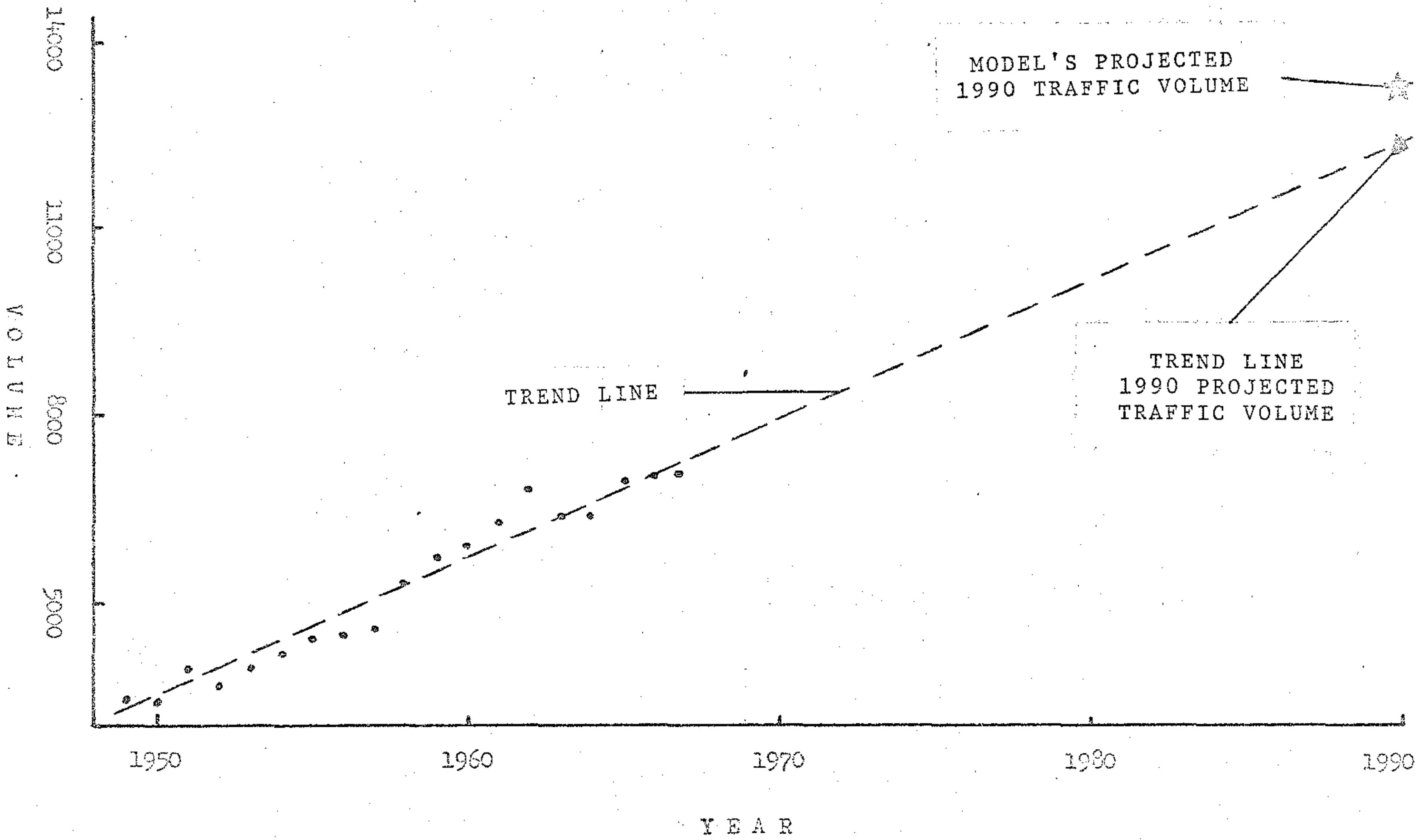
MASON



MASON - STATION 802

FORM 1751

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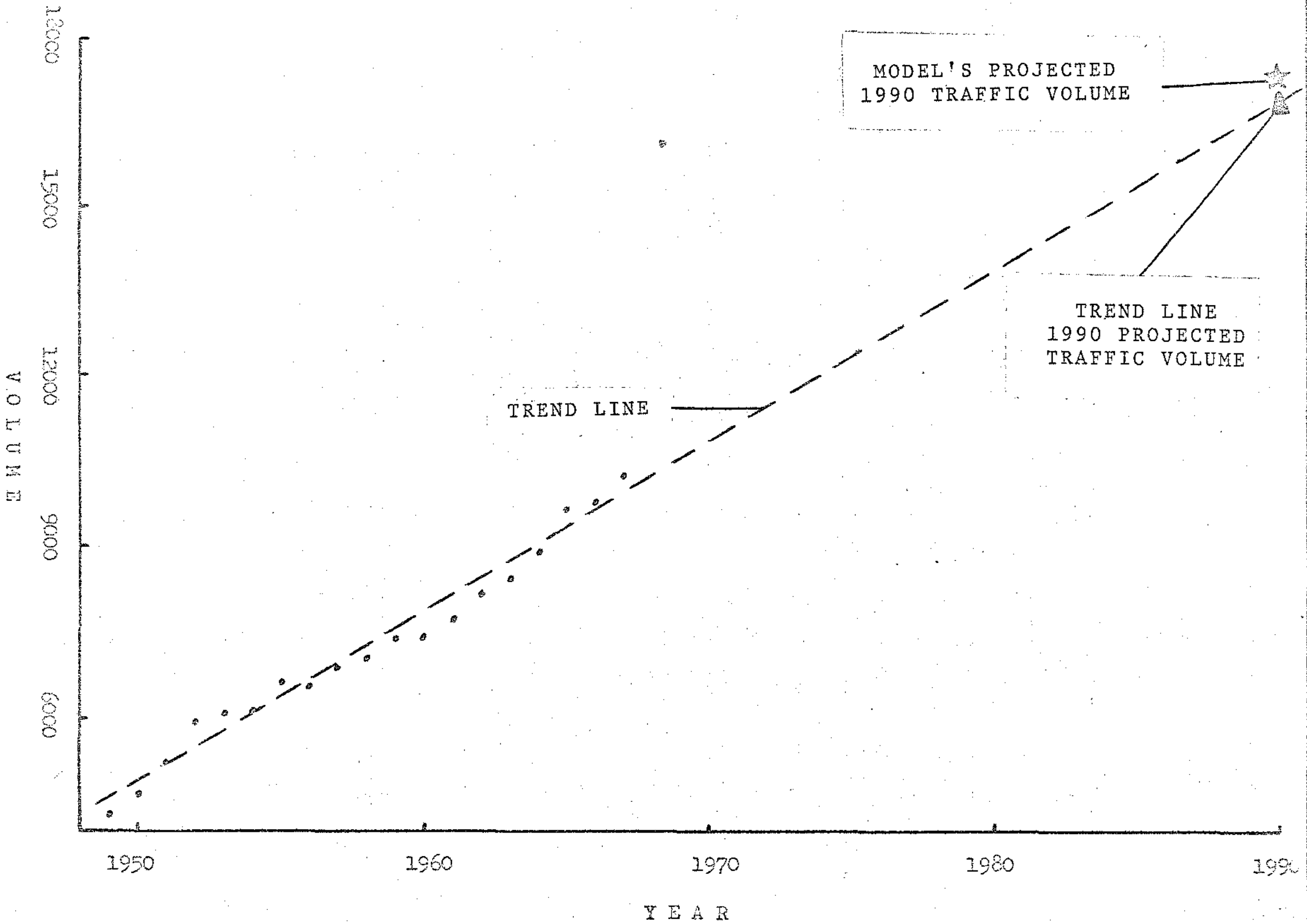

ST. JOHNS - STATION 502

STATE OF MICHIGAN
DEPARTMENT OF STATE HIGHWAYS
TRANSPORTATION
PLANNING DIVISION

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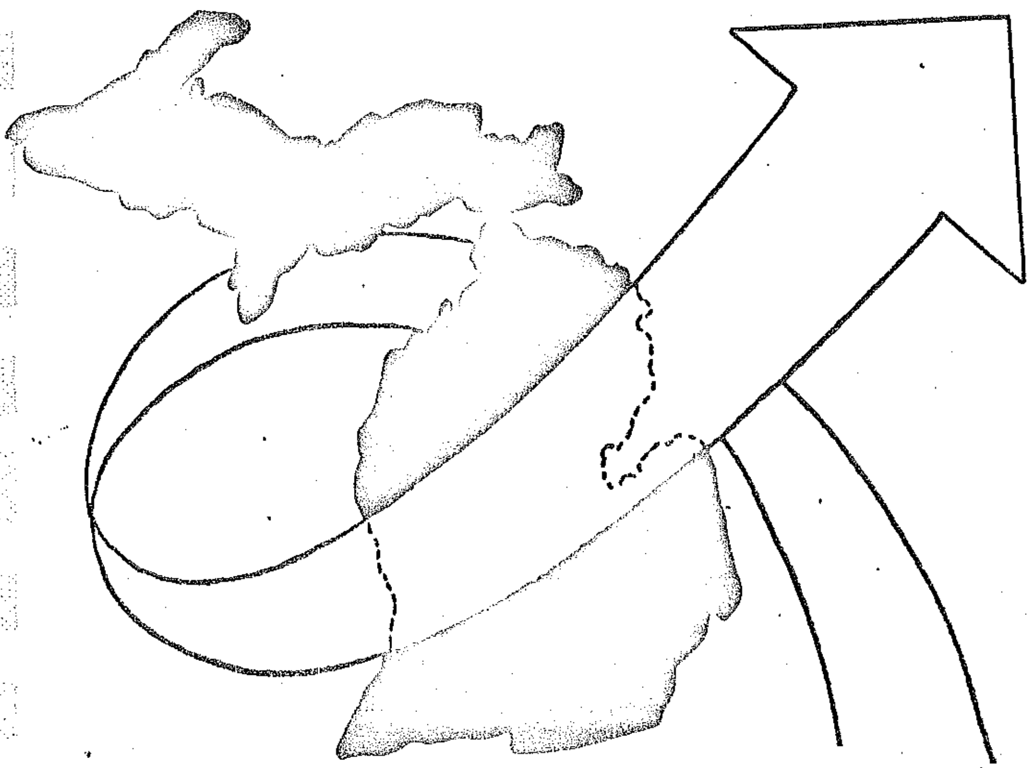
ST. JOHNS

APPENDIX C



The Nodal Method of Collision Location

MURRAY D. SEGAL, Transportation Consultant, and
ROGER L. MALLAR, Planning and Traffic Engineer,
Maine State Highway Commission

The development of accurate and efficient accident location systems is of prime importance to the highway and traffic engineer. During the past two years the Maine State Highway Commission had developed a location system that is based on network principles widely used in the highway planning field. This paper describes the development of the systems, beginning with a review of alternative methods available and ending with an evaluation of the initial results as applied to the 4,600 miles of federal-aid and state highways. In brief, this initial experience with the node-link method of accident location suggests that it is an economical and flexible tool that has greatly enhanced the capability of the engineering staff to utilize factual data in the safety program.

ACCURATE accident data, properly located and related to the highway environment, are essential to the work of the traffic engineer. Reviewing hazardous highway locations only after the accident problem has reached such proportions that the general public reacts is not a satisfactory operating procedure to the professional engineer. Therefore, current accident location data that enable the engineer to determine quickly those locations at which accidents are occurring or increasing must be made available as an everyday working tool. These data not only enable the engineer to determine high accident locations susceptible to correction, but also relate accident patterns to highway characteristics and thus provide the basis for corrective measures. Further, a properly established accident records system will provide the engineer with the basic data necessary to evaluate changes in highway design and operating policies that can lead to a reduction of accidents on a systemwide basis.

Accident location data are also of utmost importance to enforcement agencies. Selective enforcement programs, to be effective, must be aimed at those locations where changes in driving habits will lead to accident reduction. Accident rates and causes, when related to the type of enforcement activity, will allow evaluation of the enforcement program. Also, those involved in the public relations aspects of highway safety may make effective use of accident location and other data to provide a well-oriented service to the motoring public.

The first step in the process of developing an accident location system was a review of the extent and nature of the highway systems in the state. As given in Table 1, there are slightly more than 21,000 miles of highways in Maine.

State systems are described as state highways and state-aid highways. The State Highway Commission is responsible for construction and maintenance activi-

TABLE 1

HIGHWAY MILEAGES

Category	State (mi)	Includes F. A. P. (mi)	Includes F. A. S. (mi)
State highway	3,859	1,876	1,724
State-aid highway	7,628	—	779
Townways and miscellaneous	9,785	58	—
Total	21,272	1,934	2,503

Paper sponsored by Committee on Highway Safety and presented at the 48th Annual Meeting.

ties on the state highway system, whereas on the state-aid system these responsibilities are shared with the local municipality. More than 3,800 miles are designated as state highways, and some 7,600 miles are included as state-aid facilities. All but 259 miles of state highways are also designated on one of the federal systems, while only 779 miles of the 7,628-mile state-aid system are federally designated. A summary of the federal-aid and state highway system in miles is shown below:

System	F.A.I.	F.A.P.	F.A.S.	N.F.A.	Total
State highway	220	1,656	1,724	259	3,589
State-aid			779		779
					4,638

In total, there are some 4,600 miles of the more important federal-aid and state highways in Maine. Although this represents only 22 percent of the total mileage, 55 to 60 percent of the accidents are reported on these systems. In an effort to insure the rapid implementation of an effective system, a decision was made to initially limit the location system to the 4,600-mile federal-aid and state highway systems, while maintaining the flexibility for future additions.

With a total population of approximately one million and an average density of 31 persons per square mile, most of the highway system is distinctly rural in nature. Even though only 6 percent of the highway mileage is classified as urban, it was assumed that the absolute number of collisions occurring on these urban facilities was substantial, and thus flexibility of the location system to meet urban and rural needs became a design goal. Subsequent summaries of resulting data have shown that 40 to 50 percent of all the accidents reported occur in urban environments.

EVALUATION OF ALTERNATIVES

Objectives

There has been considerable discussion in recent years on the subject of collision location. Much of the published work has been concerned with the details of the physical portion of the location system—namely, the field reference markers. The decision by the Maine State Highway Commission to emphasize the improvement of the collision location process as a beginning step in improving the whole records system led to a review of previously used methods and a statement of the objectives for the accident location process.

Over the years various methods have been used to identify the locations of different design and operating characteristics and other events on state highway systems. Collisions, then, were only one item among many pieces of an inventory puzzle and were considered in that perspective. Although all of these programs present basically the same goal of inventorying a specific item on a massive highway network, the details of the inventory routine have not in the past been identical or even compatible. For this reason, the formulation of objectives for the collision location method assumed considerable importance. These objectives were summarized as follows:

1. The method should be sensitive enough to accurately identify high-frequency accident locations, and permit basic research on the relationship of design and operating elements to accident production.
2. The method should be simple enough to permit accurate use by the average policeman in the field.
3. The method should have maximum potential for use as a general road inventory procedure.
4. The method should have potential for uses other than collision (motorist information and guidance, traffic planning, etc.).

5. The cost of the system should be minimal.

The problem of inventorying collisions, design features, or any other descriptive element or event on a large highway system initially assumes substantial dimensions, but the use of high-speed computers with large storage capacities and easy access have reduced the problem considerably. The task of the state highway engineer in designing and carrying out this inventory may be compared to the inventory control problem frequently encountered in private industry.

The first requirement—that the method be accurate enough to identify high-frequency locations—was, of course, the basic reason for the program, since the requirement has seldom been met. Some of the specific accuracy problems that had plagued Maine's Planning and Traffic Division are discussed in a later section.

Because the police investigator was to remain the principal source of data collection in the foreseeable future, the method chosen for improving the location process must be simple, concise, and not involve cumbersome or time-consuming procedures in the field. A stated goal of the entire records system improvement had been the reduction of effort on the part of the police investigator.

High-speed computers offer a good opportunity to improve the highway and traffic engineer's ability to recall descriptive information useful in his design and operations' tasks. At the same time, the unification of all inventory and descriptive procedures was identified as a major goal. Keeping road inventory information on one location basis, traffic volume information on another, and bridge inventories on a third was to be avoided if possible. It was initially felt that all these inventories should be placed on an identical location basis, rather than correlating different location procedures with lengthy computer routines.

The ability to use the accident location method for non-safety purposes could be considered a fringe benefit. Motorist information and guidance is frequently mentioned as another use for the accident location system with specific recognition of the reference markers in the field. This is possible at several different levels of sophistication. For example, the mere installation of an understandable series of signs along the road has obvious use to the motorist. In more sophisticated terms, there should be some consideration of the relationship between the future development of automated vehicle guidance and control systems and collision location procedures. Substantial research and development work has been undertaken in this area by the Bureau of Public Roads' Office of Research and Development. In the highway planning field there would be considerable advantage in a collision location method that would have some compatibility with existing traffic assignment procedures, since this could simplify areawide or statewide traffic assignments.

Although the ability to accurately locate collisions is of basic importance, it is only a tool to be used in reducing collisions, and the resources committed to developing the tool should be reasonable. The maintenance and operation of the whole location process in future years was considered an important part of the total cost, which had to be balanced with the initial investment. Thus, a procedure that might eliminate the need for reference markers in the field would be desirable only if the subsequent cost of the office coding of locations was less than the cost of the markers.

Existing Method of Collision Location

For several years in Maine, some excellent work in accident data collection has been accomplished, especially by the state enforcement agency, the Maine State Police. In this state, collisions are reportable if a personal injury results or if total property damage exceeds $100. The state statutes require that the police agencies investigating accidents file standard report forms with the State Police Headquarters and that drivers file similar reports. For the most part, driver reports are not used by the State Highway Commission. The Maine State Police have had the responsibility for processing the basic information. In 1966, a total of 21,000 accident reports were filed with State Police Headquarters. The level of reporting is considered to be reasonably good, although specific areas of underreporting have become clear as the accumulated data in the new system have become available.

Prior to the development of the new location procedures, the accident report form, which is standardized and used by all state and local police departments, contained the following location information: (a) city or town name, (b) county name, (c) name or number of street or highway, and (d) distance and direction in miles and tenths to a landmark.

Police were instructed to measure the distance from a landmark to the collision site using the vehicle odometer and also indicating the appropriate direction. They were encouraged to use intersections of US- and state-numbered highways as "landmarks." Experience in using the data had defined the following kinds of problems:

1. Locations based on the name of a business or residence.
2. Locations based on a street or highway name that does not appear on available maps.
3. Locations referenced by utility pole numbers.
4. Locations that were long distances from the reference landmark.
5. Errors in the direction from the landmark to the collision site.
6. Vague or incomplete data.
7. Estimates of distance rather than measurements.

In short, the location data, as available, did not provide the necessary accuracy or adaptability to machine processing to accommodate the expanding needs of the Maine State Highway Commission and other state agencies. For that reason, early in 1967 the State Highway Commission decided to establish an interim records system that would staisfy the needs of the Department until such time as proposed modifications to the existing records system were completed. As a beginning process, copies of all 1966 source documents (police reports only) were obtained, and those accidents that could be located on the federal-aid and state highway systems (approximately 4,600 miles) were processed onto punch cards for environmental analyses.

This work provided the opportunity to test some of the recommendations made in an earlier study of the entire accident records system, and these are described in a later section.

Comparison of Alternative Methods

The first step in selection of the accident location method was to review the procedures that have been developed in other states. A review of the literature and personal contacts with some of the state highway departments revealed four basic different methods of accident location then in use or under development, as follows: (a) route number and accumulated mileage (reference markers at regular intervals), (b) route number and accumulated mileage (reference markers at irregular intervals), (c) route number and accumulated mileage (no reference markers), and (d) coordinates.

The most commonly considered method of accident location was based on route numbers and accumulated mileage, with signs posted at specific intervals (usually one mile). In its usual form the signs showed the mileage for a particular route beginning at the state line and accumulating throughout its entire length within the state. To indicate the location of a collision, the police investigator must observe the mileage signs on either side of the site, or otherwise must be aware of their sequencing, and then measure the distance to one of these sign locations. He adds the distance measured (usually to the nearest one-tenth mile) to the lowest signpost number and records it in this fashion. Measurements are commonly done with vehicle odometers reading in one-tenth mile increments.

Several problems were apparent in the application of this procedure in Maine. The first of these concerns the difficulties that are encountered with overlapping route numbers. A considerable portion of the state highway system carries more than one route number. In order to retain the ability to easily recall data for a particular route, it would have been necessary to provide for considerable manipulative ability, which would have reduced the ease of data handling. Changes in the route locations would, of course, create some reporting problems on the local level, but the entire mileage of routed highways, which is changed from one location to another, is usually quite small in any particular year. Changes in the length of a particular route because of reconstruction or relocation would, however, have a significant effect on the procedure. It would require the repositioning of a substantial number of signs in the field to maintain the continuity of the system or as an alternate solution the use of additional equations. In urban areas, the reporting of accident locations on the basis of route number and accumulated mileage would be inadequate and further information would be required. It was realized that the accident problem is urban oriented to a significant degree, even in the rural State of Maine. The last and perhaps the most serious disadvantage of the regular mileposting procedure is that the locations that are referenced in the field have little or no significance in terms of changes in the environment. The locations are strictly controlled by the posting interval and are thus not the place where traffic volumes or highway design and operating elements change. Obviously, if the locations that are referenced by signs in the field have some significance in terms of a change in the environment, then the future data processing costs will be reduced. The best example of this is the problem of recalling a particular intersection or group of intersections. This is a task that Maine's Planning and Traffic Division is most frequently required to accomplish. Under the milepost procedures, efficient recall of accident data at specific intersections would require the preparation of a comprehensive listing that showed the mileage location of each and every intersection. The cost of this correlation would be significant, and it is not clear that adequate results could be obtained for complex intersection configurations. It would be necessary to search at least two, and possibly three, different route numbers and accumulative mileage figures to be sure that all accidents are recalled for the specific location.

The posting of route mileages at existing landmarks occurring at irregular intervals would eliminate some of the disadvantages of the regular interval posting. Several states, which are using this procedure, post accumulated route mileages on signs, bridges, utility poles, and at intersections. Thus, it is theoretically possible to choose the locations for the field reference markers that have environmental significance. The freedom of choice, however, is reduced considerably in rural locations. Considerable use has to be made of traffic signs as locations for field referencing. Since these signs tend to cluster rather than occur uniformly over a given stretch of highway, and since signs are not permanent in nature, it was felt that the method had serious drawbacks for use in the state, even though reference marker costs are lower. A complete sign inventory is not available to the Planning and Traffic Division, and thus design of the locations would have had to be accomplished in the field. Such a procedure would also be somewhat more difficult for the policeman to use in the field, but this was not a major consideration.

The third possibility for an accident location procedure was to use a route-number and accumulated-mileage system, which is based on very detailed straight-line diagrams of the entire highway system. Several states are using this procedure with apparent success. In one case, the accidents are coded in the field by the police officer, which requires distribution of maps to all accident investigators. In another case, the location coding is done in the office based on the usual data reported by the police authorities. In both instances reference markers in the field are not a part of the system. The procedures would have been difficult to apply in Maine, due to the lack of sufficiently detailed straight-line diagrams. In addition, the original problems of data handling with the mileposting procedure are still in evidence. From a long-term cost standpoint it was felt that the cost of installing and maintaining field reference markers would be less than the cost of coding all accident locations in the office.

The last concept, which was under consideration by several states, is based on the use of coordinates in stating collision locations. A major advantage of this procedure is that it is readily adaptable to mechanical plotting. Two basic possibilities exist for using the method. The first would involve preparation of a series of maps with coordinate grids superimposed on a considerable amount of topographic and cultural detail. These maps would then be distributed to the investigators who would determine and report the coordinates of the collision locations. An alternate procedure would involve the coding of the locations in the office using the same maps. The former approach was ruled out, since many problems had been encountered with the data on locations as currently reported by the police investigators, and it was felt that major innovations in the reporting process would be required. The first approach, involving the distribution of maps to the police investigators, was thought to be too cumbersome and complicated for the average investigator. In addition, the correlation of accidents with highway design and operating elements would require a complete digitizing of the highway system, a long and costly process. Development times for either of the two approaches were considerable and would have meant substantial delays in this portion of the traffic safety program.

In an effort to combine some of the advantages offered by the different alternates, the Planning and Traffic Division decided to evaluate a proposal that accidents be located on the highway system according to a simple nodal principle. The proposal called for numbering and posting in the field of all major intersections on the highway system, as well as city-town lines, urban lines, railroad grade crossings, and major bridge structures. The concept was adapted from the highway planning process that simulates highway networks on a nodal basis for traffic assignment purposes. Under the procedures proposed, the policeman would indicate the accident location by one of two processes, depending on the location. If the accident occurred at an intersection, then the number of the intersection is all that needs to be recorded. If the accident occurred between intersections, then the police officer is instructed to record the intersection numbers on either side of the location and measure the distance to one of the two intersections.

For the policeman, the concept of accident location as presented by this method is very similar to the concept now used; that is, he is locating the accident site by referencing it from a known landmark. However, since the frequency of these landmarks was to be greatly increased, the distance that has to be measured is considerably decreased, with more accurate results. The confusion concerning the direction from the landmark to the accident site is completely eliminated by the provision for recording intersection numbers on both sides of the accident site. The method is adaptable to rural and urban locations, and is particularly valuable on limited-access facilities, where individual ramps can be posted according to the same basic principles as other roads. The processing of the data using the method entails a minimum amount of work. In the first place, location of the accident is reported in numerical form, which is computer oriented. Only keypunching and a minimum amount of editing is required to put the data in computer format. Second, the ease in handling the data would be considerably enhanced. It becomes an easy matter, for example, to recall accidents at any particular intersection or group of similar intersections. By the same token, accidents can be easily recalled for routes, combinations of routes, areas, or highway systems. The adaptability of this accident location procedure to the highway planning process is evident. The procedure is also adaptable to some of the more sophisticated proposals for route identification and guidance. Work now in progress by the Federal Highway Administration indicates that such systems will be based on the identification of decision points (intersections) on the highway networks.

It is emphasized that the method of identifying intersections is adaptable to description by coordinates, and it is possible that the coordinates of each node will be established at a later date as the mechanical plotting process gains importance.

DESIGN OF THE ACCIDENT LOCATION SYSTEM

Map Numbering Sequence

The first element in the design of the node-link system was a careful review of the different possibilities available for numbering the field refrerence points. It was felt that the procedures developed should be readily adaptable to the entire street and highway mileage in the state, even though the first concern would be limited to the 4,600 miles of federal-aid and state highways. This decision, coupled with the desire to maintain four digits as the maximum on the field reference markers, meant that the numbering sequence would be unique on a county level. Thus, a total of 10,000 locations would be the capacity for each county. Final design and production of the necessary location maps showed that approximately 10,000 locations would be signed initially on the 4,600-mile federal-aid and state highway systems.

A total of six alternate numbering schemes were reviewed in some detail. Most of the schemes reviewed carried information identifying the highway system and the urban-rural classification. There were significant variations in the number ranges reserved in each group and the ordering of the number ranges. The scheme finally selected carries only the system designation as follows:

Highway System	Reference Marker Number Range
Maine Turnpike, non-Interstate	9700-9999
Interstate Highway System (state highway)	9000-9699
Federal-aid primary highway system (state highway)	7000-8999
Federal-aid secondary highway system (state highway)	6000-6999
Federal-aid secondary highway system (state-aid)	5000-5999
Non-federal-aid highway system (state highway)	4000-4999

The sequence as designed provides for (a) ease of sorting by highway system, (b) continuity of numbering along major routes in each county, and (c) expansion of system capacity by at least a factor of 2.

Numbering generally was done in ascending order from south to north and west to east along routed highways. The limited-access facilities have been treated as two

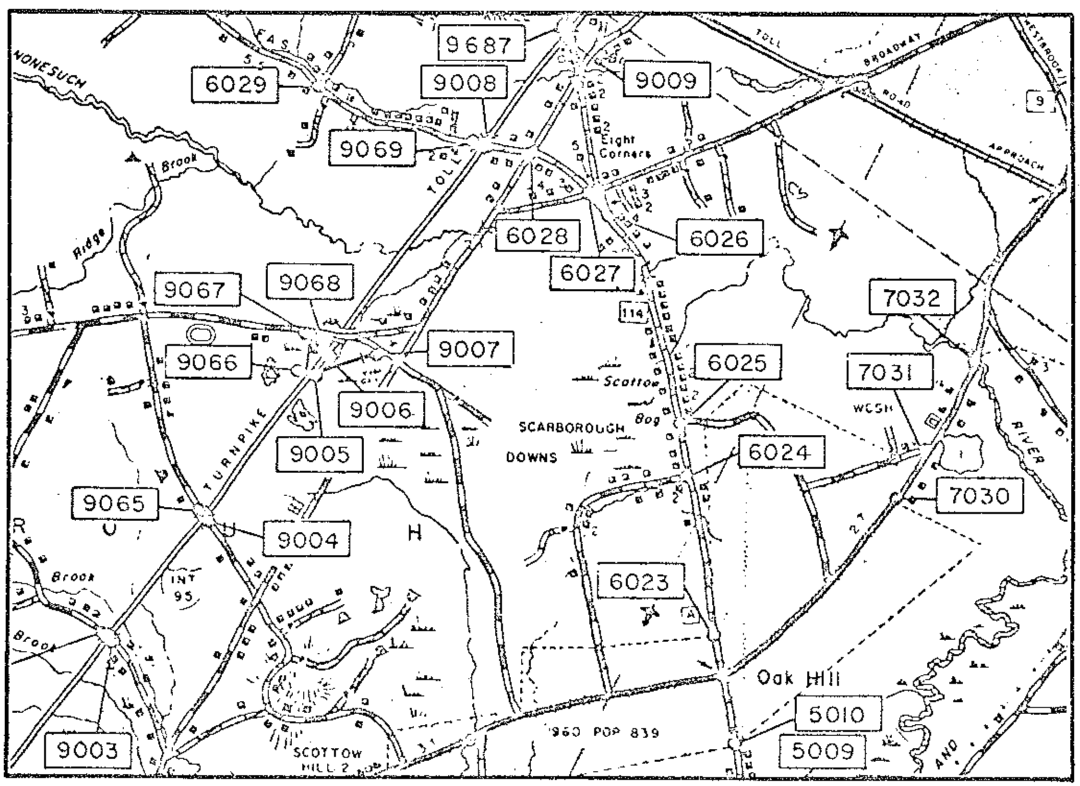


Figure 1. Typical accident location map.

TABLE 2

FREQUENCY OF REFERENCE MARKERS

County	Highway System Mileage	No. of Reference Marker Locations	Locations per Mile
Androscoggin	167	600	3.6
Aroostook	724	1,074	1.5
Cumberland	359	1,352	3.8
Franklin	243	320	2.8
Hancock	264	585	2.2
Kennebec	323	843	2.6
Knox	88	256	2.9
Lincoln	129	235	1.8
Oxford	342	493	1.4
Penobscot	453	1,190	2.6
Piscataquis	145	220	1.5
Sagadahoc	99	253	2.6
Somerset	364	622	1.7
Waldo	169	325	1.9
Washington	336	534	1.6
York	321	1,217	3.8
Total	4,526	10,119	Avg. 2.2

separate roadways and numbered accordingly with reference markers also located at ramp terminals. Reference markers have also been located at the intersections of directional roadways within major channelized intersections.

Preparation of Maps

Subsequent to defining the rules for numbering reference points on the highways, the Highway Commission prepared a series of 162 maps (Fig. 1) showing the location of each reference marker. These maps were produced to assist in the field installation phase, as well as to provide a test of the location process (without benefit of reference markers in the field). The base maps for this project were existing general highway maps prepared and maintained by the Highway Commission. The rural series (scale 1 inch = 1 mile) contains a considerable amount of culture, while the urban series (scale 1 inch = 600 feet) generally presents only street names, route numbers, rivers, railroads, and major public buildings.

Table 2 summarizes the total number of field reference marker locations in each of the 16 counties as compared with the miles of highway on all of the systems considered. The frequency of reference markers is directly related to the degree of urbanization, and this is clear from the data in Table 2. Androscoggin, Cumberland, and York counties are the most urbanized counties in the state and have the highest marker frequencies. In no case was the distance between reference markers allowed to exceed 1 mile in urban areas or 2 miles in rural areas. Where this would have occurred, due to the absence of an intersection, bridge, railroad grade crossing, or city line, a dummy location was established.

Table 3 summarizes the numbers and percentages of each type of location field referenced. It is noted that intersections account for approximately 80 percent of the total.

Test of the Location Process

The next step in the development of the records system was the creation of an accident records file for the federal-aid and state highway systems using the accident location process as previously described. It was recognized that the process itself should be subjected to a thorough test prior to an investment in field reference markers. In addition, there was a pressing need to create an accident records file of data for use in current programs. Obviously, the installation of the field reference markers,

TABLE 3

SUMMARY OF REFERENCE MARKER LOCATION TYPES

Type of Location	No. of Occurrences	Percent of Total
Intersections (and urban boundaries)	8,203	81.0
Railroad grade crossings at intersections	43	0.4
Railroad grade crossings between intersections	167	1.7
Bridges	572	5.7
City, town lines	764	7.5
Dummy nodes	370	3.7
Total	10,119	100.0

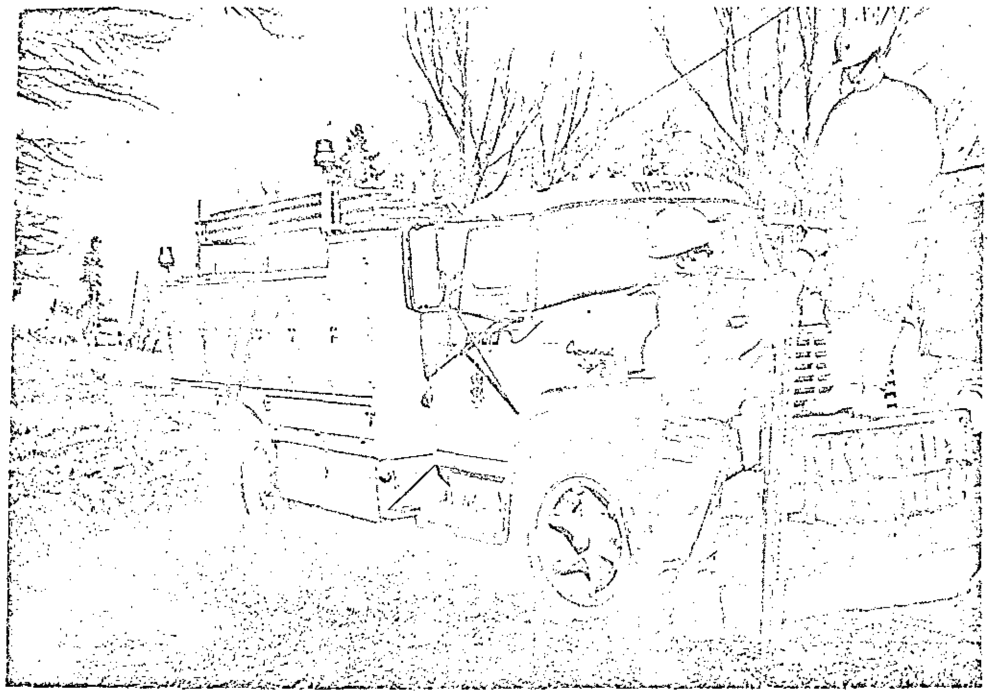


Figure 2. Reference marker installation.

the changing of the accident report forms, education of the police investigators, and the accumulation of several years of accident records would be a time-consuming process. To overcome these difficulties, a decision was made to establish a records file using existing accident reports (i.e., the previous year, 1966). Photocopies of all accident reports (police) for the calendar year 1966 were obtained and processed. Locations were fixed as accurately as possible with the existing data, and those collisions occurring on the federal-aid and state highway systems were recorded on punch cards for rapid analyses. The Highway Commission has continued to receive and process copies of the original source documents during 1967 and 1968.

In general, the coding project was a success, even though it was clear that the absence of field reference markers reduced the accuracy of the location process for the 1966 and 1967 data. The feasibility of the process has been established, and a workable file of accident records was then available. Prior to installation of the field reference markers, the location coding utilized business and city directories, commercial maps, and even telephone calls to local agencies, in addition to the routine data on the report form.

Installation of Reference Markers

Once the "map test" of the methodology was successfully completed, the Commission adopted the process and decided to install the field reference markers on the entire 4,600 miles of federal-aid and state highways. A total of 20,000 markers were fabricated in the state sign shop utilizing 3-inch numerals (silver) on a 5 by 10-inch sign blank (green). Each field installation consisted of two markers on a single support. Erection of the markers was accomplished during the winter months of 1967-68 by state crews attached to the Planning and Traffic Division (Fig. 2). Existing sign structures were utilized in approximately 60 to 70 percent of the installations. This phase of the program cost a total of $57,000 and was partially funded by the National Highway Safety Bureau.

TABLE 4

STATEWIDE ACCIDENT DISTRIBUTION, 1966

No. of Accidents	Number of Locations					
	Nodes			Links		
	Urban	Rural	All	Urban	Rural	All
1	717	369	1,086	991	1,571	2,262
2	249	112	361	309	563	872
3	119	34	153	104	235	339
4	73	18	91	55	124	179
5	45	4	49	27	55	82
6	26	2	28	12	22	34
7	21	1	22	10	12	22
8	14	—	14	5	6	11
9	9	—	9	1	3	4
10+	44	—	44	6	4	10

Initial Experience

During the period of field installation of the reference markers, the Maine State Police, which serves as the central records agency, modified the standard report form to provide for direct reporting of accident locations by node-link identification. At the same time, additional changes in the report form were made and a series of regional training sessions scheduled to instruct state and local police officers in the use of the new form. Initial results with the system have varied. Few problems have been noted where the system is used, but some of the local police agencies had not been consistently reporting locations using the node-link identification. The State Police, who account for approximately 50 percent of the accident reports, are using the system consistently and with no apparent problems. Additional training and orientation sessions with individual local police departments have been held to encourage use of the node-link system and thereby further reduce the office coding burden to a minimum. These efforts have been most encouraging. In addition to location-to-location data, 49 columns of other information are coded on the keypunch form. Of the total of 21,281 accidents reported to the central agency in 1966, 11,948 or 56 percent were located on the 4,600-mile federal-aid and state highway systems (22 percent of the total mileage). All coding, punching, and editing of the 12,000 reports that are processed by the Commission's Planning and Traffic Division consume 1½ man-years of effort annually. Coding of the data makes up most of this total, and a significant part of the coding task involves the manual checking of location data and a comprehensive classification scheme. In summary, the initial experience with the process has been good, and the small cost of data processing suggests a high level of operational efficiency.

Use of Accident Data

Prior to the development of the data described, all principal accident studies done by the Commission's engineering staff required the use of the original report form document and involved large investments in searching and processing of the data. This problem, combined with the inaccuracies of the then existing location methods, severely limited the use of accident records. The availability of computerized accident information accurately located on a systemwide basis has effectively removed these restraints.

Early work with the collision data involved summaries of accident frequencies by highway system and type of environment. One of these summaries appears in Table 4 and consists of a distribution chart for urban and rural nodes and links for the year 1966. A total of 11,000 accidents are represented by these data, with 64 percent occurring on links and 36 percent at nodes. It is interesting to note that this preliminary information shows a much greater dispersion of link collisions as compared to those that occur at nodes. Approximately 18 percent of all nodes had one or more collisions in 1966, as opposed to 40 percent of all the links. It seems clear from these data that more than one year's information is necessary to satisfactorily identify high-frequency locations, particularly in the case of nonintersection locations.

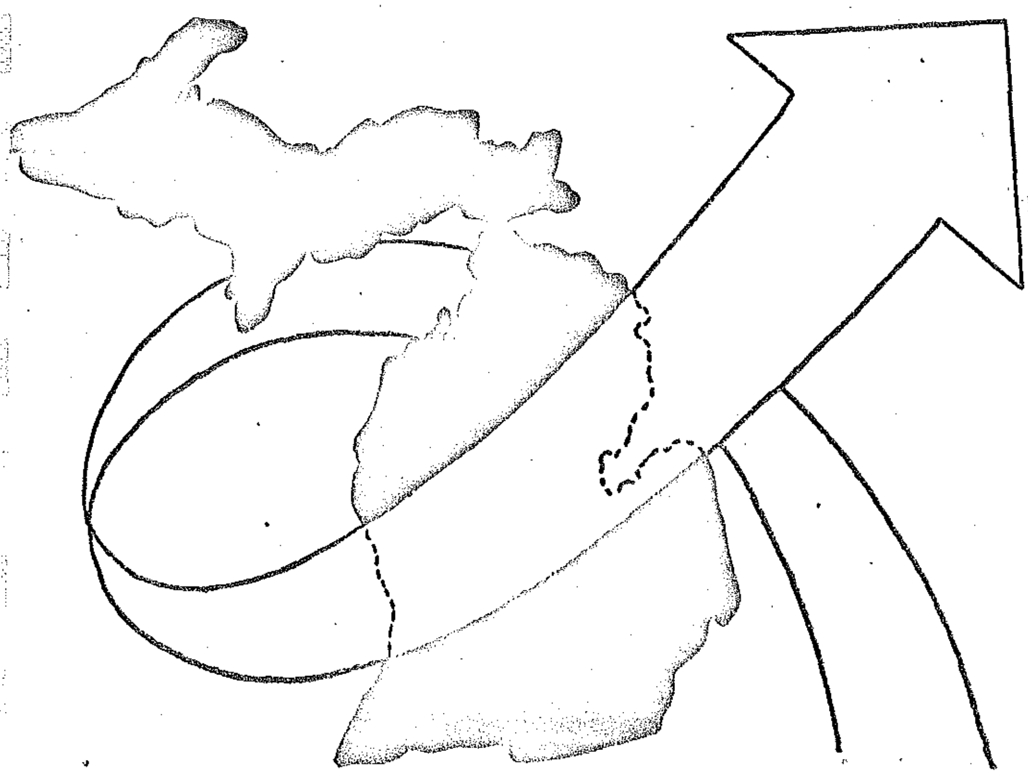
In the short time since they became available, the data have been used for a wide variety of projects. The following represents a partial list of completed projects:

1. Comprehensive listing of high-accident links and nodes based on travel volumes followed by field reviews.

2. A study of bridge accidents.
3. A study of fixed-object collisions.
4. A study of collisions involving animals.
5. Analyses of specific locations initiated both internally within the Highway Commission and externally by other state and local agencies.

A recently completed project has established the framework for future data systems that will be used for the correlation of collision records and highway design and operating variables. Expansion of the data is now underway, as is a first step research project that includes an examination of at least the following relationships: (a) collision severity and collision type, (b) collision rate and intersection configuration, (c) collision rate and type of traffic control device, (d) collision rate and access control, and (e) collision rate and traffic volume.

APPENDIX D



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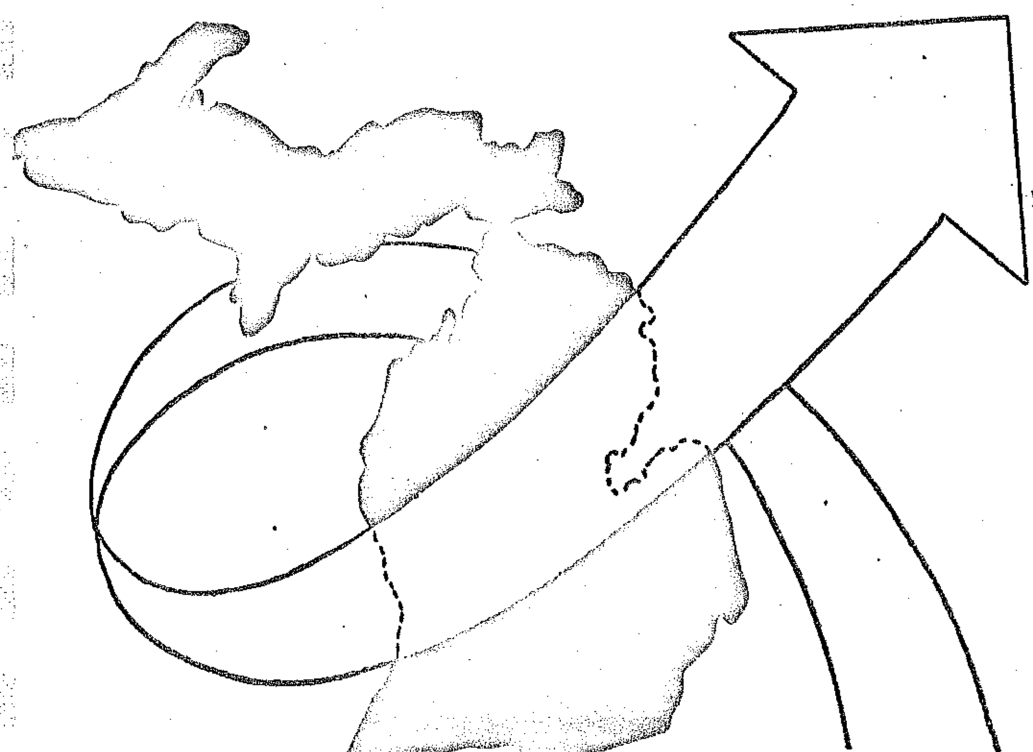
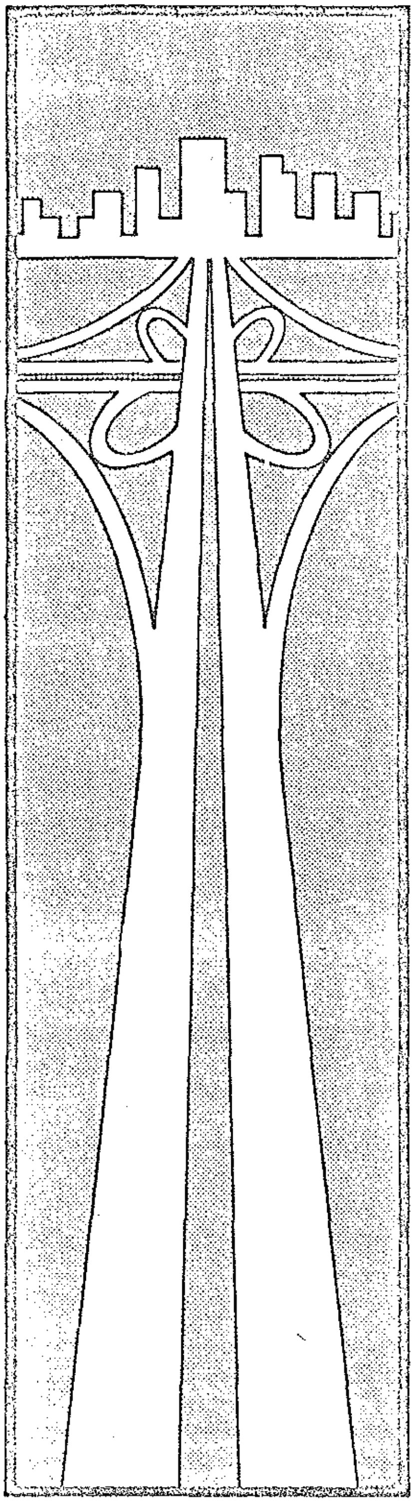


HIGHWAY PLANNING TECHNICAL REPORT



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Coordinated Data System for Highway Planning

U.S. DEPARTMENT OF TRANSPORTATION
Federal Highway Administration
Bureau of Public Roads

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U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
BUREAU OF PUBLIC ROADS
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Coordinated Data System for Highway Planning

By
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INTRODUCTION

The Current Planning Division conducted a review of highway planning electronic data processing in 43 State highway departments during the past year and a half. This review showed that, in many of the planning activities, improvements could be made in the manner in which computers are being used.

Two reasons that possibly explain why such improvements have not been made are:

1. Planning people have not been sufficiently familiar with computer systems analysis or programing techniques. Consequently, few changes have been made in the processing steps when a manual operation has been converted to a computer oriented operation. Insufficient consideration has been given to the interdependencies of data requirements among the different planning activities.

The data processing people doing the conversion work have known little about the interdependencies, usually because they had not been advised by the planning people and because they did not have time to study the planning requirements. The result has been that a program developed to convert an operation merely performs by computer the same steps that had been done manually.

2. Until about two years ago, many planning divisions had access only to computer systems that essentially restricted users to card input and output.

Since the processing of planning data generally involves a need for a large input and output of records, this restriction caused considerable difficulty to planning people using those computers. Many States now have computers, or are getting computers, with the potential to handle practically all planning processing needs, but planning people are still trying to use the equipment in the same way they did with older, less versatile computer systems. This report describes a system that should result in more efficient use of computers to process planning data.

TYPES OF DATA IN THE SYSTEM

Planning data may be grouped into two categories - that which can be related to the roadway and that which cannot.

1. The first group includes road inventory, traffic characteristics, condition rating, road life, historical, maintenance and accident information. It is suggested that a separate file be made for each of these kinds of information. However, road inventory data should probably be broken into four files: one file made up of cultural data, one with roadway characteristics, one with geometric data, and one containing administrative system information and locations of jurisdictional boundaries. The system should also include a file of map coordinates, which are related to the roadways, to provide for graphically displaying any of the planning data.

2. The second group includes information on finances, cost indexes, and highway statistics. Although these data should also be in separate files, the retrieval of data from them will be done on a different basis from that for the first group. These are essentially individual files that are not directly related to other files as in the first group. The basis for retrieving data items from files in the first group is always the roadway, regardless of the items wanted. For the second group, the basis is whatever item of data is needed and that item will vary from user to user.

INDIVIDUAL DATA FILES

A "Coordinated Data System" is based on establishing coordinate data files. A definition of coordinate is "equal in rank or order." The several classes of highway planning data, such as road characteristics and traffic volumes, are considered to be equal in importance and usefulness. Each class of data should, therefore, be stored in a file that is equal to, but separate from files containing other classes of data. Each file should not contain more than one class of data and all data elements in the file should pertain to that one class.

Usually, there are several sections in the planning divisions, each responsible for collecting and processing some class of data and for supplying these data to various users. In many cases, these users are coding, storing, and processing the same data elements, thus duplicating each other's efforts. In the Coordinated Data System, the section which collects the data is responsible for maintaining the basic computer file of those data.

Many of the several classes of planning data are related to roadways. In recording observations of these data along the roads, there are points where characteristics of the data change, causing new values to be recorded. These points of change, or breaks, must be recorded relative to one another.

When the data are related to the roadways, the breaks should be represented in a computer file as the information about the roadway actually exists. This is illustrated in Figure 1. The breaks, or lengths between breaks, are not necessarily the same for one class of data as they are for another, nor are they the same for one user as they are for another. It is difficult for the data recorders and users to agree on breaks compatible to each of their needs. Thus, each one ordinarily changes the breaks to fit his own requirements. However, too often breaks are based on user considerations rather than on what actually exists. This causes data observations to be broken into more lengths than necessary, resulting in duplications, extra coding, and a loss of flexibility.

An advantage of separate files is that they allow the breaks to be recorded and stored for each class of data in the way they are determined when data are collected.

By having separate files for each class of planning data, duplication in data handling can be reduced, the data file can be more current, and uniformity can be established in the basic data that are used by different groups. This is possible because newly collected information does not have to be distributed to all users, some of whom may not update their files with the new information immediately.

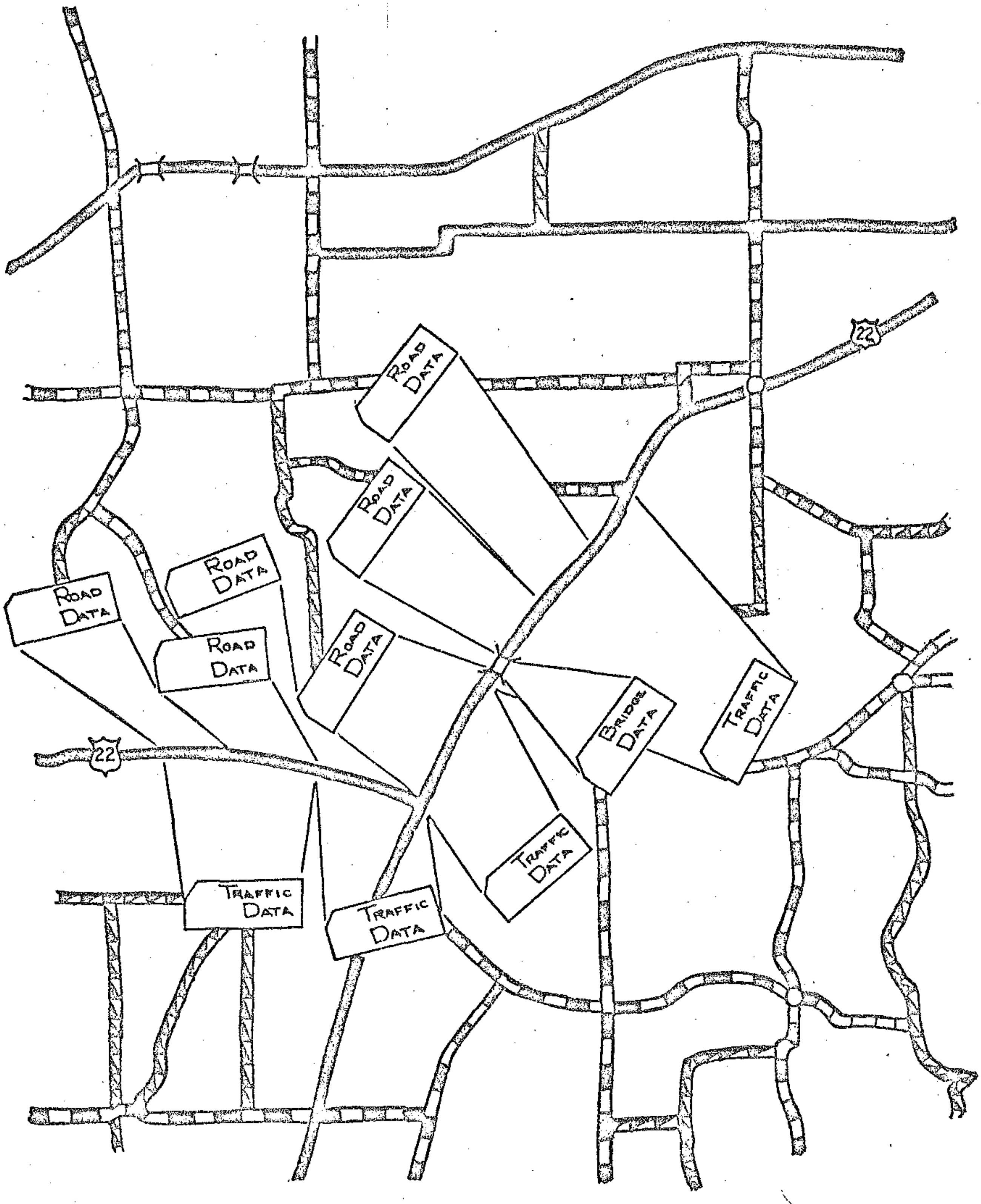


Figure 1. Storing Roadway Information as It Exists

Several States use to advantage a single planning data file containing all classes of data. However, it should be noted that the more kinds of data in a file, the more times the file is out of circulation for updating and processing and the more times the entire file is not available for either of these uses. This point is illustrated in Figure 2.

CORRELATION OF THE DATA

1. Common reference base.

There must be a way to tie the separate files together so that data can be combined by computer to produce analyses and reports. This is done in the Coordinated Data System by relating all data to a common base of reference. Since the data are related to the highways, it follows that the reference base should be the highways.

The method used to relate data to the highways should be simple to use for persons collecting and recording the data and flexible enough to allow correlation of several classes of data through computer processing. The following sections are concerned with approaches to this problem.

2. Location reference system.

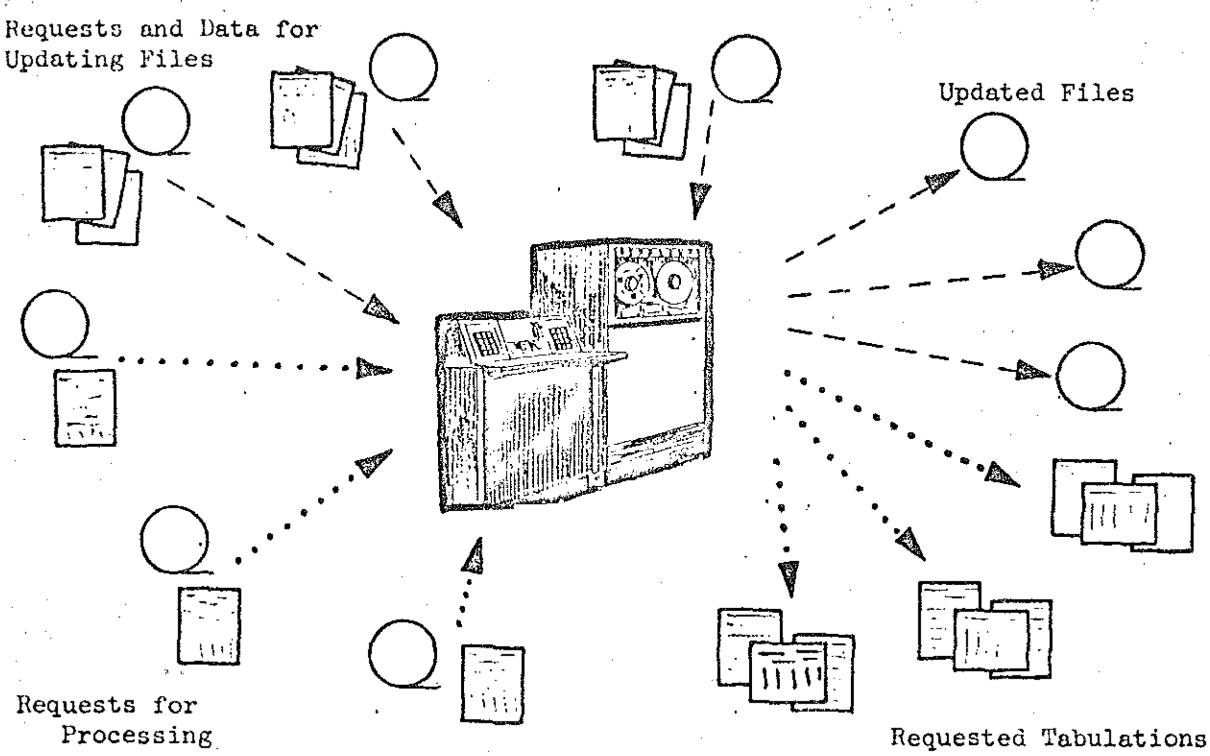
Persons recording data observations along routes must have a method for locating themselves along the routes. This method may be termed a location reference system. It provides a means of uniformly reporting locations of data observations, for finding the locations of previous data observations, and for giving motorists information about their highway location.

A location reference system provides information about the location of specific points along a route. The location of non-specific or in-between points is determined by measuring from the specific points which is discussed under "Location of Data Using a Common Base of Reference."

Different kinds of location reference systems presently being used or under consideration are reviewed in the following sections.

a. Uniformly spaced mileposts. The most familiar kind of reference system is the one in which mileposts are placed along the roadway at even milepoints, the distances between the mileposts usually being the same. This has been the most widely used location system. Mileposts are normally installed on toll roads and have been placed on many Interstate highways as well as on Primary State highway routes, in some States.

SEPARATE DATA FILES



SINGLE DATA FILE

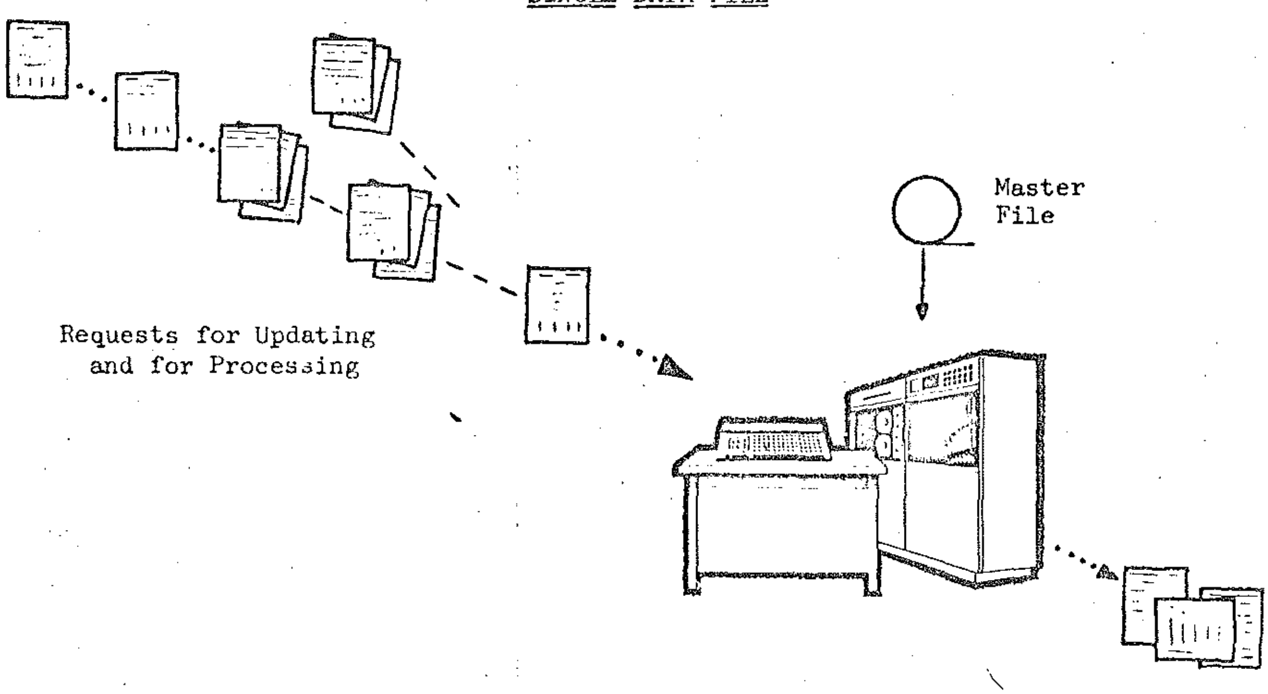


Figure 2. Separate Planning Data Files versus A Single File

The mileposts are usually signs that vary in size and shape from one State to another. The information provided on the signs also varies from State to State. The route number and the milepoint are always included. Usually a county name is given, although this may be a county number. A description of the type of signs used in 19 States may be found in a publication of the Insurance Institute for Highway Safety entitled, "A Summarized Review of Mileposting on State Maintained Highways in the United States."

Advantages of the uniformly spaced milepost method are: the method is familiar to many people; the location information is provided for the motoring public; and the uniform spacing means that one knows he has to go no farther than a fixed distance, usually one mile, to find a milepost.

Two disadvantages associated with uniformly spaced mileposts are: any construction change that shortens or lengthens the route will require a relocation of all mileposts that follow the change, and the placement of the milepoints creates a problem for maintenance forces that must work around them.

b. Nonuniformly spaced mileposts. 1/ A system similar to the uniformly spaced mileposts is the nonuniformly spaced mileposts system. The only difference is that signs are not necessarily at even mileposts, but are spaced irregularly. The type of installation is the same as noted for the uniform mileposts.

One disadvantage of this method is that construction changes necessitate a change in the sign, although in this case, the sign information alone can be changed and not the sign location. Again, maintenance forces have the problem of working around the signs unless existing signs and features are used. If the latter is used, it is probably difficult for the motoring public to find the information unless they are educated in the system.

Two States have made use of existing signs along the roadway to serve as mileposts. Mileage information is printed on some material which is then attached to the back of the existing signs. (One State uses a reflective material and the other aluminum strips).

c. Reference posts. The reference post method is similar to both the uniformly spaced and the nonuniformly spaced milepost methods. The big difference is that reference posts do not carry route or milepoint numbers but carry instead an identification number. The actual

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1/ The report, "Highway Design and Operational Practices Related to Highway Safety," by the Special AASHO Traffic Safety Committee, dated February 1967, refers to this kind of milepost as reference markers.

locations of the signs are kept in central office records which show the county, route, and milepoint associated with each identification number.

The major advantage of reference posts is that changes in lengths of a route or in a route designation do not cause changes either in the location of the reference posts or the information shown on them. The central records are revised to show new route or milepoint numbers for the identification numbers (reference posts).

A disadvantage is that location information is not provided to the motoring public for their direct use. The problem of the maintenance forces having to work around the signs exists for this method too.

d. Route special feature log. There are no signs or posts connected with the route special feature log method. Instead, a straight line diagram or a log is kept in the central office of the milepoints associated with special features on a route. These are usually intersections and bridges, but could include monuments and other well established points along a route.

The log or straight line diagram, which is used by field personnel of highway departments and law enforcement officials, gives basically the county, route,name and milepoint for each special feature. These special features are analogous to the mileposts in the irregularly spaced milepost system and the log is analogous to the information on these mileposts.

The advantages of this system lie in the fact that no signs are needed. This means no installation costs, no changes because of construction or renumbered routes, and no maintenance problems.

This method does not give location information to the motoring public. The log or straight line diagram must be maintained on a current basis. This requires that revised sheets of the log or straight line diagram be sent to people using the system and that they replace old sheets in their possession with the new ones.

e. Coordinates. Another procedure that has been tried is that of using coordinates, usually State plane coordinates, to locate points of data observations. This method has been considered in connection with accident location. There have also been attempts to record locations of traffic and inventory sections by coordinates in order to tie these data to accident records.

Location of data in the field by use of coordinates requires a map along with a template or some other means of scaling the coordinate location on the map. A variation, which has been considered in one or two States, is to record a distance and direction from a point having known coordinates and then compute the actual coordinates of the desired point in the central office.

The major advantage of using coordinates is that a coordinate is a fixed point in space and is unaffected by changes in route length or name. Thus, a point on a route located by a coordinate identification is always located at the same place regardless of route changes.

There are four major problems associated with the use of coordinates as location identification:

(1) Special equipment and, in many cases, training is required to get the coordinate of a position.

(2) The process of getting a position coordinate is a slow one when compared to other methods. This makes it impractical for a field crew or even an office force to use this procedure for recording locations of planning data along highways.

(3) From a data processing standpoint, coordinate identification makes it difficult to sequence records in their proper relation to one another. Further, if data are wanted between any two points, a manual effort is needed to determine the coordinates of those two points.

(4) There is no location information available to the motoring public.

f. Most favorable system. Whatever system is used, an education process is needed to teach people to use the system properly and an updating process is needed to keep the location information current.

Thus, making a decision as to which system is best requires consideration of the costs of installation, the educational effort required, the flexibility of the system (since it must be a practical procedure for locating all types of data), and the costs of keeping information current and accurate. A consideration of the extent to which the motoring public is served may also be pertinent.

Probably the most economical and practical method is to use reference posts. An educational effort can teach people, including the motoring public, to measure and report locations using reference post numbers as well as they can using mileposts. Additionally, the reference post numbers can be a combination of route numbers and milepoints, or just milepoints such that they closely reflect the actual mileages, unless a route was lengthened or shortened by a large distance. Generally, the numbers will be sufficiently accurate that the motoring public will still be provided with useful information. Also, the numbers could be the State plane coordinates of the reference post location, if desired.

It may be easier, or possibly necessary, to locate certain data by route and milepoint. It should be recognized that data can be related to the roadway by a combination of any of the methods described and still be compatible since the reference base is the same.

3. Location of data using a common base of reference.

Part 2 under CORRELATION OF THE DATA described ways to locate roadway characteristics in the field. This part of the report will cover ways of identifying in data records the location of data relative to the roadway for data processing purposes. The following procedures provide the means of coordinating several different planning data files effectively even though the files are physically separate.

a. Route and milepoint. Probably the simplest and most familiar method of relating data to routes is to use route numbers and milepoint identifications in all data records.

With this method, every record in the data files is related to a route by recording a route number and to a section of that route by recording a beginning and ending milepoint, or a milepoint and a section length. Figure 3 illustrates this procedure by adding a beginning and ending milepoint to the records. It should be noted that there is no record in either of the files having both beginning and ending milepoints that are the same as the beginning and ending milepoints in any record of the other file. The milepoints in Figure 3 were chosen to illustrate how a group responsible for one of the files may record necessary milepoints and to show how it is unnecessary to match the breaks that were chosen by another group that is responsible for maintaining another file. The milepoints are the distances from an origin point on a route.

There is some opinion that the origin point should be at the beginning of each route in a State. However, many people think the origin points should be at every county line. If the latter procedure is used and if data are to be represented in storage as they exist on a route, a code must be provided in every data record to sequence the counties along that route. Such a sequencing code is necessary also for the control sections that are presently being used in several States.

(1) Problem of changes in route length. Two problems are associated with the use of milepoints and route identification.

a. Construction changes which lengthen or shorten a route make obsolete the milepoints previously used in the data records affected by the changes.

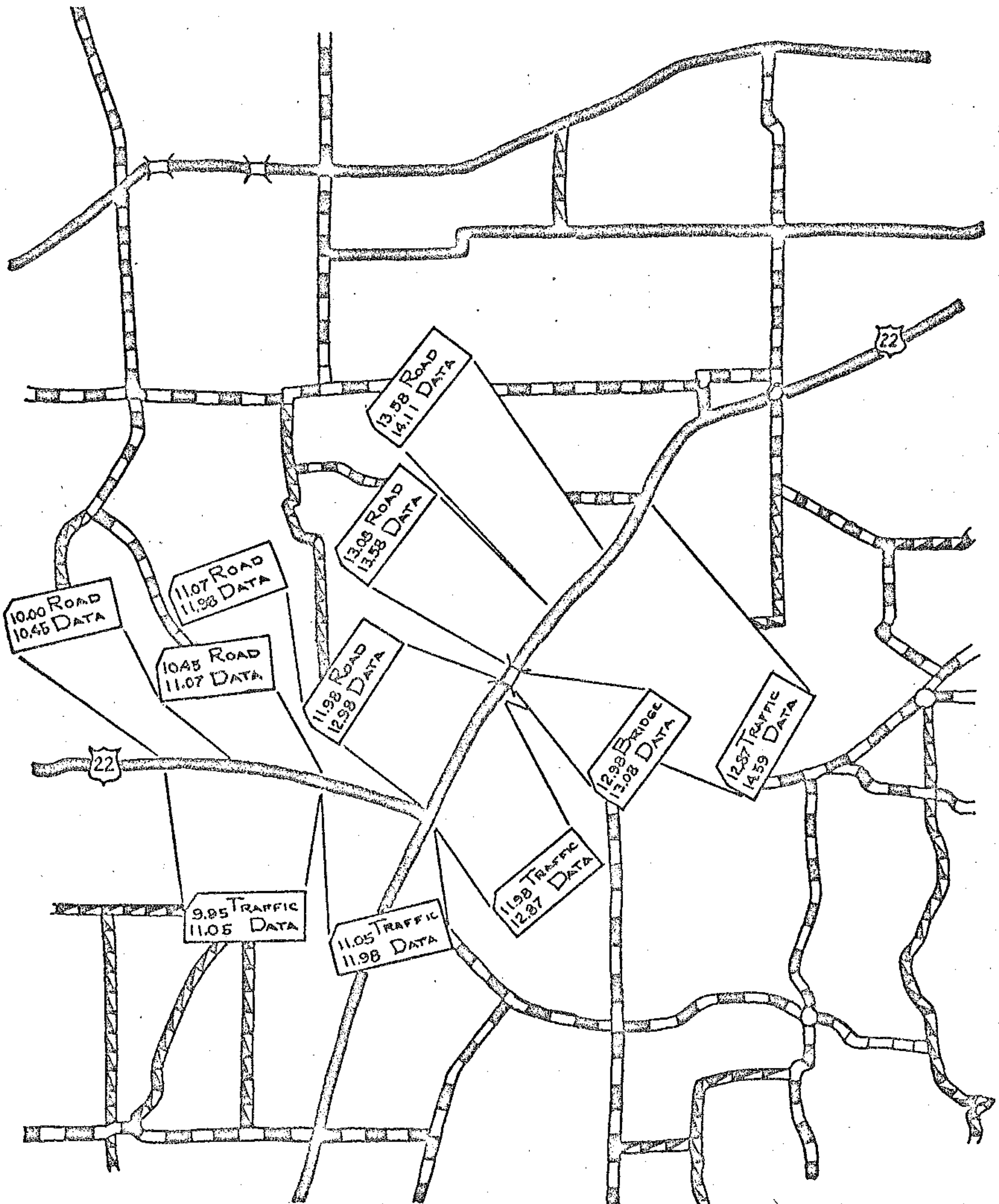

Figure 3. Relating Information to the Roadway With Beginning and Ending Milepoints.

b. A change in the designation or number of a route makes obsolete the route's identification in the data records.

Many records would have to be updated because of these changes; and yet, information about the route before the changes would need to be kept for historical purposes. One way to solve the first problem is to use equations. Another solution is to change, by computer program, all the records in each file so they contain the new milepoints caused by the construction changes. However, both solutions would require every file to be changed. Additionally, the last solution would change the relationship of the files to any location reference system in the field.

A method to solve the problem of route number changes is to have a computer program that will write every record with the old route number into a historical file and update the existing records with the new number. Again, this would cause a loss in efficiency because every data file would need to be changed.

(2) <u>Missouri's method.</u> Other solutions can probably be developed for these problems. One solution has been devised by members of the Missouri highway department's planning division.

Corridors across the State are formed from latitude and longitude coordinates. These corridors are given numbers, odd from west to east and even from south to north. The number of a corridor where a route begins in the State is used to get a basic route number. Certain control milepoints along the route are associated with the basic route number in a control file. These points are equated with the current route number and the current milepoints for those points. Initially, the milepoints for both basic and current numbers on the same route will be the same. As changes are made in the length of a route, the basic milepoints will equal a different current milepoint. The same kind of equality occurs with the basic and current route numbers.

A record is coded for entry into a data file by identifying current route number and current milepoints. The updating program converts this identification into the basic route number and basic milepoints from the control file and enters the record into the data file with basic identification. Data are retrieved from the file in the same manner.

This method has two good points.

a. Only one file must be updated with changes in route lengths and numbers.

b. No matter what the current milepoints and route designations change to over the years, data are stored and retrieved for the same sections of roadway. This is illustrated in Figure 4.

With a method such as this, it is possible to determine the period of useful historical data for each file in the system, two, three, five, or more years, and carry data for these periods on the same file as the current year's data.

b. Milepoint computed from reference post locations. Another method that is relatively simple from the standpoint of recording data in the field involves coding a distance and direction from a reference post and the reference post number. This information is then used by a computer program in conjunction with the reference post location file to compute and store route and milepoint identification in the data records.

The statements made in section 2. (c) on page 7 also apply to the records developed under this method. The principal advantage of this method is the ease of location and recording of data in the field. The field crews do not have to know what the actual location or route number is, only the reference post number.

A disadvantage is the fact that every different route must have at least one reference post, including very short side routes.

c. Length identification using reference posts. A variation of the method just discussed gives the same simplicity and greater flexibility. The procedure is to store in the data records, as the location identification, the distance and direction from a reference post and the reference post number. This may be done for both ends of a road segment or for just one end. In the latter case, the length of the segment is stored.

The milepoint locations of the segment ends are computed by using the reference post location file. Thus, this method does allow for retrieving data with a milepoint specification.

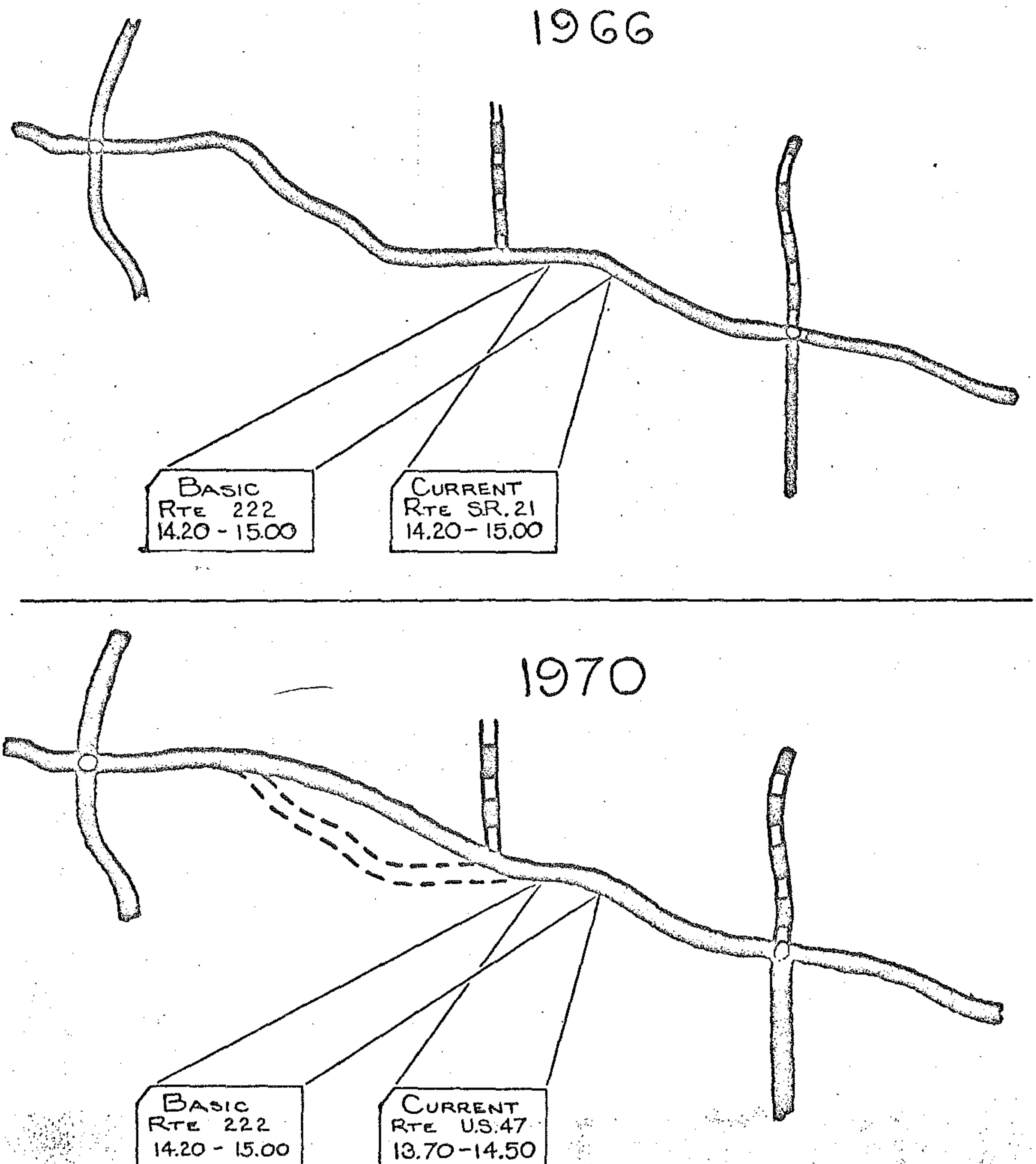

Figure 4. Showing relationship of Basic identification to Current identification before and after route and construction changes

An advantage of this method, besides the ease of recording in the field, is that the records in the data files do not have to be changed when there is a change in the route length or in the route number. Such changes would only affect the reference post location file. This would then require only making changes in one file as compared to having to change many other data files that would be affected under other methods.

d. Point identification using reference posts. Another method is to store in a data record the distance and direction from a reference post and the reference post number, of the point where some data characteristic changes, that is, at a break in the data. The data in the record is representative of the roadway until the point is reached where the data changes. At this point, another record is stored with the point located as described above.

As in the previous method, the actual milepoint would be computed from a reference post location file.

This method allows simple field recording, and data records in the files do not have to be changed because of changes in route location and number. There is an additional advantage with this method, new data records can be inserted anywhere in any file without changing any other record. With any other method discussed, insertion of a new record would cause at least one existing record and possibly more to be changed with regard to length.

e. Most favorable location identification method. Of the methods discussed, either of the reference post methods is believed to have the most flexibility. The reference post method using point identification is probably better for updating or file maintenance, since records in a file can be added with no affect on other records. The reference post method using length identification may have an advantage from a processing standpoint, since a segment length is inherent in each record and it is not necessary to read the next record to find the segment length.

Either of these methods can be used in conjunction with records identified by route and milepoint. The common reference base makes the identification methods compatible for data processing.

EXAMPLES OF HOW THE COORDINATED DATA SYSTEM MIGHT BE USED

1. Route and milepoint identification

Assume that a series of separate data files have been established as discussed in this report. Also assume that two of the files contain road characteristics data and traffic characteristics data that are related to the roadway through route and milepoint identification in the data records. This is shown in Figure 3.

Although not shown in Figure 3, assume that there is a file of accident data for accidents that have occurred at several points along the route, and a file of condition ratings that includes records for the route between milepoints 10.00 and 12.00, between 12.00 and 12.98, between 12.98 and 13.08, and between 13.08 and 14.59.

Finally, assume that some department head wants to know something about Route 22 between milepoints 11.00 and 13.00. Say that he wants to have information about the accidents that occurred during the past year in this 2-mile section. He also wants to know about the surface widths and the adequacy ratings between the given points.

A computer program takes the given milepoints and the information wanted as control parameters. It then retrieves the appropriate data, and prints the desired information. The printed output for this case could look something like that shown in Figure 5, keeping in mind that the numbers shown are arbitrary.

The example used was to answer, via a special purpose computer program, a request for certain information that is derived from a particular section of road. The termini of the section was given as request parameters. It should be remembered that many routine and periodic programs can be developed with such parameters built in. It is likely that such programs would not list information as shown in Figure 5 but would make some computation or analysis with the retrieved data. The output in these cases may be anything from a single line to a complete tabulation.

2. Reference post and distance identification

This example shows how distances to reference posts can be used as identification in data records to relate data to a roadway.

For comparison with the use of route and milepoint identification, assume, for this example, the same data files and records used in the route and milepoint example above.

ROUTE U. S. 22

BETWEEN MILEPOINTS 11.00 AND 13.00

ACCIDENT NUMBER	LOCATION	DATA
XXXXX	11.01 TO	
XXXXX	11.90 TO	
XXXXX	11.95 TO	
XXXXX	11.97 TO	
XXXXX	11.97 TO	
XXXXX	12.00 TO	

SURFACE WIDTH	LOCATION
22.0	11.00 TO 11.07
23.0	11.07 TO 11.98
24.0	11.98 TO 12.98
24.0	12.98 TO 13.00

TRAFFIC VOLUMES	LOCATION
1555	11.00 TO 11.05
1500	11.05 TO 11.98
1950	11.98 TO 12.87
1975	12.87 TO 13.00

ADEQUACY RATINGS	LOCATION
75	11.00 TO 12.00
90	12.00 TO 12.98
85	12.98 TO 13.00

Figure 5. Sample output for example of Coordinated Data System usage.

Assume a reference post location file exists that stores the actual locations of reference posts by route, county, milepost (from beginning of route in the State) and suppose that the reference posts placed as shown in Figure 6 have the following information in a reference post location file:

Reference post	Milepost	Route	County
380	9.00	US 22	Jason
384	11.25	US 22	Jason
388	14.00	US 22	Jason

Two ways in which reference post identification can be established were discussed in the section, CORRELATION OF THE DATA, 3.c. and 3.d. Assume that the data records of the route and milepoint example above are identified as described in the section, CORRELATION OF THE DATA, 3.c., in which both ends of a road segment are stored in a data record. Figure 7 shows the identification information used in the route and milepoint example and the corresponding identification used in this example. The beginning points on each line are the same and the ending points are the same.

As in the previous example, assume that a department head wants to know how many accidents have occurred between milepoints 11.00 and 13.00 and what the surface widths and adequacy ratings are between these points. As stated before, a computer program takes the given milepoints and the information wanted as control parameters. The printout would be the same as that shown in Figure 5 for the previous example.

A variation of this procedure, which is described under the section, CORRELATION OF THE DATA, 3.d., is to identify in the data records the beginning points only of the road segments they represent. If this is done, the printout would still be as shown in Figure 5 and the control parameters would still be as shown in the two examples.

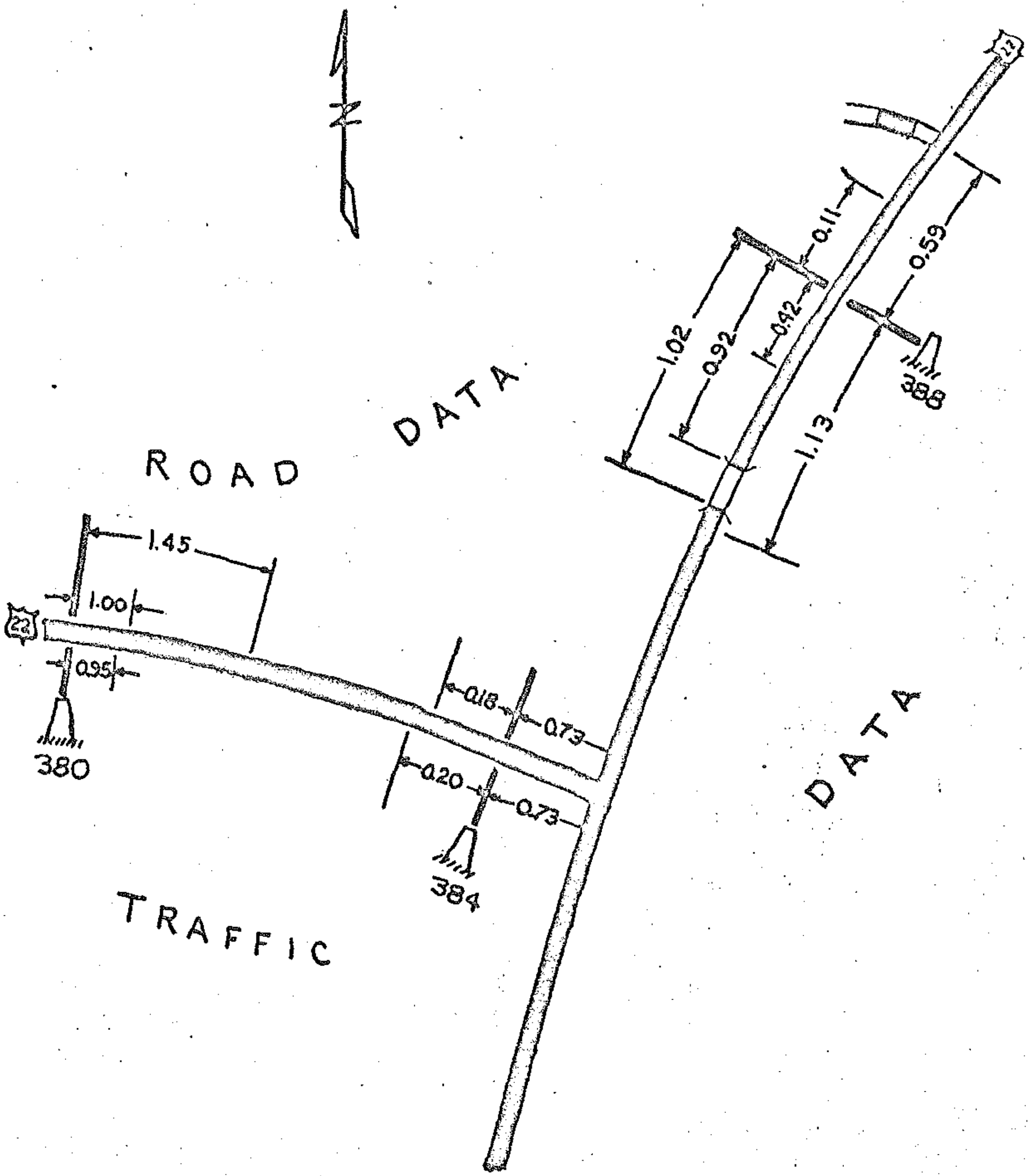

Figure 6. Locating Points by Relating Them to Reference Posts

Route and milepoint identification			Reference post and distance identification					
Road data file								
Route	Begin	End	Begin			End		
US 22	10.00	10.45	1.00	E	380	1.45	E	380
US 22	10.45	11.07	1.45	E	380	0.18	W	384
US 22	11.07	11.98	0.18	W	384	0.73	E	384
US 22	11.98	12.98	0.73	E	384	1.02	W	388
US 22	13.08	13.58	0.92	W	388	0.42	W	388
US 22	13.58	14.11	0.42	W	388	0.11	E	388
Traffic data file								
US 22	9.95	11.05	0.95	E	380	0.20	W	384
US 22	11.05	11.98	0.20	W	384	0.73	E	384
US 22	11.98	12.87	0.73	E	384	1.13	W	388
US 22	12.87	14.59	1.13	W	388	0.59	E	388

Figure 7. Identification of the points shown in Figure 3 by Route and Milepoints and by Distance to Reference Posts.

CONCLUSION

The system described in this report will require the development of a large number of computer programs. A large number of programs undoubtedly would be useful even without a Coordinated Data System, but would not provide the efficiency in the collection, storage, and use of data.

To summarize several features of the Coordinated Data System:

1. The system provides a flexible procedure to collect, record, and code data in an easy uncomplicated way. It can provide maximum simplicity in collecting and recording data in the field, and yet provide the facility to analyze all data sources with any relationship desired.

2. Data can be collected as it exists without having to consider how a user needs the data.

3. Data values are stored in a computer file in the way they exist in relation to one another along a route.

4. Data can be retrieved according to the user's specifications. The user can establish control sections or segments of any length for the purpose of summarizing data or retrieving information.

5. The system is modular. It can be developed one file at a time. Additional files (that is, new data) can be added to the system at any time without disturbing any other file. Such additions would also require development of new computer programs.