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# Highway Safety Improvements through Utilization of Merged Accident and Roadway Data

Volume I

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# INTRODUCTION

In 1976, the North Carolina Board of Transportation contracted with the University of North Carolina Highway Safety Research Center to design and implement an information system which merges accident and roadway characteristics data in a usable form. The resultant system will hopefully be of great value in determining relationships between roadway characteristics and accident involvement on either an individual site or a statewide basis, and will therefore aid both in selecting highway improvements based upon accident information and in evaluating such improvements.

This report is organized into two volumes. Volume I presents the project accomplishments in three sections. The first section is entitled SYSTEM DESIGN and covers the background study of available data sources, the data selection process, the system analysis procedure, the operational information system, the update mechanism for this system, the developed user programs, and the proposed system additions. The second section, SYSTEM IMPLEMENTATION, describes the non-design work performed to implement the system, such as editing data and preparing computer programs for the information system. A final section entitled RECOMMENDATIONS outlines suggestions for future improvements and related work.

Volume II presents detailed system descriptions and user documentation in three sections. The first section is entitled UPDATE SYSTEM and describes in detail the update procedures for the system data files. The second section, OPERATIONAL SYSTEM, gives detailed information on each operational system component and details each component's relation to other components. The final section is entitled USER PROGRAMS and documents the user programs produced under this project.

# SYSTEM DESIGN

## Data Selection

A study of the availability of accident and roadway characteristics data was performed and the following data sources were identified.

### Accident data sources.

A. Mileposted Accident Tape (05 tape) - the tape containing mileposted accident information on all accidents which occur on the primary system (or on a secondary road within 500 feet of its intersection with a primary road). The milepost attached to an individual accident is derived through a computer match up with the Location Inventory Tape (see below). This 05 tape is the primary accident data source used by Traffic Engineering.

B. Research Accident File - an accident file prepared by HSRC which incorporates supplemental data (such as occupant restraint) not found on the standard accident files prepared by DMV and DOH.

C. Accident Narrative File - a file containing the investigating officer's accident narrative maintained by HSRC as a supplement to the research accident file.

### Roadway characteristics data sources.

A. Mileage Inventory Tape (Characteristics Tape, MIT) - a tape containing mileposted roadway characteristics data (e.g., ADT, median width, shoulder design, etc.) for the North Carolina Rural Primary System. The information on this tape file is obtained from the same sources as the straight line diagram information, but does not contain all of the variables on the straight line diagram (e.g., curve data, passing sight distance). The tape is maintained and updated by the Planning and Research Branch on a project-by-project basis.

B. Location Inventory Tape (LIT) - the tape used in the mileposting of accident locations. This tape contains a mileposted listing of all major roadway junctions and other reference points (e.g., urban boundaries, county lines) which the investigating officer might note in the location section of the accident report form. Other mileposted features such as bridges and railroad crossings are also contained in this file. The Planning and Research Branch maintains and updates the master copy (Version I) of this tape on a yearly basis. Version II, the actual LIT used to milepost accidents, differs from Version I only in the use of alphabetic codes (e.g., I-40 for Interstate 40) rather than numeric codes (10040).

C. Structures Inventory File (Bridge File) - a file of information on all state-maintained bridges and many other structures such as overhead signs and tunnels. This file contains information on individual structures, such as structure type and type of construction. This file is updated by the Bridge Maintenance Branch when new structures are added or maintenance effecting the structural stability of an existing structure is performed.

D. Federal Railroad Crossing Inventory File - a computer tape containing information about railroad crossings, such as signalization, number of tracks, and crossing number. It is maintained and updated by the Federal Railway Administration of the United States Department of Transportation using data supplied by highway departments and railroad companies.

E. Straight Line Diagrams - a straight line representation of primary roadways which incorporates a mileposting scale and data on such variables as number of lanes, degree of curve, passing sight distance, ADT, etc. As noted earlier, while the basic variables are the same as those found on the MIT, the mileposting scale on this file does not correspond exactly to mileposting on the Mileage Inventory Tape. These diagrams are generally maintained and updated by Planning and Research on a project-by-project basis.

F. Skid Resistance Inventory - a county by county inventory of skid resistance values for homogenous sections ($\geq$ 1 mile long) of primary highways. The inventory is currently recorded on paper (not computerized) and is referenced to road junctions but not to the existing mileposting scheme.

G. Traffic Signal Inventory - a non-computerized description of traffic signal devices. This data source contains information on individual signals such as signal type, number of heads, number of phases and signal identification number. Data on rural and secondary signals are combined.

H. Photolog System - a photographic representation of the rural-primary roadway system organized by county route and milepost. This is a good source for information lending itself to photographic representation. However, the photolog is incorrect for those sections of roadway which have been altered since it was made, and the data from the frames have not been reduced to digital form.

Once these possible data sources were isolated, the contents of each source was listed and presented for discussion at a meeting of the liaison committee of DOH/HSRC personnel that had been established to provide guidance and coordinate the effort. Each data element from each source was reviewed by the committee and suggestions were made as to which elements were needed in the new system. Based upon these suggestions and on discussions concerning the difficulty acquiring data and the reliability of the various data sources under consideration, data elements from the following sources were selected for utilization:

I. Mileposted Accident Tape
II. Mileage Inventory Tape
III. Location Inventory Tape
IV. Structures Inventory File
V. Federal Railroad Crossing Inventory File

These comprised the initial level of the merged system. (As will be noted later, the system was to be designed to allow for the subsequent addition of other data elements and data sets.)

The Mileposted Accident Tape is the basis of the entire system. The use of the Research Accident File to supplement the data on the 05 tape was considered, but the time lag in acquiring supplemental data made this prohibitive. The integration of Accident Narrative Data into the system was also considered but the unwieldy magnitude of these data made this impractical at this time. In lieu of this, it was proposed that HSRC's currently operational Narrative Search System be made available for use by DOH.

The Mileage Inventory Tape was chosen as the primary source of information about homogenous segments of roads. The Location Inventory Tape was selected to use as a descriptor of roadway features such as intersections, bridges, and railroad crossings. Data were pulled from the Structures Inventory File and the Federal Railroad Crossing Inventory to supplement this tape.

One source of data, the Straight Line Diagrams, which initially figured to be a prime source of curve, grade and other characteristics data was not used. Some of the problems identified in using this data source were (1) lengths of curves have not been included, (2) mileposting designations on the Line Drawings do not correspond to those in other data sources, and (3) Planning and Research indicated that, because in recent years the Line Drawings have not been rigorously updated, many may reflect incorrect information. Two other sources of characteristics data which are available but were not included in the initial system are the Skid Resistance Inventory and the Traffic Signal Inventory. Both of these are non-computerized files which require massive manual efforts to be incorporated. Traffic Signal Inventory currently contains data on all signals, and thus the rural primary signals which would be linked with the other system information would have to be manually identified. The Skid Resistance Inventory, containing two items of information on surface texture and skid number would need to be maintained as an entirely separate file or merged into an existing file. Again, it is noted that while these two data sets are not included in the initial level of the merged system, they are both important sources of information. Both sets can, and probably will, be added to the merged system at a later date. Indeed, analysis of the Skid Resistance File resulted in data collection guidelines and preliminary system design recommendations which we discuss in a later section.

The inability to capture good curve and grade data from any available source led to the exploration of options in collecting these and other data in the future. This topic is discussed as a proposed system addition later in this section.

## System Analysis

After determining the data elements to be utilized and their origins, the structure of the system was considered. The basic question was whether to implement a modified tape system or a direct access disk system. Advantages and disadvantages of both approaches were presented to the liaison committee. It was decided that inadequate data were then available to make a meaningful decision; therefore, a system analysis was carried out by HSRC.

This analysis was performed in three phases. First, the existing needs and problems were reviewed. From this review, the objectives which a new system should satisfy were determined. Based upon these objectives, a computerized information system was proposed. The rationale for and details of this analysis are presented below.

Determination of existing needs and problems.

Because the system being developed was to answer existing DOH data needs, the decision concerning basic system form had to be based in part on existing needs and problems. This information was obtained from various sources.

The original contract documents covering the overall project efforts had to be written in somewhat general terms since part of the project effort was to identify specific needs and to design a specific system that could meet these needs. However, the contract itself did specify two basic problem areas:

1. Roadway characteristics existing in an accessible form need supplementing by adding characteristics data items not readily accessible at present.
2. A straightforward mechanism for linking accidents with roadway characteristics which may have contributed to their occurrence was not available.

The second major source of information relevant to the proposed system was the existing system. Review of this system and its standard outputs indicated that available information fell into two categories: (1) accident information and (2) roadway characteristics information. The accident information is derived from statewide accident data collected by all police agencies within the state.

Several standardized reports and printouts of accident information are produced on a cyclical basis as general working documents, while other listings are generated upon request. The accident data sets from which these reports are derived are three physically separate files all containing the same or a subset of the same information but each arranged in a different sequence. Ordering by different sequences is done to facilitate the retrieval of information in the proper order. Each of these three sequences is formatted in monthly, quarterly, and yearly files, and all three files are updated on a monthly basis.

As was noted in the original data set listing, the roadway characteristics data have been traditionally kept on several separate files with several branches of the Division of Highways assuming responsibility for the maintenance of the various files. The bridge department has built a computerized structure file which contains detailed information on bridges and their approaches, overhead signs, and other structures. The Location Inventory File contains location information and some detailed information about highway features, such as intersections and bridges. This file is presently used in plotting the position of accidents by milepost under the present system. A companion file to the Location Inventory File, the Mileage Inventory File, describes the characteristics of homogeneous segments of roadway, and represents the primary source of computer-accessible roadway characteristics information in the existing system. An inventory of railroad crossings is also available in a machine-readable form.

Several data sources exist which have not been previously computerized. These are line drawings, and skid resistance, traffic signal and railroad crossing signal inventories.

Thus, study of the existing system indicated that a wealth of information was available to attack the many problems presented to the Department of Highways. However, as is so often the case, the increased sophistication of the data users had generated the need for a great deal of interaction between the above mentioned files, which, under the existing system were accessed mostly in a stand-alone fashion. In addition, increasingly sophisticated users' requests could no longer be satisfied by listing a subset of accidents, but had to be met by making detailed summaries, cross tabulations, and certain statistical analyses readily available. Thus, the ever increasing demands placed on the existing system require a large amount of both manual and computer time and effort.

It is anticipated that this effort can be reduced with no reduction in productivity through adoption of a somewhat more powerful information storage and retrieval system.

In gathering information concerning the two general problems noted above, HSRC staff began a series of meetings with DOH personnel. Since the primary users of the system will be the Traffic Engineering Branch of DOH, special emphasis was placed on collections of detailed and thorough information from its members. By working with computer information specialists at UNC, HSRC project personnel developed a structured format for interviews with DOH individuals. The following is a partial listing of the topics discussed in these interviews.

1. Current Requests
   a. Who makes what requests and how often?
   b. How are requests entered into the computer?
   c. How long does it take for the computer to supply an answer?
   d. What outputs does the current system supply?
   e. What information requests are received that cannot be answered with the current system and how frequent are these?
   f. Are there any specific problems?
2. Prospective Requests
   a. What information would be requested if it were readily available?
   b. Are there reports not currently available which are needed?

In the discussions of the information system needs, many specific points were noted by various users and data processors. In summary, the following basic needs were identified as those which should be met by the proposed system.

1. Information to be obtained more quickly by the users.
2. Information to be presented in a summarized form.
3. A greater flexibility in selecting, combining and analyzing various accident characteristics data items.

4. A flexible system for subsetting accident and characteristics data using information existing on other files (e.g., pulling a subset of accidents based on specific roadway characteristics).
5. Provisions to allow editing of certain variables (such as accident type) by system users.
6. A linkage and analysis capability to access accident narratives.

<u>System objectives</u>.

Based on the reviews of the existing system and the contract requirements, and on the data gathered in the previously described interview process, it was determined that the general objectives of the proposed system are as follows:

1. Expand the amount of usable characteristics information by reformatting and editing data sources into a more readily accessible form.
2. Provide a mechanism which will enable accident and characteristics data to be linked for analysis purposes.
3. Provide a mechanism to allow the insertion and deletion of data from the system without major revisions.
4. Provide flexible user-oriented data inquiry subsystems which will enable users to obtain information quickly in a usable form.
5. Provide a data editing ability on selected data items (e.g., accident type).
6. Provide a linkage and analysis capability for accident narratives.
7. Accomplish the above objectives efficiently without introducing an undue burden on computer resources.

The remaining part of this paper describes the system proposed by HSRC to meet these system objectives. The proposed system will be able to fulfill many needs being handled by the current system and should eventually be able to satisfy most, if not all, of the information requirements for the Division of Highways. However, the proposed system, as it has been initially developed, is intended to supplement rather than replace the existing system.

Based on the results of the above-described system analysis, the basic form of the proposed system is a direct access disk system. The details of the proposed system are described in the following section.

## Proposed System

The following accident/roadway information retrieval system has been designed to meet the system objectives defined above without putting undue pressure on computer resources. To add flexibility to the design so future problems and objectives can be met as they are defined, the system was designed in two parts. The first is basically a specialized data base management system which retrieves and updates data from the various files in the system. The second part consists of user-oriented application subsystems which will use data from the data base management system to provide users with the various types of information they need.

Of equal concern are the physical limitations which must be imposed on both the file structure and the operating system. Care has been taken to reduce the usage of main core while keeping file access time at a minimum. Files will be retained on direct access disk packs referenced by indices residing in main core. This method will limit seeks to approximately one per request on specific road segments. Sequential searches of entire files should be accomplished in batch mode in order to alleviate any problems that the increased computer usage would cause.

### Data base management system.

A large degree of flexibility has been incorporated into the proposed system. Modules which access and update data files have been completely separated from application programs. This will allow the user complete freedom in specifying subsequent analysis requests without delving into the system structure. By making multiple references to the different file(s), he will be able to subset specific information both within and across file boundaries.

Potential growth of files is also possible without seriously affecting core requirements or processing time. New files may be added with little difficulty, with file size limited only by the amount of disk space available. This disk space may be optionally online or offline depending on the frequency of use and the discretion of the operations staff at ADP. Should growth continue in the future, a greater reliance on this system may make it desirable to incorporate interactive techniques into data retrieval and analysis on small subsets of files. The direct access system designed in this project is a necessary basis for future shifts to interactive inquiries and is therefore consistent with such a system expansion.

At the core of the proposed information management system is information derived from the currently existing file: mileage inventory, location inventory, roadside structure, railroad crossings, and accident data files. Data from these files are structured into three system files: accident, structure, and segment characteristics files. (See Figure 1.) Though containing different data elements arranged in a format unique to each file, the basic structures will be the same across the system. Records will be ordered by county, route, then milepost. Each county-route boundary within a file will begin on a new track on disk. Information within a county-route which spans multiple tracks will be allocated contiguously. Records are variable format but are structured into fixed blocks using one block per track.

Direct access retrieval both among and within files is accomplished with a multiple index structure. One index exists for each file and resides in core during the time that a particular file is being referenced. The index format consists of a tree structure with an entry for each county-route subset. Pointers within the entries link county-routes in such a way as to allow a binary search when locating a unique county-route key. Contained in each entry is the relative track number and the milepost range associated with the tracks of that county-route. Indices for files not in use reside on an online disk to be retrieved when needed.

Two modes of data-retrieval are available to the user. Requests which do not specify a specific location (i.e., county, route, milepost range) are handled by processing the appropriate index sequentially to obtain the location of the desired data. These requests may specify any combination of county, route type, route number and milepost range. Only data meeting the specified criteria are retrieved, thereby providing a subsetting mechanism intrinsic to the retrieval system.

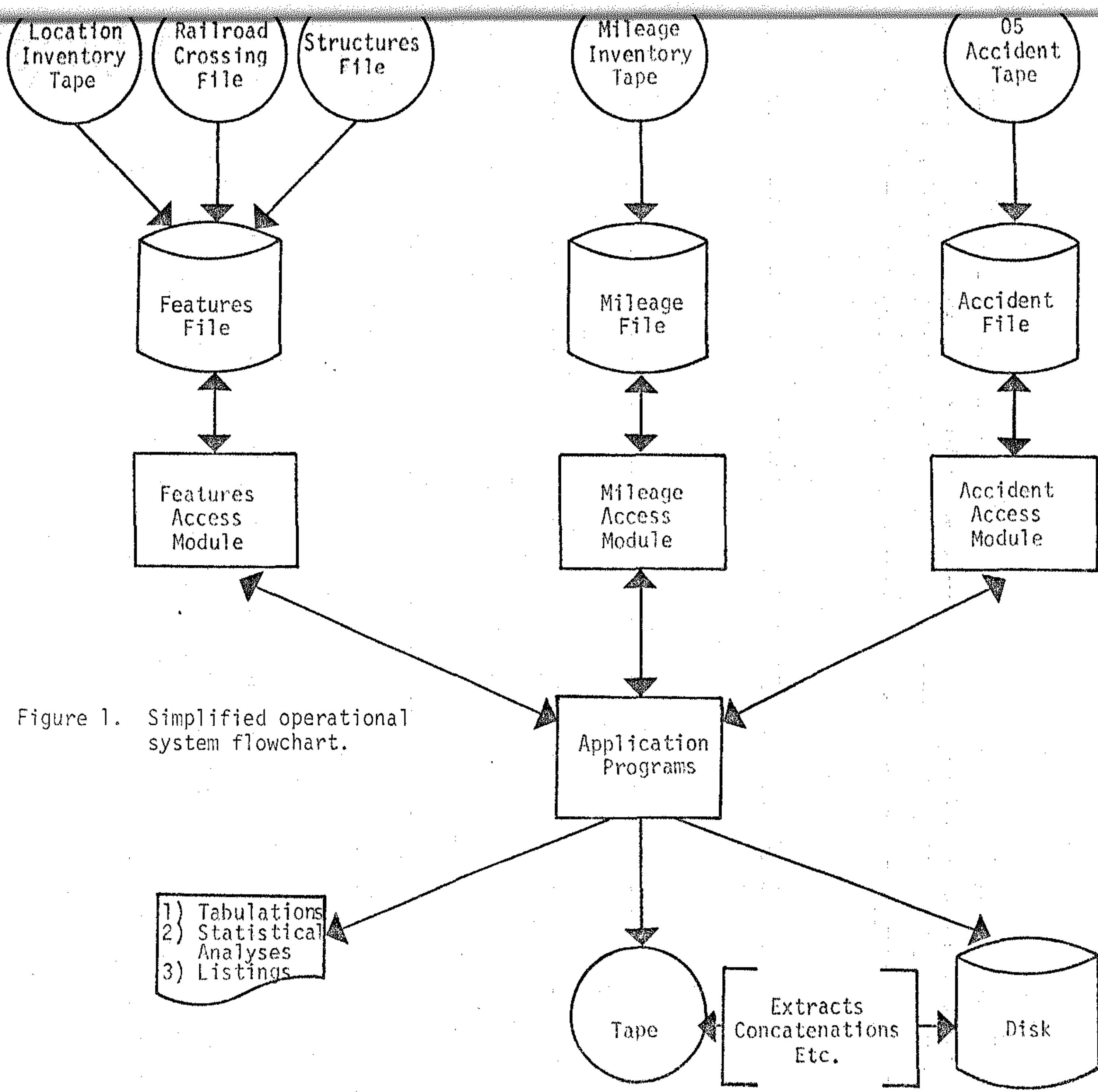


Figure 1. Simplified operational system flowchart.

A second mode of data retrieval is available when requests can be retrieved on a county, route, milepost range basis. References made to the proper index will locate the exact track(s) on disk where a record exists by comparing the county-route keys on the index entries to the target key of the request--using a binary search technique. A binary search is the most efficient method for locating a specific key. For example, each index will initially contain 930 index entries. Maximum binary search length will be 10 comparisons. By doubling the number of entries to 1860, the maximum search length will increase by only one additional comparison.

Once the correct index entry has been located the relative track number is determined from the milepost range values. The system then reads this track of information into core for subsequent use by the application program.

Periodically, it will be necessary to update the system data files. Through discussion with DOH data processing personnel, it was determined that the most reasonable approach to updating is to utilize the updated parent files and reload the affected system file(s) and indexes.

Several edit and file formatting steps have been introduced to supplement the file preparation currently performed. A complete write-up on the update process is available in Volume II.

Complementing the information retrieval system is a set of user-oriented application programs developed as part of this project. These programs utilize modules from the data base management system to access the proper data files and retrieve the data necessary to answer specific requests for different branches of the Division of Highways. Requests of such broad nature as may be asked are best served with this form of system. For example, spot checks may be made on accident data along a short segment of a county-route. At the other extreme, entire files may be searched for accidents involving certain roadside structures, linking these with their respective narratives. Given any reasonable request, it will be possible to develop an application program or use an existing one to produce the desired results.

Allowing for a large degree of flexibility, the proposed information management system is basically a set of program modules to retrieve, subset, and update information present in the data base. It is the responsibility of the application programs to assimilate information supplied by the modules and generate reports, perform statistical analysis, and tabulate summaries.

Operational system structure.

This section describes the composition of the information system as it will be implemented on the DOH computer system. A pictorial representation of the system (flowchart) is given in Figure 2 and should be studied to better understand how the different parts of the system interact.[1]

There are seven main components in the operational system: 1) Inputs, 2) Data Retrieval Modules, 3) Data Selection and Conversion Modules, 4) Auxiliary Modules, 5) Application Programs, 6) Output Modules, 7) Outputs. Each of these is represented in Figure 2 as a row in the flowchart. The components of these divisions are outlined below; detailed user documentation for each component is given in Volume II. Computer programs, source code modules and data sets are named in accordance with approved DOH naming conventions. Additionally each operation on all flowcharts has been assigned a reference number (e.g., I.P1).

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[1]*In all flowcharts which follow, each component will be designated by a reference number (e.g., I.F1, II.P1, I.L1) for use in the text. For convenience, the alphabetic characters in the reference numbers refer to the following:*

*F - data file*
*P - program*
*L - listing*
*C - card deck*
*M - partitioned data set number*
*S - compiler source module*
*E - manual examination of errors*

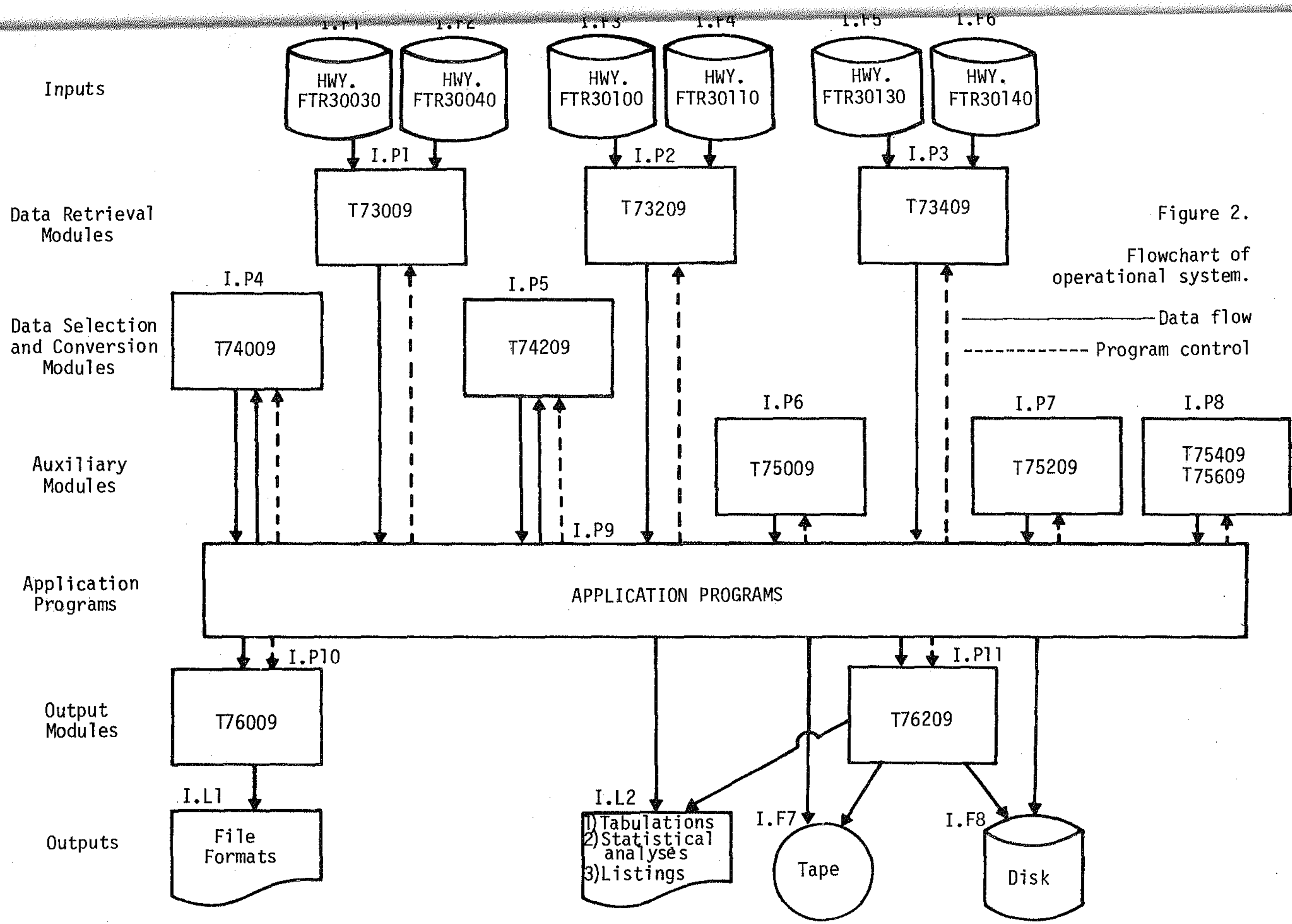



Figure 2.

Flowchart of operational system.

Inputs

A. HWY.FTR30030, I.F1 (Segment Characteristics File). This system data file describes homogeneous segments of roadways. It is derived from the Mileage Inventory Tape and contains information such as ADT, median width and shoulder design.

B. HWY.FTR30100, I.F3 (Features File). This is a system data file containing information on roadway features such as bridges, intersections, railroad crossings, political boundaries, overhead signs, tunnels, ferries, retaining walls, pedestrian overpasses and culverts. This file is derived from the Location Inventory Tape with supplemental data from the Structures Inventory File and the Federal Railroad Crossing Inventory File.

C. HWY.FTR30130, I.F5 (Accident File). This data file contains mileposted accidents occurring on the rural primary system or on intersecting non-primary system roads within 500 feet of a rural primary road. The basis for the file is the Mileposted Accident Tape (05 tape).

D. HWY.FTR30040 (I.F2), HWY.FTR30110 (I.F4), HWY.FTR30140 (I.F6) - Data File Indexes. One index file is present for each system data file (I.F1, I.F3, I.F5). Each index is arranged by county, route, and milepost so as to correspond to the data files. The use of the index permits the direct access of data for a specific location without having to read the entire file.

Data retrieval modules - T73009 (I.P1), T73209 (I.P2), T73409 (I.P3).

These modules are designed to retrieve disk-formatted records from any of the above data files based on county, route, and mileposted range, where range may be either one or N mileposts long. As explained above, the respective file index (I.F2, I.F4, I.F6) is used to facilitate the efficient direct access of the proper records.

Data may be retrieved in the following ways:

1. A certain milepost for a county-route.
2. A milepost range for a county-route.
3. All data for a particular county.
4. All data for a particular route type (i.e., Interstate, U.S., or NC).

5. All data for a particular route.
6. All data for a particular route type in a certain county.
7. All data for all counties without regard to route, route type or milepost.

The Data Retrieval Module's action is controlled by an Application Program (I.P9) and the record retrieval is placed into an area contained in the application program.

Data selection and conversion modules.

A. T74009 (I.P4) - When a string of variables is requested by a user input (i.e., applications program), this module extracts internal descriptive information from a master data description table for each variable requested. This descriptive information (e.g., location and length of data string for each variable) is then converted into a readily usable format and the list is passed back to the applications program for subsequent use by modules T74209 (I.P5) and T76009 (I.P1Ø).

B. T74209 (I.P5) - When called by the applications program, this module examines the data description list outputted by T74009 (I.P4) above, expands each of the data elements from their compressed format into a zoned decimal format, and concatenates them into a single output string for use by the applications program.

Auxiliary modules.

A. T75009 (I.P6) - When called, this module tells whether or not a route is coinciding in a certain county at a particular location. As an option the module will return all routes (if any) coinciding at the point referenced and the corresponding mileposts for each.

B. T75209 (I.P7) - This program module converts the five (5) digit coded numeric route designation into the standard six (6) digit alphanumeric designation.

C. T75409 (I.P8) - Converts the standard DOH county codes and a six character alphanumeric route designation to the standard three byte binary representation of county-route; it also returns the DOH five byte numeric route code. A second entry point for this module (T75609) converts the standard DOH county codes and the five byte numeric DOH route designation to the standard three byte system county-route designation.

Application programs - I.P9.

These are user programs which utilize data from the system through usage of the Data Retrieval and Data Selection and Conversion Modules discussed above. All control of data retrieval, conversion, and selection is initiated by the Application Programs. Once the proper records are obtained in the correct form, application programs can process these to give various system outputs. Application programs may be executed in a batch or interactive environment depending upon the specific requirements of the Division of Highways.

Output modules.

A. Module T76009 (I.P10) outputs a record format giving variable name, position, length, and type for each data element in a record described by the binary data description list outputted by T74009 (I.P4).

B. Module T76209 (I.P11) writes fixed length blocked records of any proper LRECL-BLKSIZE configuration, based upon information supplied through call list parameters or a DD card at run time.

Outputs, I.L1, I.L2, I.F7, I.F8.

System outputs are defined by specific user needs. One form of output is mass data (e.g., disk or tape) files (I.F7, I.F8) containing extracts and/or concatenations of data from one or more system input files (I.F1, I.F3, I.F5) which can be used as input to packages such as SPSS. Specialized reports, data tabulations and listings, and statistical analyses are some of the other outputs possible.

Update system structure.

This section describes the procedures necessary for updating the operational system input data files. Figure 3 is a flowchart of the update process and should be referenced to gain an understanding of the interactions of various update steps. This update procedure is performed either annually or more often using the new DOH Location Inventory (II.F1, II.F12), Mileage Inventory (II.F4), and Mileposted Accident (II.F18) files. Data from the Structures Inventory (II.F9) and Federal Railroad Crossing Inventory (II.F8) files are used to supplement the Location Inventory data.

Some editing of the Location, Mileage, Structures, and Federal Railroad Crossing Inventory files not performed in the past is included in this system. Errors detected in these steps will be corrected through already existing update mechanisms. The only changes in the current file generation procedures employed by DOH is that some additional data corrections will be indicated by the above mentioned procedures, and the preparation of the Location, Mileage, Federal Railroad Crossing, and Structure Inventory files will need to be more closely coordinated. After all edits and corrections on these files are completed, they are effectively frozen for the year (or until the next update). If changes are made to one system file (II.F6, II.F15, II.F19) affecting the mileposting or some other organizational factor for that file, the other files must also be updated to reflect the change.

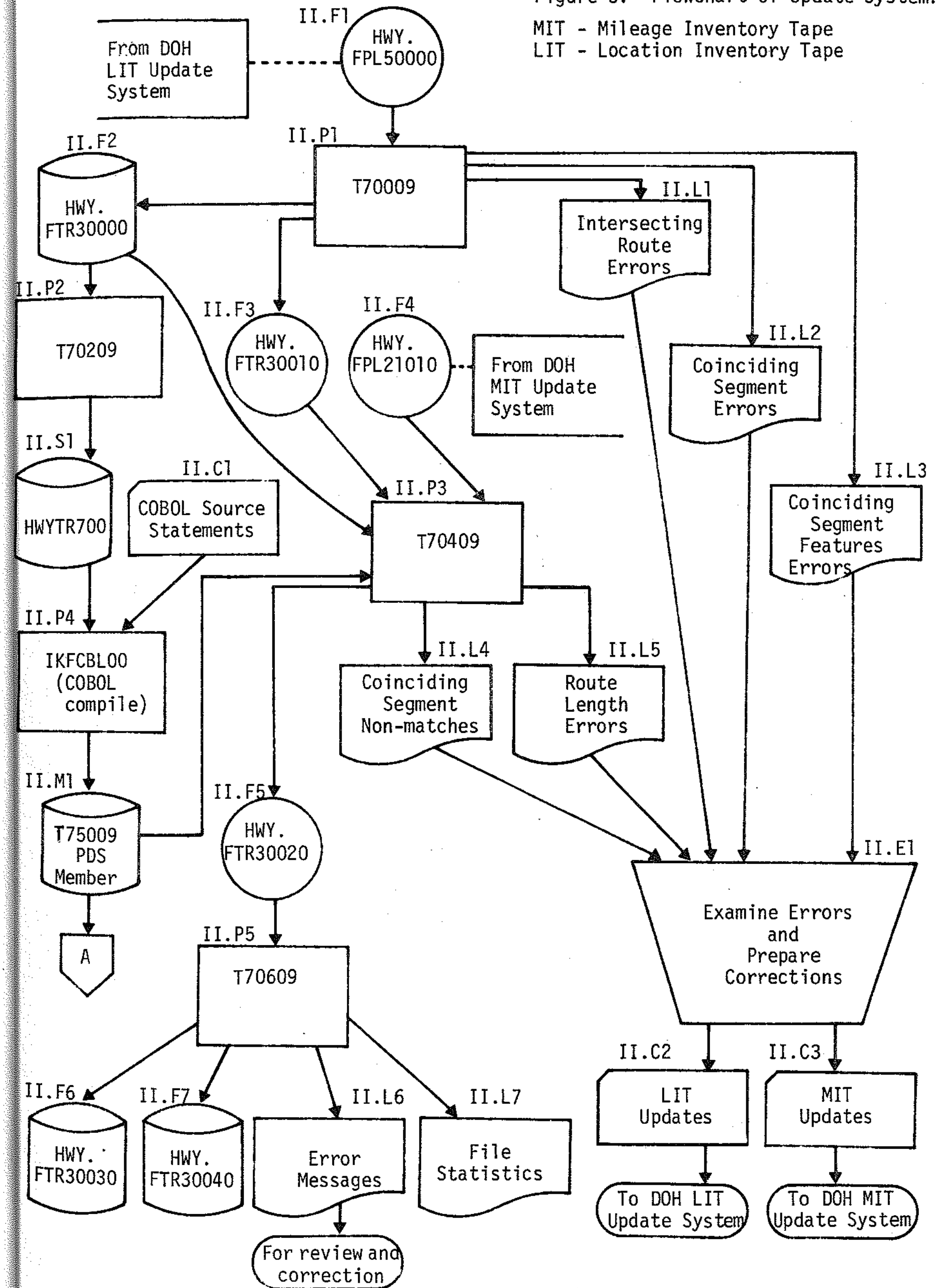
The Update System is logically comprised of five major sections: 1) Location and Mileage Inventory Edits, 2) Segment Characteristics File preparation, 3) Features File preparation, 4) Accident File preparation, and 5) System Module preparation. Each of these processes will be discussed in detail. References in the text to programs, files, listings, manual operations and card decks are keyed to Figure 2. Detailed documentation of the Update System is given in Volume II.

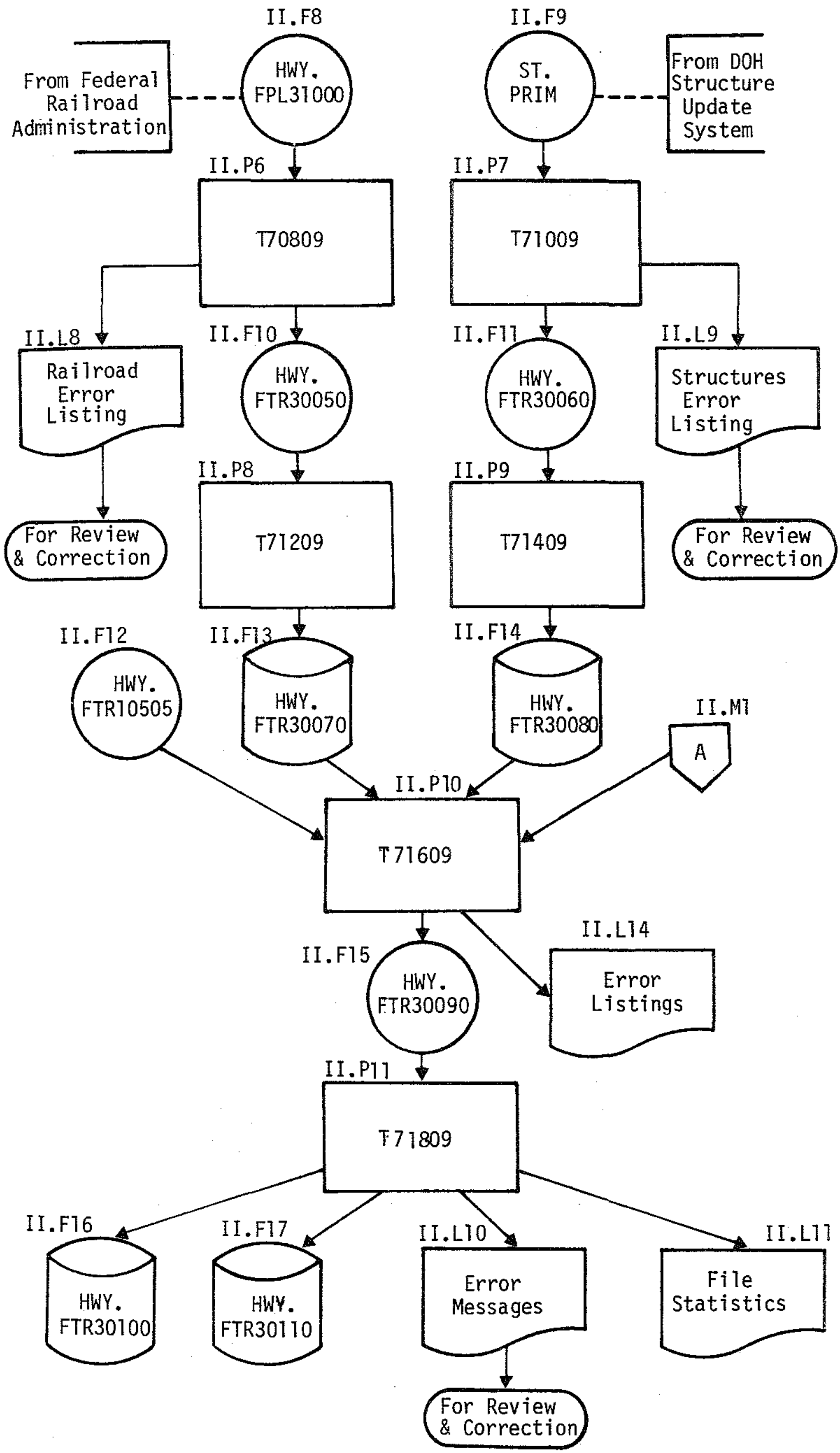
Location and mileage inventory edits.

The initial program (II.P1) in the edit process, using the Location Inventory Tape (II.F1), checks to see that each defined coinciding segment has a valid corresponding segment on the route it coincides with in that county. It determines same or reverse direction of mileposting from the better match of all physical descriptors (i.e., all bridges, intersections, etc., in one description also occur in the other at the same position) and generates a coinciding segment file (II.F2) and a total route

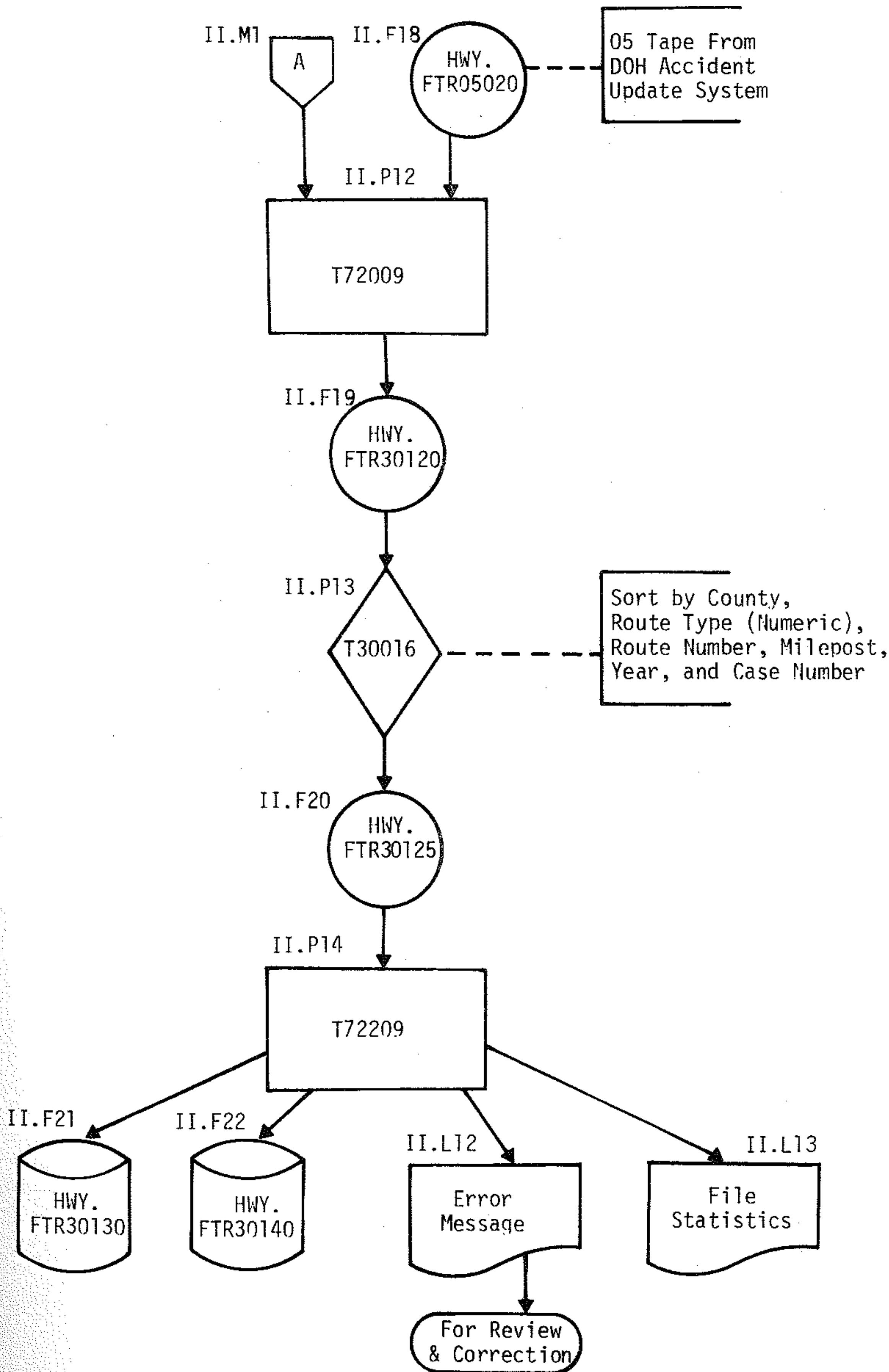
Figure 3. Flowchart of Update System.

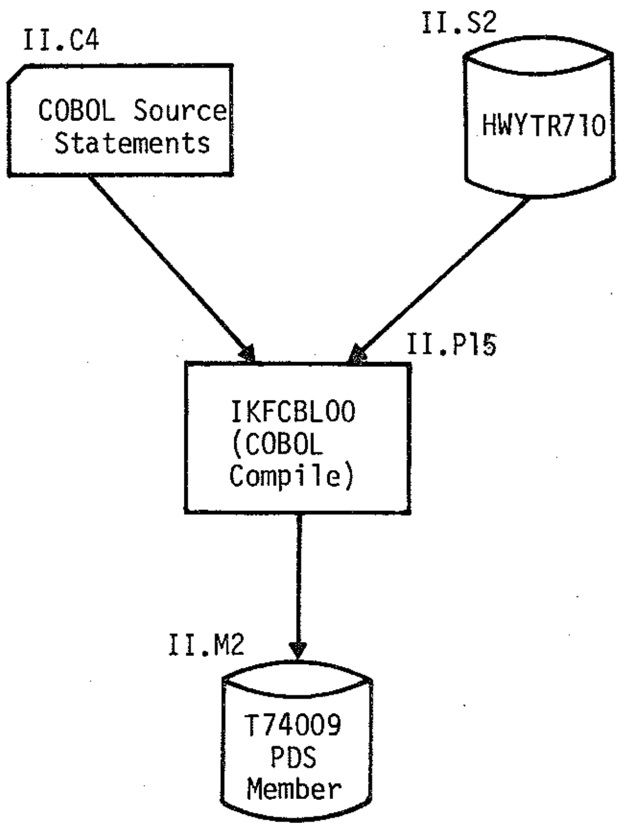
MIT - Mileage Inventory Tape
LIT - Location Inventory Tape





II.F8
HWY. FPL31000
II.F9
ST. PRIM
From Federal Railroad Administration
From DOH Structure Update System
II.P6
T70809
II.P7
T71009
II.L8
Railroad Error Listing
II.F10
HWY. FTR30050
II.F11
HWY. FTR30060
II.L9
Structures Error Listing
II.P8
T71209
II.P9
T71409
For Review & Correction
For Review & Correction
II.F12
HWY. FTR10505
II.F13
HWY. FTR30070
II.F14
HWY. FTR30080
II.M1
A
II.P10
T71609
II.L14
Error Listings
II.F15
HWY. FTR30090
II.P11
T71809
II.F16
HWY. FTR30100
II.F17
HWY. FTR30110
II.L10
Error Messages
II.L11
File Statistics
For Review & Correction


II.M1
A
II.F18
HWY.
FTR05020
05 Tape From
DOH Accident
Update System
II.P12
T72009
II.F19
HWY.
FTR30120
II.P13
T30016
Sort by County,
Route Type (Numeric),
Route Number, Milepost,
Year, and Case Number
II.F20
HWY.
FTR30125
II.P14
T72209
II.F21
HWY.
FTR30130
II.F22
HWY.
FTR30140
II.L12
Error
Message
II.L13
File
Statistics
For Review
& Correction



II.C4
COBOL Source Statements
II.S2
HWYTR710
II.P15
IKFCBL00 (COBOL Compile)
II.M2
T74009 PDS Member

length file (II.F3). Segments which are known to be coinciding but for which no description can be found on one of the proper routes, and segments for which the corresponding segment is a different length, are listed as errors (II.L2). When segments with corresponding descriptions of identical length differ in physical description, the descriptions of both segments are printed (II.L3). This program also verifies that all rural primary routes described as intersecting routes are also defined as an actual route in the same county. Those not meeting this condition are listed as errors (II.L1).

The second edit program (II.P3) checks the Coinciding Segment File (II.F2) and Route Length File (II.F3) against the Mileage Inventory Tape (II.F4) to assure that coinciding segments and route lengths agree between the Location and Mileage Inventory files. Those not agreeing are listed as errors (II.L4, II.L5).

All the error listings mentioned above (II.L1, II.L2, II.L3, II.L4, II.L5) are examined manually to reconcile any errors noted. Cards (II.C2, II.C3) to correct the Location and Mileage Inventory Tapes are punched and entered into the DOH update system for the proper file. Once the files have been corrected in this manner, they may be passed through the edit process again to check for any new or uncorrected errors, or, if the files are substantially correct, they may be used to produce the system characteristics files (II.F6, II.F7).

<u>Segment characteristics file preparation</u>.

The parent file of the Segment Characteristics File (II.F6) is the Mileage Inventory Tape (II.F4), which contains the characteristics of homogeneous segments of roadway. On the Mileage Inventory Tape, coinciding segments are described on the lower numbered route only, while the higher numbered route contains a notation telling which lower route gives the information describing the coinciding segment. (Note: In this numbering convention, Interstates are lower than U.S.'s which are lower than N.C.'s.

If two roads of the same group coincide, the lower numbered road will be the one with the smaller numeric portion - e.g., N.C. 54 would be lower than N.C. 55.)

This file characteristic presented two problems. Since the data for both the Location Inventory and Accident Files is repeated for each route (e.g., if an accident occurs on a coinciding segment, it will be in the file once for each road that is coinciding at the point the accident occurred) and it is not for the Mileage Inventory File, different data retrieval logic would be needed, necessitating multiple seeks to retrieve characteristics data for higher numbered coinciding routes. The second problem with obtaining segment characteristics data for a higher numbered route from the lower numbered route description is that the lower and higher routes may be inventoried in different directions, resulting in an incorrect description of the coinciding roadway segment for the higher numbered route.

To overcome these problems it is necessary to extract the coinciding segment description from the lower numbered route and insert the information into the higher numbered route's data in the proper position. As initially described on a preceding page, the Coinciding Segment File (II.F2) is derived from the Location Inventory Tape (II.F1) by program II.P1. This file is then passed to program II.P3 which, in addition to its editing functions described earlier, also identifies, extracts, adjusts, and reinserts records describing the features of coinciding segments from lower numbered routes into the proper position in higher numbered routes data. This same program formats Mileage Inventory records into a tape file of disk formatted records.

Program II.P5 then loads this disk formatted Segment Characteristics File tape (II.F5) onto a Direct Access Segment Characteristics File (II.F6) and creates an accompanying Segment Characteristics Index (II.F7). [It should be noted that the same program (II.P4) is used to generate all direct access system files (II.F6, II.F16, II.F20) and their respective indexes (II.F7, II.F17, II.F21). Individual records on all input files (II.F5, II.F15, II.F19) for program II.P5 contain a common information segment from which the program (II.P5) obtains the information necessary to build the direct access files and their indexes.]

Features file preparation.

The parent file of the Features File (II.F16) is the Location Inventory Tape (II.F12). Data from the Federal Railroad Crossing Inventory File (II.F8) and the Structures Inventory File (II.F9) are used to supplement the Location Inventory Tape (II.F12) information .

The preparation of data from the Federal Railroad Crossing Inventory File (II.F8) and the Structures Inventory (II.F9) is similar. Both files are formatted and edited (II.P6, II.P7) producing output tape files (II.F10, II.F11) of disk formatted records. These records are then loaded by programs II.P8 and II.P9 onto indexed sequential files (II.F13, II.F14) in crossing number and structure number sequence respectively.

Program II.P10 then takes the Location Inventory Tape (II.F12) and processes it sequentially adding data from these Indexed Railroad Crossing (II.F13) and Structure (II.F14) files to produce a packed disk formatted Features File (II.F15). Using the Coinciding Segment Module (II.M1), all records for coinciding segments in the Features File (II.F15) except those on the lowest numbered route are flagged so they can be eliminated in analyses when appropriate (e.g., to avoid double-counting of accidents in a statewide summary).

The Features File (II.F15) is then processed by Program II.P11 to produce the Direct Access Features File (II.F16) and its Index (II.F17).

Accident file preparation.

Data from the Mileposted Accident or 05 tape (II.F18) are processed by program II.P12 to produce a packed disk formatted accident file (II.F19). Again, using the Coinciding Segment Module (II.M1), all records for coinciding segments on the Accident

File (II.F19), except those for the lowest numbered route, are flagged so they can be eliminated for analysis purposes.

Data from file II.F19 are then sorted into county, route type (numeric), route number, milepost, year and case number sequence by program II.P13 and written on file II.F20.

This Accident File (II.F20) is then formatted into a Direct Access Accident File and an index is generated for it by program II.P14.

System module preparation.

Two of the system modules are data base dependent and require updating to remain current.

Coinciding route module - T75009.

This module (II.M1 and I.P6 in the operating system flowchart) must be updated each time the system files are updated in order for it to reflect the current status of coinciding routes in the roadway system. To accomplish this, program II.P2 processes the Coinciding Segment File (II.F2) and creates COBOL source statements which are then compiled along with program cards II.C1 into the Coinciding Segment Module (II.M1).

Data description module - T74009.

This module (II.M2 and I.P4 in the operating system flowchart) must be updated when a change occurs in the record format for a file. When this module is compiled, all programs using it must be relinked to incorporate the new version.

User programs.

Several meetings were held with DOH personnel to determine specific user programs to be produced under this contract. Three programs were identified for implementation; these were 1) a "Sliding Scale" program, 2) a Features Analysis program and 3) a General Merge program. While detailed information and documentation on these programs are included in Volume II of this publication, an overview is presented below.

Sliding scale program - T77009.

This program uses a sliding scale or moving window technique to locate high accident roadway segments as defined by user input parameters. The window moves down a specified route and determines which section or sections of a predetermined minimum length have accident rates greater than the inputted cutoff level. After the segments are located, a summary of the accidents on each segment is printed. Information on each accident may also be listed.

Features analysis program - T77209.

This program analyzes accident clusters occurring on specific roadways around certain features (e.g., accidents within 50 feet of bridges on Interstate roadways). Both the roadway segment and feature type are specified by the user. A summary of accidents and/or an individual listing of accidents is available as output.

General merge program - T77409.

This program will match records from any or all of the system input files by county, route, and milepost or milepost range as specified by user-provided parameters. A merged output file as specified by the user is written. This general purpose merge program is designed to build a file of data which can then be analyzed with either a canned analysis package (e.g.,SPSS) or with a specific purpose analytical program.

## Proposed System Additions

Several additions and changes to the system have been included in the RECOMMENDATIONS section of this volume. Two of these have been studied extensively during the course of this project and are discussed in detail below:

Skid data.

As requested by the liaison committee, the possibility of adding skid data to the data system was investigated. In this investigation, HSRC staff talked with potential data users in the Traffic Engineering Branch and with Planning and Research Branch personnel who collect and maintain the data and who also will be major users of the information. Based on these discussions,HSRC formulated a proposed procedure for inclusion of this skid data in the merged system. This procedure is discussed below. However, it should be noted that this is only a proposal based on the information which could be collected at the current time. The final decision concerning the use and form of the data will be based on the DOH needs which exist when it becomes feasible to computerize the information.

One primary consideration in utilizing the skid data is where they are to physically reside within the system. Two feasible alternatives exist. The first is to create a new file containing only the skid information. The second alternative is to integrate the skid information into an existing data file.

Two problems inherent in using the first approach are: 1) more computer resources would be required for an extra file and file index, 2) an update mechanism would have to be created and coordinated with current system updates.

Because study of the second alternative indicated that it would overcome both of these problems, it appears that the most feasible procedure would be to enter the skid data into the Segment Characteristics File. As is indicated later in this section, the system has been designed to accept the data in this form.

The second major consideration is the preparation and entry of the skid data into the system. The addition of currently available skid data would take an extensive manual effort due to the difficulty in locating the various roadway segments accurately. Since new skid data are to be collected by the Planning and Research Branch in the near future, it is felt that these data should be collected in a manner conducive to utilization in this system and used instead of the old data. A tentative format for these data is listed below.

| POSITION | DESCRIPTION | VALUE |
|---|---|---|
| 1-2 | County Number | Zoned Decimal<br>Beginning with Alamance Co. "00" counties are numbered consecutively through Yancey County "99" |
| 3-7 | Route Inventoried | Zoned Decimal |
| (3) | Route type | 1 - Interstate<br>2 - US<br>3 - NC<br>4 - SR |
| (4) | Route Subtype | 0 - Regular state highway<br>1 - Alternate<br>2 - Business<br>3 - North<br>4 - South<br>5 - East<br>6 - West |

| POSITION | DESCRIPTION | VALUE |
|---|---|---|
| (5-7) | Route Number | Leading zeroes |
| (Note: | State secondary routes coded zoned decimal in | have a 4-digit route number col. 4-7.) |
| 8-11 | From Milepost | Zoned Decimal |
| 12-15 | Segment Length* | Zoned Decimal<br>Length in hundredths of mile of skid segment |
| 16-19 | To Milepost* | Zoned Decimal<br>End milepost of skid segment |
| 20 | Inventory Control | Zoned Decimal<br>Indicates the scope of this record<br>1 - Both directions of travel<br>2 - Northbound lane only<br>3 - Southbound lane only<br>4 - Eastbound lane only<br>5 - Westbound lane only |
| 21 | Surface Texture | Zoned Decimal<br>Classification based on comparison to known standard textures.<br>1 - Smooth<br>2 - Fine textured, rounded<br>3 - Fine textured, gritty<br>4 - Coarse textured, rounded<br>5 - Course textured, gritty |
| 22-24 | Skid Number | Zoned Decimal<br>3 digits, 1 decimal place |

(Reference for Skid Values: NCHRP Report #37, "Tentative Skid-Resistance Requirements for Main Rural Highways" (1967) Publ. 1541.)

*Note: Those responsible for coding these data should decide whether to code end milepost or segment length. The other should be computed.

The logic for extracting these data from the Mileage Inventory File and Placing it on the Segment Characteristics File has already been programmed into the system. This logic expects to find skid surface texture in position 86 and average skid number in positions 87-89 of the Mileage Inventory File (HWY.FPL21010). The data elements for skid information (currently containing non-stated codes) are included in the Segment Characteristics File (Record type M variables E14 and E15).

Curve, grade, and roadside hazard information.

As stated in a progress report for this project, the most important gap in existing characteristics data is the lack of curve and grade information in a usable form. While grade data exist on straight line diagrams, they have not been computerized. Usable curve data are non-existent. There have been and continue to be accident analysis requests which cannot be met because of this lack of data.

For this reason, and as instructed by the liaison committee, HSRC has taken preliminary steps toward testing the feasibility of collecting curve, grade, and roadside hazard information using an instrumented vehicle.

The vehicle would be equipped with a three-axis gyroscope which would measure vertical curvature, horizontal curvature, and superelevation. Analog output voltages proportional to the deviation from level and a given compass heading would be converted in the vehicle to digital information and outputted on magnetic tape. As the vehicle travels down a roadway, an observer with a keyboard would key information into the system about various roadside hazards such as trees or bridge abutments. These inputs would be recorded along with the distance traveled on the same digital tape. This tape would then be input to a series of computer programs which would prepare this information for use with the data currently available in the merged system.

The integration of this information into the existing system might be accomplished in two different manners. The first method would entail merging these new data into existing files. For example, the hazards, being associated with a point along a route, could be merged into the Features File (I.F3). It might also be possible to merge the curve and grade data into the existing Segment Characteristics File (I.F1). However, this would appear to require extensive redefinition of homogeneous segments. In addition, placing hazards on the Features File would probably double or triple the amount of data now in the file. While the final decision concerning how best to handle these data should be made after preliminary analysis of the type and amount of data available, a second alternative method which appears more promising at present would be the creation of three new files along with the appropriate access mechanisms. The "roadside hazard" file would be assigned a county, route, and milepost much the same as has been done on the features file and would be retrieved in the same manner. Roadside hazard records would contain information such as the type and location of hazards.

The curve and superelevation file would be characterized similarly to the Segment Characteristics File (i.e., one record would describe a curve or segment of a curve beginning at a certain county, route, and milepost and continuing for a certain length). A user program seeking to gain information would reference the file by county, route, and milepost. The program would either be provided a "curve and superelevation" record if the milepost were found to be within the arc of a curve, or a "no data" flag meaning no curve data for the point defined would be sent back. The curve and superelevation record could contain such information as "sharpness" of curve (as determined by total deviation from tangent divided by length of deviation), minimum and maximum superelevation, and other information deemed desirable by the users of the system.

The Grade File would be organized similarly to the Curve and Superelevation File in that the beginning and length of a "positive" or "negative" grade would be defined. Access would be similar to the Curve and Superelevation File also in that either of two conditions could prevail when the file is accessed. The user program accessing the file might be provided with a "grade" record, or a "no data" condition (level ground) could be returned. The "grade" record would contain such information as the degree or percent of grade as well as other data that might be desired by the users.

This information, along with the "skid number" information when merged with the already existent information on pavement, accidents, and features of the roadway should serve to provide some of the necessary information to help meet the existing analysis means.

Preliminary study of possible hardware has indicated that the instrumented vehicle concept appears feasible. However, because runs using some instrumentation have indicated the need for more accurate equipment, because the horizontal gyroscope could not be obtained prior to project termination, and because Tennessee has begun collection of curve and grade data using an instrumented vehicle, additional feasibility work should be conducted before a large scale data collection project begins.

The SYSTEM DESIGN section has described the planning and considerations involved in designing this information system as well as outlining the structure of the operational and update systems. The following section, SYSTEM IMPLEMENTATION, deals with the work that was accomplished in implementing the system.

# SYSTEM IMPLEMENTATION

## Initial Processing

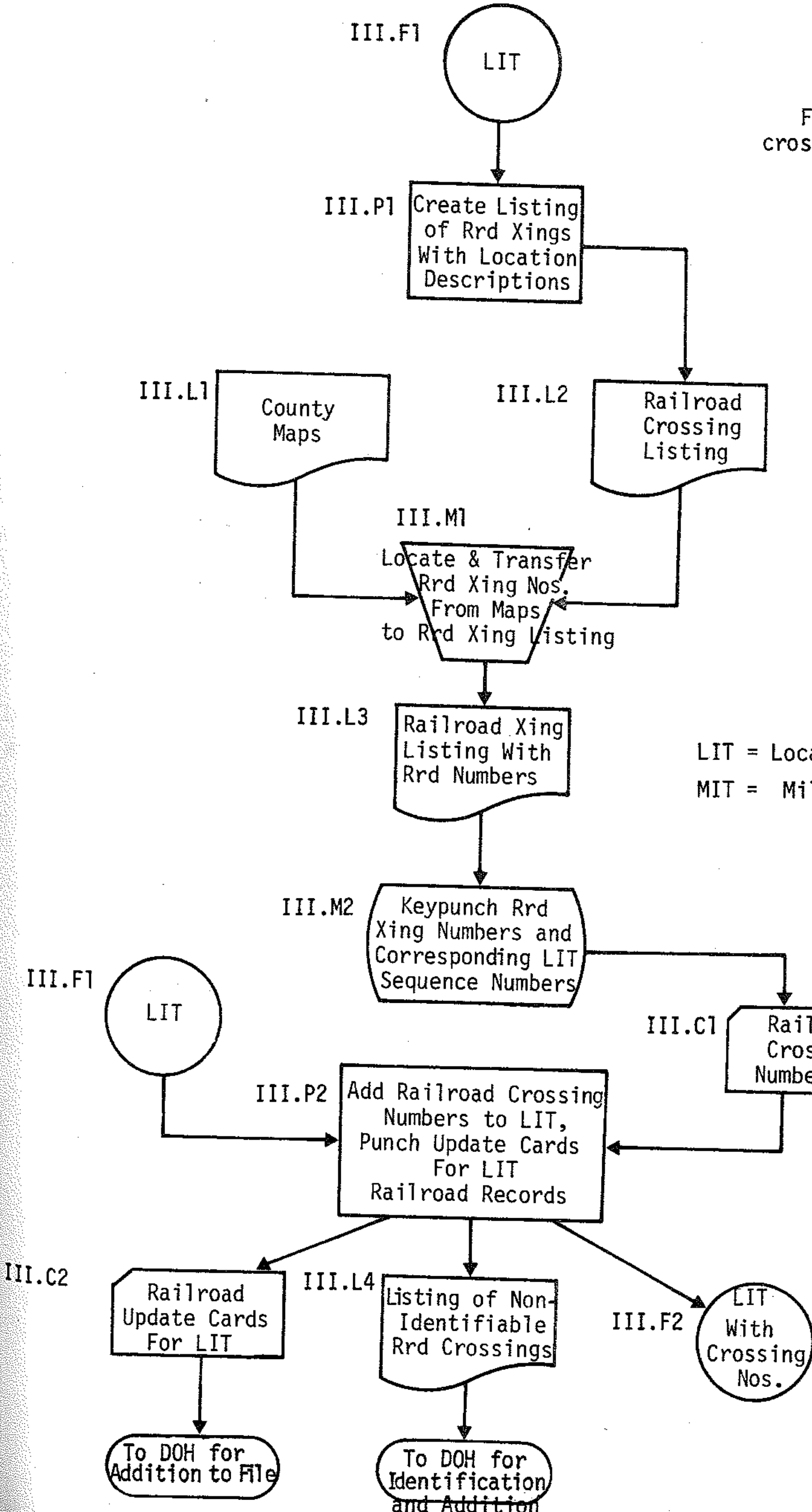
The initial phase in implementing this roadway information system consisted of 1) adding federal railroad crossing numbers to the Location Inventory Tape, 2) isolating and defining coinciding segments, 3) determining direction of mileposting for roadways containing coinciding segments, 4) reformatting and producing new Mileage Inventory common (coinciding segment) records, and 5) performing edit procedures on the Mileage and Location Inventory Tapes. The first procedure (1 above) is graphically represented as a flowchart in Figure 4.

The addition of federal railroad crossing identification numbers to the Location Inventory Tape (III.F1) required several steps. Initially, the Location Inventory Tape (III.F1) was processed by program III.P1 to produce a listing of railroad crossing (III.L2) including the sequence number of the Location Inventory railroad crossing record and location information such as distance to and description of roadway features on either side of the crossing. The railroad crossings on this listing were then identified using county maps (III.L1), and federal crossing numbers from the maps transcribed onto the listing. From this listing (III.L3), a card file (III.C1) was punched containing the federal crossing number and the sequence number of the corresponding Location Inventory railroad crossing record. In the final step, (III.P2) this card deck (III.C1) was matched to the Location Inventory Tape (III.F1) by sequence number and the federal railroad crossing identification numbers added to the Location Inventory railroad crossing records. Outputs from program III.P2 were a new Location Inventory Tape (III.F2) with federal railroad crossing numbers added, a listing of non-identifiable crossings (III.L4), and a deck of update cards to be entered into the DOH Location Inventory update system.

The remainder of the initial processing is outlined in the flowchart in Figure 5 and is explained below. Program IV.P1 processed the Location Inventory Tape (IV.F1) and produced a Coinciding Segment File (IV.F2), a listing of coinciding route errors (IV.L1), and a listing of rural primary routes described as an intersecting route but not described as an actual route in the same county (IV.L2). Both of these listings were sent to DOH for review and correction.

Figure 4.

Flowchart for adding crossing numbers to LIT.




LIT = Location Inventory Tape

MIT = Mileage Inventory Tape

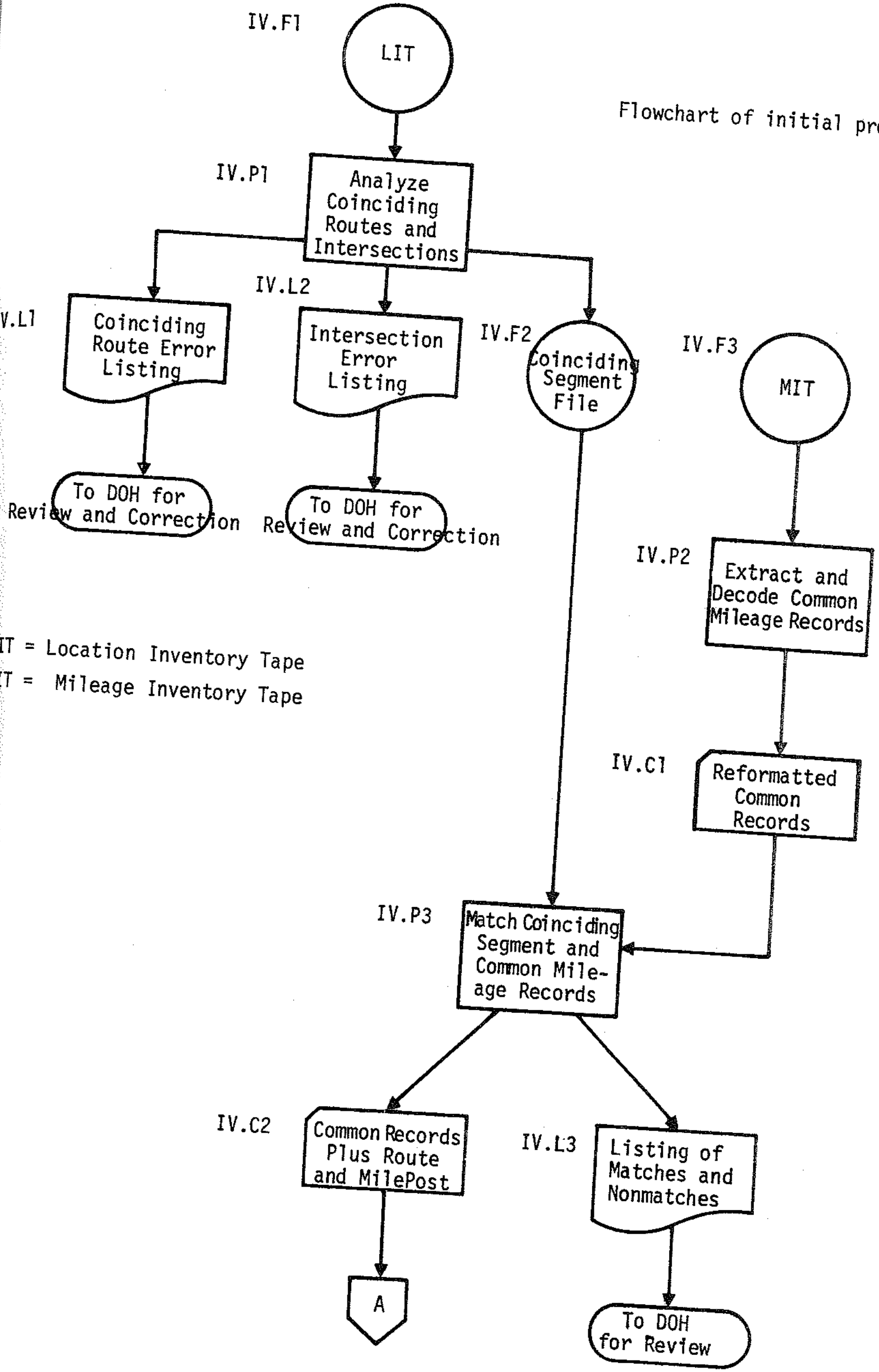



Figure 5.
Flowchart of initial processing.

LIT = Location Inventory Tape

MIT = Mileage Inventory Tape

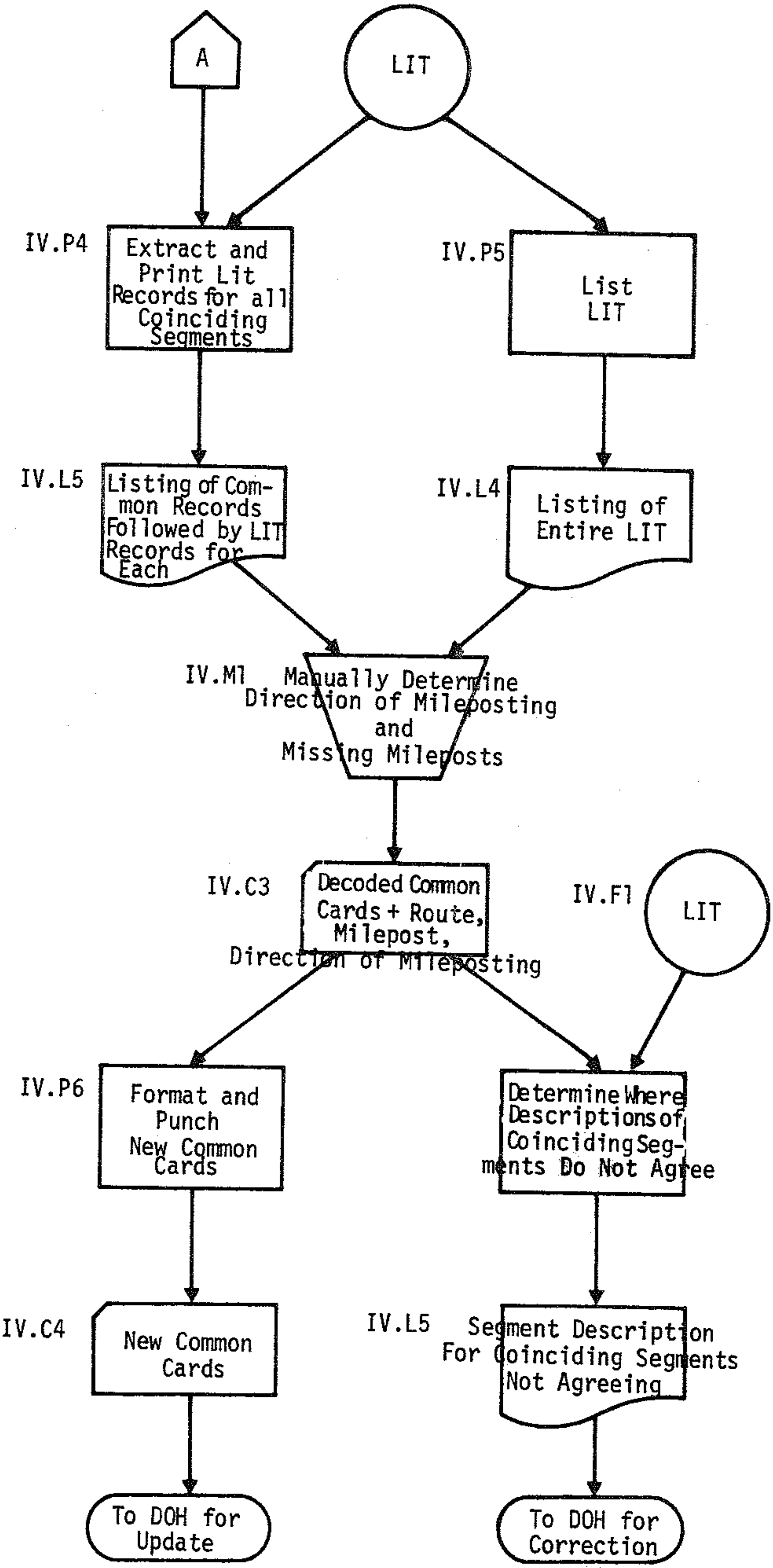
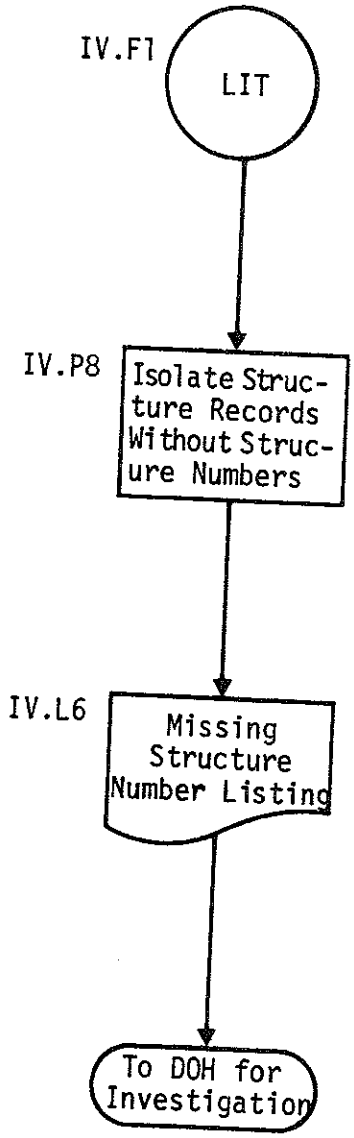



Figure 5.
(continued)

Figure 5.
(continued)



As a concurrent step, program IV.P2 selected common (coinciding segment) records from the Mileage Inventory Tape (IV.F3) and extracted the lower coinciding route identification from a freeformat field. This information was output as card deck IV.C incorporating the coinciding route identification from the freeform field into a fixed format field.

Program IV.P3 then processed this card deck (IV.C1) against the Coinciding Segment File (IV.F2) producing another card deck (IV.C2) containing all data from IV.C1 plus the beginning milepost for the corresponding lower coinciding segment. A listing (IV.L3) of the coinciding segment data from the Location and Mileage Inventory Tapes for matches and non-matches was written. This listing was forwarded to DOH for their review.

The card deck (IV.C2) of common records was then used by program IV.P4 to extract from the Location Inventory Tape (IV.F1) and list (IV.L5) the description of all coinciding segments. A listing (IV.L4) of the entire Location Inventory Tape produced by program IV.P5 was then compared manually (IV.M1) to listing IV.L5 to determine the direction of mileposting for each route having a coinciding segment. After the direction of mileposting was determined it was manually added to the common records in card deck IV.C2 producing card deck IV.C3. Program IV.P6 reformatted IV.C3 into a card deck (IV.C4) of new common records in the proper form for use as update records in the DOH Mileage Inventory Tape update cycle. Card deck IV.C3 was also processed against the Location Inventory Tape by program (IV.P7) to determine where the features of corresponding coinciding segments do not agree. A listing (IV.L5) of these discrepancies was forwarded to DOH for review and correction.

Finally, structure records on the Location Inventory Tape (IV.F1) were examined by program IV.P8 and those not having a structure number were listed (IV.L6) and forwarded to DOH for examination and correction.

The initial processing mentioned above contained several steps which are not necessary in the yearly update process. Also, some of the data editing procedures used initially were refined and improved through testing on the actual files. These improvements were incorporated into the yearly update system.

Functional Systems

After the initial processing was completed, the update and operational systems were programmed, tested, debugged and implemented on the Triangle Universities Computation Center (TUCC) computer system. Using the data and program modules available in the operational system, the User Programs described in the SYSTEM DESIGN section were implemented at TUCC.

After all systems had been successfully tested at TUCC, the entire package was loaded onto the Department of Transportation computer system and tested. Detailed documentation (Volume II) was prepared and discussed with DOH data processing personnel. Consultation has been and will continue to be provided as necessary to insure a smooth transition to utilization of this system on the DOT computer.

# RECOMMENDATIONS

Several recommendations and system improvements were and are being made within the existing DOH system. Other problems requiring an effort beyond the scope of this project have become apparent during the course of this project's execution.

## Accident Data

While studying the available data sources, accident data items available only on the HSRC Research Accident File (e.g., occupant restraint and injury for each seating position) had to be eliminated from consideration due to the time-lag in obtaining these data. This delay in being able to obtain the enriched accident data is due to the fact that supplemental data, although a standard part of the accident report, are prepared separately from the remainder of the data.

A second problem with the accident data are existing inaccuracies in the location information provided by the investigating officer. Since the linkage of accidents to roadway features is totally dependent upon the accuracy of accident mileposting, it is extremely important that the location information gathered by accident investigators be correct. A related problem is that under current operating procedures, these errors are not detected until all accident data has been computerized -- weeks after an accident occurs. Because of this delay in detection, no corrective action is feasible.

Two possible solutions are recommended. First, because the police agencies who investigate accidents must improve their training and reporting procedures, it is recommended that Traffic Engineering use whatever means it can to inform the police agencies of the importance of their work and to obtain assurances from them that they will upgrade their methods. [This recommended course of action has recently been undertaken by Traffic Engineering in meetings with the North Carolina State Highway Patrol concerning location data and through presentations made in a series of statewide traffic records workshops involving local police.]

A second possible solution would involve "front end" accident data edits (both manual and computerized) in which location information would be checked for obvious errors as soon as it reaches the Division of Motor Vehicles, just as other data items are currently checked. The report in error (or a copy of the report) could then be returned to the investigating officer for correction through his superior officer. Similar data checks could be made at the same time on such variables as accident type.

The problems mentioned above and others could be most effectively dealt with by changes to the basic accident data collection and preparation system now in operation in the Department of Transportation. To effectuate the necessary changes an extensive analysis of the requirements and a major computer programming effort would be required.

## Additional Data Collection

While studying the roadway characteristics data available for use with this new system, it became apparent that no adequately reliable source of curve and grade data exist. These items would be of great value in the analysis of accident roadway characteristics.

A methodology for collecting curve, grade, superrelevation and roadside hazard information in a computer processable format through the utilization of an instrumented vehicle was investigated as part of this project. The results of this preliminary investigation have been noted earlier in the PROPOSED SYSTEM ADDITIONS section of this volume.

As noted earlier, two other data sets currently exist in DOH files that could be incorporated into the merged data system -- the skid inventory file and the traffic signal inventory. Both files would require rather extensive data editing and keypunching. The incorporation of skid data into the system was made at the request of the liaison committee. The proposed procedure is documented in the PROPOSED SYSTEM ADDITIONS section of the publication. The addition of traffic signal inventory data were not studied in the detail that skid data were, but still remains a possibility for future incorporation into the system.

## SUMMARY

A system has been developed which provided means for linking previously unmerged data files used by the NC Division of Highways. It is hoped that this merged data system will help meet the needs defined in the earlier sections of this report and will be a valuable planning and evaluation tool. It is noted that this system is not the final answer. It is incomplete in the sense that it is only a step in the continuing process of upgrading the Division of Highways' data systems. While recommendations have been made concerning two data sets which could be possible system additions, future use of the system will in all likelihood reveal the need for either new data sets or new techniques of merging old data sets. However, it is anticipated that the system as it now stands can aid the engineer in decisions he must make concerning program implementation.