AN INFORMATION SYSTEM DESIGN FRAMEWORK FOR STATE RAIL PLANNING

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PURPOSE

This paper describes an information system developed to support the state rail planning process, with special emphasis on the factors related to disposition of abandoned rail rights-of-way. Care has been exercised to design an information system to support rail re-use planning that is expansible to rail distributional analysis and rail management, that is compatible with information systems for other modes, and is relatable to land use information systems.

RAIL PLANNING BY STATE GOVERNMENTS

State involvement in rail planning is in part a result of concerns about drastic reductions in the nation's rail system caused by the abandonment of low density branch lines, recognition of the externalities produced by other modes, particularly trucks and a desire to minimize the overall efficiency of transport. These concerns have resulted from recent environmental legislation, threatened reductions of fuel supplies, and the threat of wholesale abandonments of rail service to many parts of the northeast and midwest.

State governmental activity in this area is very new. Basically there have been three types of causes. First, significant interest groups are in imminent danger of losing essential rail service due to bankruptcy of carriers. These range from large groups of commuters, through heavy industries in metropolitan areas, to midwestern farmers and grain elevator operators.

For instance, at this writing the Rock Island and Pacific Rail Road is being operated on a day to day basis because Texaco Oil has threatened to cut off engine fuel supplies due to fear that the line cannot pay its bills. Even if supplies are continued, Rock Island officials claim they must have $30 million by July and, eventually, a $100 million subsidy to continue operations. If the railroad stops service, 26 thousand Chicago area commuters

1,700 grain elevators, nearly 5,000 factories and 23 major utilities will be directly affected.[1] A similar situation in 17 midwestern and eastern states produced the Regional Rail Reorganization Act designed to permit the continuance and improvement of rail service on seven insolvent lines by means of a federally funded reorganization and subsidy program. A Final Systems Plan is being prepared as a basis for allocating specific lines to an appropriate operator for continued operation or to an abandoned status. An analysis of the rail network in the subject states was conducted by the U.S. Department of Transportation. The subsequent report recommended abandonment of a large number of specific unprofitable branch lines.[2]

While the immediate effects of branch line abandonment are basically local, they individually tend to cross jurisdictional boundaries and collectively to have a significant enough effect on the overall transportation system to demand solution at a higher level of government. Further, recent ameliorative action, at the federal level especially, offers a limited number of subsidies for low density or deteriorated branch lines. To qualify, the states must inventory the rail network, and nominate links which are not economically viable but which possess some significant non-economic value for funding. Finally, it seems very likely that a large scale reorganization of the rail network is eminent. Besides causing a large number of readjustments in the transportation system, other consequences will have to be planned for. A great many rights-of-way will become abandoned, providing an opportunity to create a system of recreational trails and public open space corridors. System is emphasized since all will be available within a relatively short time on a predictable basis so that each right-of-way can be compared to a large number of others and ranked according to its desirability for acquisition or development on the basis of its unique attributes in relation to all others. A balanced system of recreational trails can thus be planned and created since it seems likely that the configuration of national rail system will stabilize as a result of the coming reorganization and few opportunities for the acquisition of rights-of-way will present themselves thereafter. This opportunity is unique.[3]

In summary, the rail system is at the point of a major reorganization in much of the country. This is evident from the financial state of a large number of lines, federal legislation affecting the northeast and proposed legislation of a similar nature for other areas, pressures on the ICC to liberalize its regulatory policy, and the general malaise of the bulk of railroad carriers vis-a-vis other modes. A great deal of planning for readjustment of the transportation system will have to be done and it will have to be done in a systems context. Further, a tremendous potential resource exists in the mileage of rights-of-way which will be abandoned. States are the only units of government with wide enough jurisdiction, yet local enough accountability, to do this planning.

The exact nature of the state rail planning process which is developing is as yet unclear and will probably be variable between the states. The Wisconsin and Michigan Departments of Transportation are currently developing state rail planning processes under federal sponsorship, and their experience will likely be a prototype or at least of aid to other states.[4] For the present, it is possible to make some speculations on the nature of state level rail and re-use planning processes which the information system described here is designed to support. Based on eligibility requirements for subsidy under Title IV of the Regional Rail Reorganization Act, observations on rail-related activities of some states, guidelines for a state re-use planning process from some companion papers,[5] and some general characteristics of the transportation planning process, an information system design is proposed.

The Regional Rail Reorganization Act alluded to earlier provides subsidies for rail lines which are not economically viable, but which have substantial non-economic, importance. Eligibility for subsidy is contingent upon recommendations contained in an approved state rail transportation plan. This plan is to be prepared and administered by a designated state agency and must provide for the equitable distribution of subsidy between local and regional transportation planning authorities. Further, this state agency is given authority and administrative jurisdiction for the general regulation of rail services in the state. Importantly, rail planning is to be accomplished in the context of a coordinated and balanced transportation system to multi-modal transportation planning is required by implication. Further, plans are to contain a listing of specific lines recommended for subsidization along with a statement of goals for these lines. Specific requirements for data upon which the plan is to be based include: inventories of existing rail services and facilities, including a classification of the state's rail system by categories of the lines; a statement of present and future rail service needs; a description of the possibilities for modal substitution for rail service by line; calculations of social and environmental costs and benefits of all alternative configurations of the above; calculation of the competitive statures of the different modes, and; an analysis of possibilities for achieving economies through reorganized rail operation.[6] It should be emphasized that only states in the northeast and midwest covered by the Regional Rail Reorganization Act are affected, but is is to be expected that future federal legislation of a similar nature affecting other areas of the country will contain similar requirements. Some of the difficulties which have been experienced in the development of the Wisconsin Rail Plan have recently been described by Fuller.[7]

Some state action has taken place without federal stimulus. The legislature of the state of Iowa recently provided $3 million to upgrade branch rail lines in order to improve service to grain shippers. The lines were chosen for subsidy partially on the basis of a study conducted at Iowa State University in which the multi-modal transportation system connecting a high grain producing area with distribution centers both within and outside the state was modeled using a linear programming formulation.[8] This subsidy program provides loans to rail companies and requires repayment commitments from rail operators and/or shippers. It has proven quite successful thus far and seems likely to continue over the next several years. An expanded version of the grain shipment study which supported the initial recommendations is presently being conducted for the entire state to serve as a basis for continuance of this program.

A third source of information suggests the likely nature of the state rail right-of-way re-use planning process. It is presented in a companion paper[9] which recommends a legal and organization context for state re-use planning. Basically it calls for the establishment of a re-use planning agency and specifies a process to create and execute a right-of-way re-use plan. The re-use plan is to be based on an inventory of both abandoned and operating railroad property. It is to consider the relative advantages of possible alternative configurations of development, joint uses, and, especially, the degree of irrevocability which might be imposed by a planned re-use with regard to reconversion at some later time to rail use. Stock piling or perservation of selected lines for future use is designated as desirable where feasible. Transportation and recreation are singled out for special emphasis, but any re-use which benefits the general public is to be considered.

Plan implementation is to be accomplished by requiring that the agency designated for plan creation and implementation approve of all actions which might modify any abandoned right-of-way, and by providing the agency with the authority to exercise preferential acquisition rights over all abandoned rail properties. Finally, special powers are given to the agency for plan implementation. It must approve of all planned alterations of rights-of-way, and is to monitor development to insure that consistency with the overall re-use plan is maintained. The participation of the public and private interests throughout the process is insured by a pertinent series of procedural requirements. The agency designated to perform overall state rail planning would seem to be most appropriate for preparing and implementing the re-use plan. Since the data and capabilities required by both the rail plan and abandoned right-of-way re-use plan are basically similar, they would be best contained in the same information system.

Finally, the paper describes the current reorganization of state transportation planning and administration into single, multi-modal organizations. This new structure permits multi-modal simulation and evaluation for the first time. The importance of this development for rail and re-use planning is that methodologies for estimating demand and simulating various levels of multi-modal supply for transportation services are coming into existence. These sorts of methodologies will make comprehensive transportation planning possible for the first time.

In summary, the state rail planning process will have a very broad scope. The rail network will be considered in the context of a multi-modal transportation process which will, in turn, be related to the requirements expressed in state and regional land use plans. Plan development will require a fairly close analysis of the medium to long-range transport system in states. The general demand for this sort of transport will have to be related to supply for present and for predicted needs, and the consequences of decreases in supply — i.e., abandonment of links — must be predictable. The development of plans for optimization of transport efficiency among the modes will require a capability for network analysis on the supply side, and a means for identifying and relating demand — goods and services to be moved in this case.[10] The needs for planning for abandoned links are similar. Since a large number of these potential recreation sites will become available in a short period of time, they should be considered in a systems context with their relation to centers of demand (population) being highly significant. Also they should be considered in the context of appropriate governmental land use and recreation plans. The general requirements for a supporting information system are fairly clear-cut. It should facilitate planning in a systems rather than a link-by-link context. Spatial attributes of the rail transportation net are very important elements both for analysis of the rail system and for relating demand to supply in a spatial context. Since other transport and socio-economic factors must be considered, the system should be very flexible with regard to the addition of other networks and point and area files of data. Ideally, this would be accomplished by making the rail information system one element of a comprehensive statewide land-use and transportation information system.

Finally, it must be recognized that state rail planning is in its infancy. Neither overall goals nor specific operational information needs have yet been described. For that reason the basic unit of observation of the rail network should be flexibly defined to fit changing and developing applications. The listing of attributes for each link should be similarly flexible. Thus the file structure for storage of data about the rail network should be open ended with regard to adding attributes and dividing or combining links.

INFORMATION SYSTEMS

The information system described herein is designed to support the state rail and re-use planning processes generally described above. Some general considerations relating to its design are described first, followed by a general description of the system design. Finally the technical description of the implementation process and examples of some test applications are provided.

This discussion is intended to set forth a framework within which an information system for state rail planning can be designed. It should be recognized that the environment, both with regard to the rail configuration and the existence of other related information systems, is quite variable between the states, so adjustments to meet the dictates of particular situations will be required. It is the purpose of this section to introduce some fundamental concepts related to information systems design.

In the systems analysis context the rail transport planning process must be defined as a sub-system within the overall state planning and management functions. The sub-system elements and interfaces with other sub-systems comprising these planning and management functions must therefore be made explicit. Although many of the data requirements for rail planning are common to and inseparable from data needs for broader transportation planning and management functions, differences in the scope of objectives of different subsystems may prevent joint utilization of a single system for multiple purposes. The major problem in combining information systems for these functions is that the emphases of these two activities differ considerably. A system designed for management and operations has certain real time data needs of an aspatial nature, while an information system for rail or other sectoral planning requires greater locational specificity, less detailed data, and does not require frequent updating. While these differences do not preclude adoption of a joint system, designers should be aware that slight incompatibilities between the two types of data needs can result in severe problems when magnified in a system with numerous entries. However the commonality of data requirements between rail and re-use planning is sufficiently strong to warrant the development of joint systems where these inconsistencies can be eliminated. Also, it should be noted that a rail transportation information system will not, in general, be capable of generating sufficient information for rail management information systems.[11]

Another general issue affecting system design is a current trend toward reorganization and consolidation of government. This trend is reflected by such things as the A-95 review process, and a trend to reogranization along functional lines resulting in consolidation of previously fragmented but related agencies.[12] One consequence of this reorganization that is of particular importance for state rail planning is that the development of multi-purpose statewide planning information systems is eminent. The result will be the creation of hugh data banks created partially to reduce costs of data acquisition and storage and retrieval, and partially to make the hugh amount of data previously collected and stored in incompatible form by a large number of incompatible agencies more accessible. These new data banks will create a hugh potential for in-depth, novel applications such as the comprehensive statewide planning process described earlier. These systems may be developed under federal guidelines, so if all state systems are compatible and inter-connected a great deal of potential for regional and federal planning may be realized in the long-run. It is thus essential to plan for consistency both within and between state systems.

This does not necessarily require that all state systems be the same. Rather data should be obtained in compatible formats and be capable of aggregation to comparable areal units in comparable form. For instance land use classification designations should be similar — at least at the more aggregate levels, and areas to which aggregations are made, e.g., MCD's or watersheds, should be compatible between states. For the present application little difficulty should be expected in making information systems for different modes compatible, particularly where they are organized in a state Department of Transportation. Implementation of a rail planning information system will require representation of transportation networks in forms compatible with the state land use inventory. Transportation networks and land use inventories both require locational control for data and rely on developments in geographical data systems. These systems are distinguished from more conventional information retrieval systems by the need for spatial identification orgeographical referencing of data observations. Data about land use or land resources are initially represented in two dimensional form on maps. These include various public and private facilities, housing, roads, streams, etc., which represent the supply side for human, social, economic, and political needs. Similarly, the composition and distribution of population constitutes the demand side. An important aspect of planning is represented by the spatial configuration of supply and demand for various facilities and services. Consequently, a wide variety of such phenomena must be recorded as geographically referenced data in a planning information system.[13]

All geographic data may be represented as a combination of points, lines, and areas. Points can reference phenomena such as homes, or events such as traffic accidents. Lines represent such features as roads, railroads and streams. Vegetation types, land uses and political jurisdictions etc., are represented as areas or polygons. There are three main techniques for converting map images to computer compatible form. An arbitrary grid can be placed over a particular source map and the appropriate attribute assigned to each cell by recording its presence or absence. This data can then be punched onto EDP cards and the resulting digital file can then be stored and manipulated using matrix techniques. Alternatively the X,Y coordinates of centroids of homogeneous areas, lines, or simply the location of points can be digitized and the resulting file analyzed. Lastly, the X,Y coordinates of points on polygon boundaries can be converted to digital form and stored to provide descriptions of areas. The grid method has proven to be a particularly efficient for storing data and for later analysis. Coding in this form is very labor intensive and highly tedious. Also, maps made from grid files require grid cell approximations of lines and patterns.

Centroid coding is useful where data are for sample points or are to be aggregated to fairly small areas in comparison to the region to be mapped, where the areal extent is of lesser importance than the juxtaposition of values at those points.

Digital polygon encoding produces more cartographically accurate maps, but files produced in this manner are much more difficult to process in the computer. Digitizing requirements are more extensive and the associated technology is rather new and unproved, but can be expected to improve rapidly — particularly when the market expands as information systems proliferate.[14] In order to demonstrate the state rail planning information system developed for this project a system capable of storing and manipulating area, point and line data was used.

The Planning Land Use System (PLUS) developed by Michael Goodchild at Western Ontario University, is currently being made operational at the University of Iowa. It is felt to combine all the desirable capabilities required for statewide land use planning. PLUS is basically a hybrid system which accepts digitized point, line or area files and can convert them to a grid structure for analytic manipulations where desired. The process is illustrated in Figure 1 which shows the steps involved in processing the source document -- in this case a map of Iowa's rail net. The first step is to convert the rail configuration to sequences of line segments in machine readable form by digitizing X,Y (state plane or UTM) coordinates of end-points and points of inflection. In this case, the source document is digitized by tracing the rail network with a point digitizer, coding end points and points of inflection along each rail line between junctions of rail lines. Next, polygons defined by a bounded set of rail links are assigned an arbitrary number which is recorded along with the X,Y coordinates of a point inside that polygon. The produce of this process is thus two sets of punch cards: one containing a string of coordinates for each link in the rail network; and the second containing coordinates and a unique identifier for each arbitrary polygon. Next, the data are processed through a program, POLYSORT, which reconstructs the original image in the computer, then combines center identifiers and coordinates with line coordinates to produce a file consisting of a unique identifier — the left and right polygon numbers — and an X,Y coordinate string for each line segment (or link) in a manner similar to the DIME files produced by the U.S. Census.[15] This structure greatly facilitates editing and subsequent operations with the file. At this point the file can be plotted and/or the

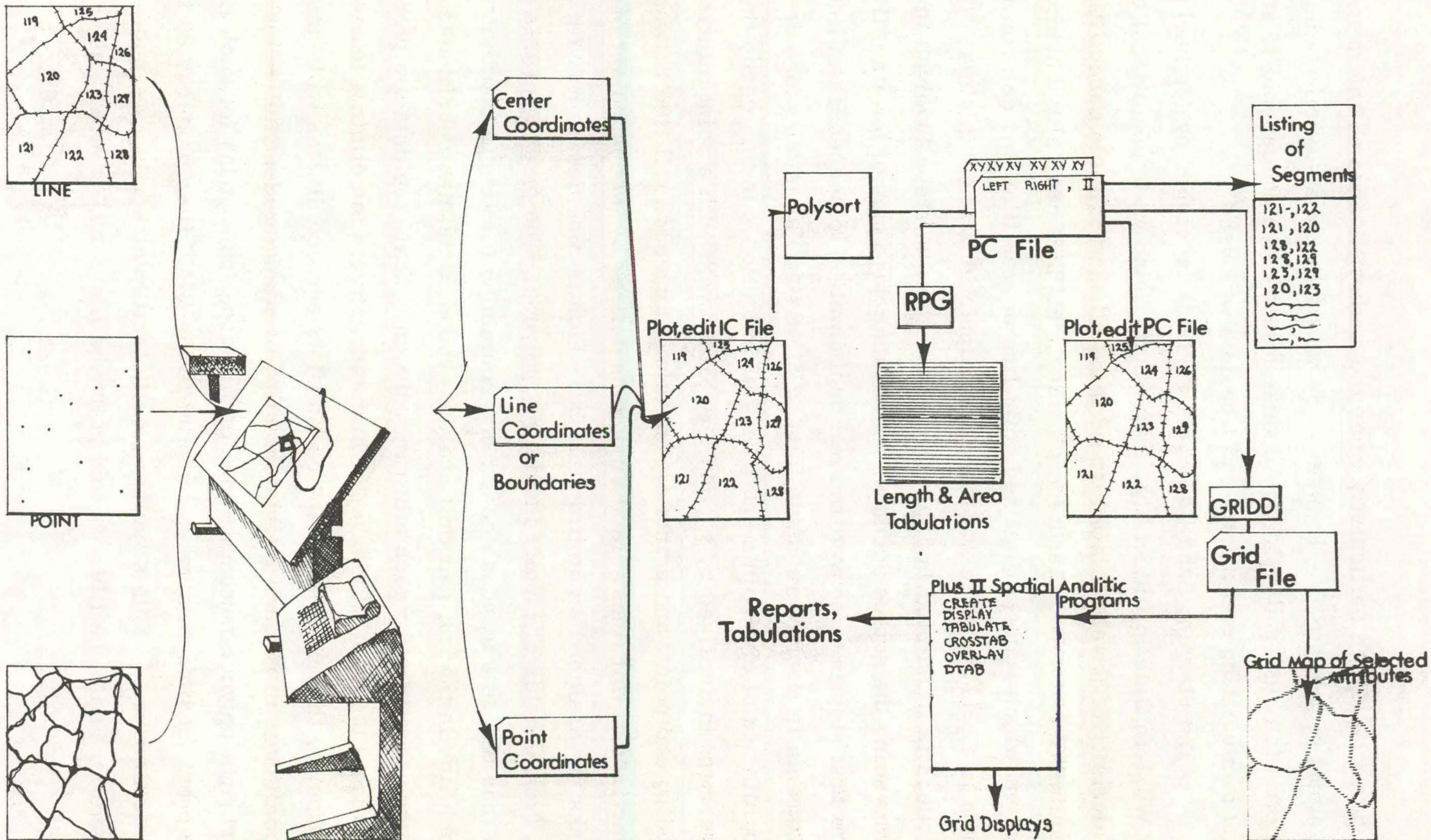
LINE
POINT
POLYGON
Center Coordinates
Line Coordinates or Boundaries
Point Coordinates
Plot,edit IC File
Polysort
XYXYXY XY XY XY
LEFT RIGHT , II
PC File
RPG
Length & Area Tabulations
Plot,edit PC File
Listing of Segments
121,122
121,120
128,122
128,129
123,129
120,123
GRIDD
Grid File
Plus II Spatial Analitic Programs
CREATE
DISPLAY
TABULATE
CROSSTAB
OVERLAY
DTAB
Reports, Tabulations
Grid Displays
Grid Map of Selected Attributes

Figure 1.

areas or lengths of desired features measured. If further analysis, including overlay on "demand" type files, is desired another program — GRIDD — is available to convert the file from a polygon to a grid format. The gridded file is suitable for manipulation with the PLUS II package or for output as a map on the conventional line printer. Figure 2 shows the relationship between the various programs in the package and the analytic package in more detail. In the grid file structure railroads and other linear features are handled as a sequence of cells for analysis. The amount of aggregation of data within cells is determined by the size of the grid network in relation to the size of the study area. Both can be varied as desired through the use of programs WINDOW and POLYSORT. This is a fairly unique capability of PLUS, since most operational systems which use the grid format for analysis encode data at a single level or resolution (ratio of grid cell size to size of the area being studied). Since PLUS retains the original digitized image as a PC file (see Figure 1), resolution is limited only by the exactness of the source map.

Perhaps the most desirable feature of this system — or any system supporting planning — is simplicity of use. While the creation of files of map data necessarily requires a fairly high level of skills and facilities, their use is extremely simple and straight forward. Given a set of "clean" files, any planner can perform analyses and displays with PLUS II. The program package uses the BASIC computer language which is simple to use and "prompts" the user by suggesting the next question to be asked. Finally, an inexpensive typewriter type or Cathode Ray Tube (CRT) terminal can be connected with the central computer by phone lines so that the central data bank can be independently and inexpensively accessible to any user. Reliance on technical personnel for performing analyses is thus eliminated.

A more detailed description of the functions and capabilities of the PLUS program is provided in Appendix I. Additional documentation for the system is available.[16]

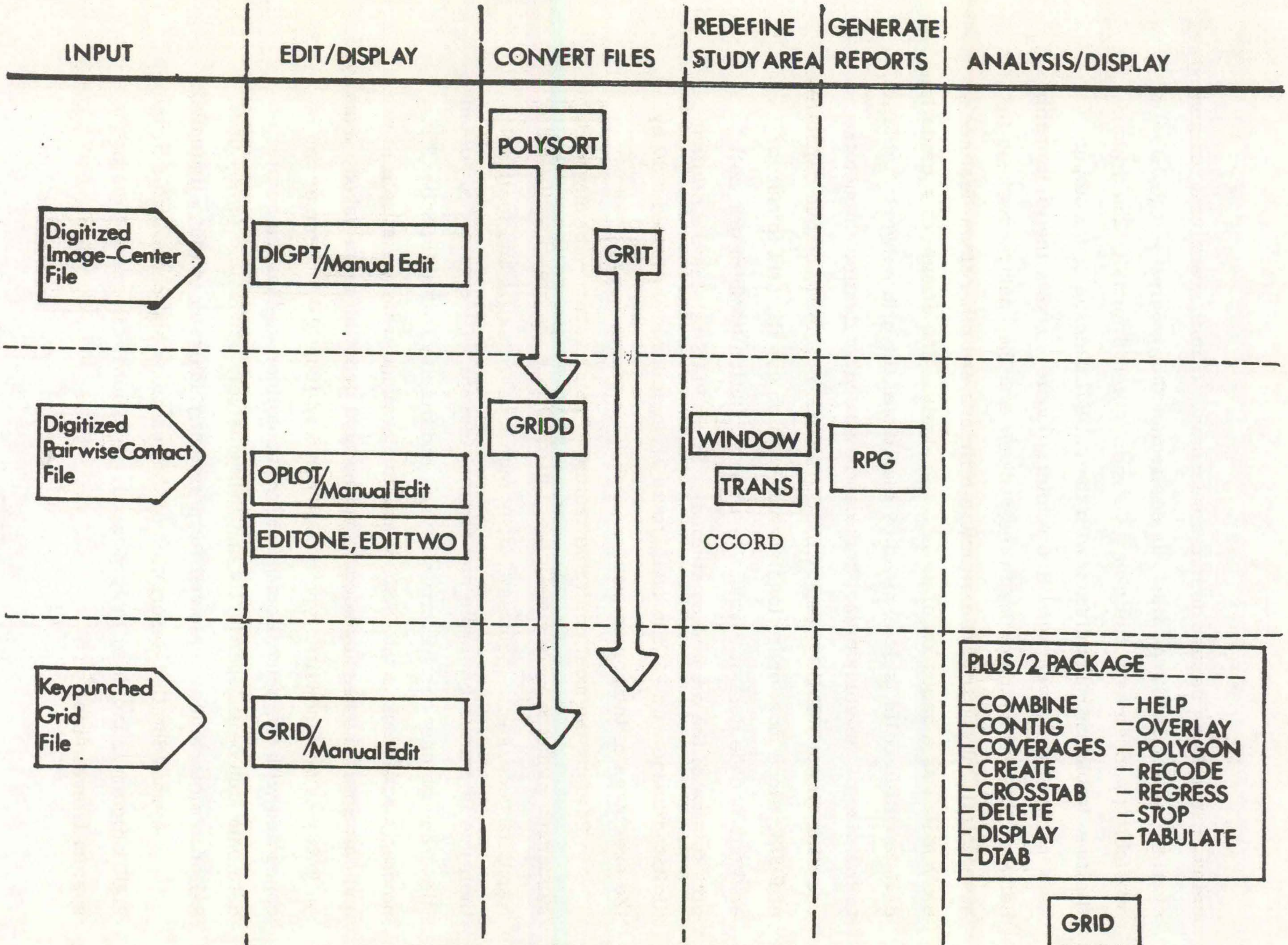

FIGURE 2 THE PROGRAM PACKAGE

TECHNICAL DESCRIPTION

Since it is highly desirable that rail and right-of-way re-use planning activities will be part of an overall rail planning system, which in turn will be related to an overall state transportation and land-use planning and management process it was decided to assume that re-use related analysis will be one sub-function, of an overall state geographic information system. For that reason, a two layered file structure was adopted. It is illustrated in Figures 3 and 4. A general rail file is visualized as being one of several potential master modal files. It contains a number of attributes of general relevance for mail and transportation related planning. These attributes are described for each link, abandoned or operating, in the state rail net. Additionally, pointers are coded to sub-files — e.g., abandonment. These sub-files may or may not have been compiled depending on the status of particular links. Sub-files are similarly structured, consisting of a listing of attributes by link (see Tables 1 and 2). The master rail file would contain general data while sub-files would contain specific data performing to specific planning or managment needs. In addition to more detailed data links could be sub-divided in sub-files if some attribute were not uniform throughout the link or if attributes such as the location of shippers, bridges, or county boundaries would be designed as end points of links, rather than junctions of rail lines.

The geographic base file described here was prepared from a 1968 U.S. Geological Survey Iowa Base Map (1:500,000). Rail lines in operation at that time are shown on the map. It was compared with the most recent version of the Iowa Rail Map, produced annually by the Iowa Commerce Commission as a supplement to its annual report, for accuracy and currency. Abandoned lines were identified and located on the base map by comparison with a 1918 U.S.G.S. geological map of the state which also showed rail lines. It was assumed that all lines in the state were constructed prior to 1918 and that any lines present on the old map and absent on the new one are presently

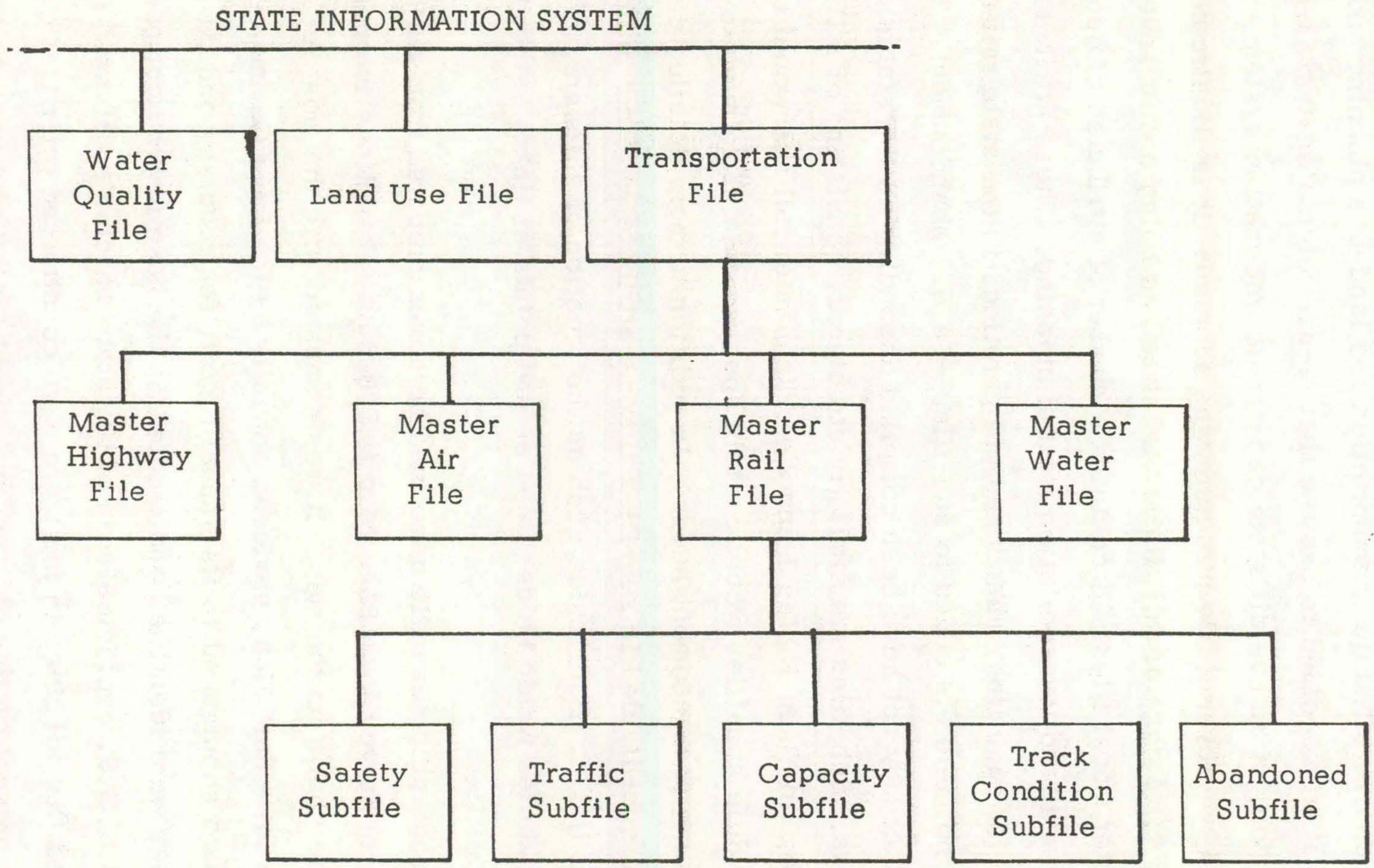
STATE INFORMATION SYSTEM
Water Quality File
Land Use File
Transportation File
Master Highway File
Master Air File
Master Rail File
Master Water File
Safety Subfile
Traffic Subfile
Capacity Subfile
Track Condition Subfile
Abandoned Subfile

Figure 3

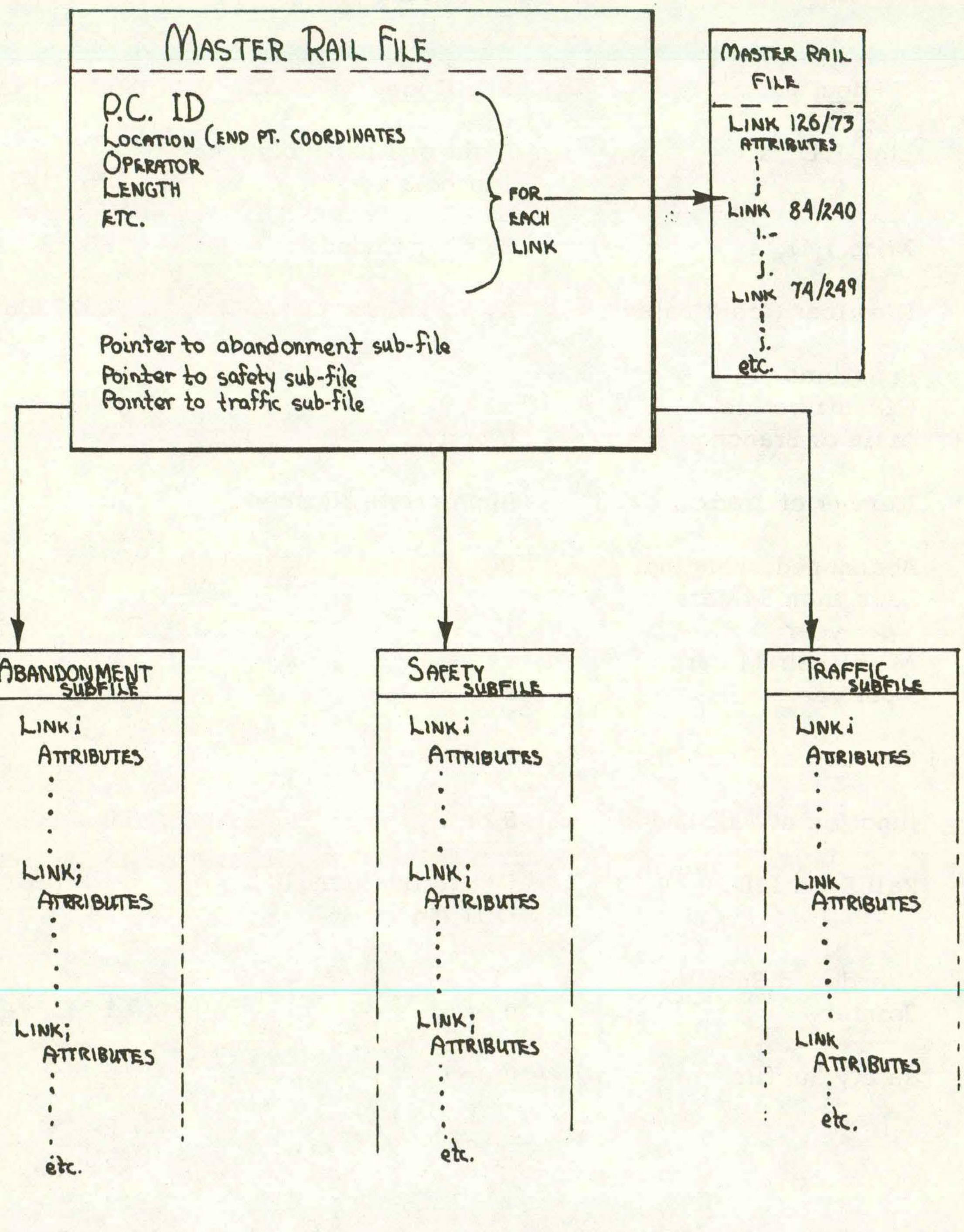
MASTER RAIL FILE
P.C. ID
LOCATION (END PT. COORDINATES
OPERATOR
LENGTH
ETC.
FOR EACH LINK
Pointer to abandonment sub-file
Pointer to safety sub-file
Pointer to traffic sub-file
MASTER RAIL FILE
LINK 126/73
ATTRIBUTES
LINK 84/240
LINK 74/249
etc.
ABANDONMENT SUBFILE
LINK i
ATTRIBUTES
LINK j
ATTRIBUTES
etc.
SAFETY SUBFILE
TRAFFIC SUBFILE

Figure 4

Table 1

Master Rail File Data

Item	Code	Example
Link I.D.'s	Right and Left Polygon Numbers	26, 143
Node I.D.'s	Number Coded	83, 9
Digitizer Coordinates	X, Y, Points	46773089524677906210
Functional Classification Main or Branch	0 or 1	0
Number of Tracks	Appropriate Number	2
Abandoned, Pending,	0	
Less than 34 cars per year	1	
More than 34 cars per year	2	3
Junction at Head End	0 or 1	1
Junction at Tail End	0 or 1	0
Rail Road I.D.	Digitizing using U.S. DOT Code	14
Abandoned Subfile Pointer	0 or 1	1
Safety Subfile	0 or 1	0

Table 2

Abandonment Sub-file Data

Item	Code	Example
Link I.D.'s	Right and Left Polygon Numbers	26,143
Accessibility	Number of points where link crossed big paved road or impaired road within two miles of paved road	6
Roadbed Condition	Good (3), Fiar (2), Poor (1)	2
Within Recreation Corridor?	Yes (1) No (0)	0
Recreation Potential	High (3), Medium (2), Low (1)	2
Ownership	Rial Line (0), Single (2), Multiple (3)	2
Width of Right-of-Way	Feet	80
Scenic Quality	High (3), Medium (2), Low (1)	2

abandoned. A further check on the completeness and accuracy of lists of abandoned lines could be made by checking annual reports or other documents produced by the agency which serves as the particular states representative to the Interstate Commerce Commission rail abandonment hearings.

The first entry in the master file consists of a numerical identifier for each link, and its digitizer coordinates. The identifier for each link is unique, consisting of the right and left hand polygon numbers assigned during coding. Spur lines are also uniquely identified in this manner since left and right identifiers consist of the same number. In only one case does more than one spur line occupy a polygon (see Figure 5). An additional file was created to include the intersections of links. Arbitrary numbers were simply assigned to each intersection and its coordinates and emanating link identifiers were recorded (see Figure 3). Next the file was plotted and edited. Finally it was reformatted, using the GRIDD program, from a polygon format to a grid format.

Both lines and points must be converted to polygons to be compatible with GRIDD. This is done by adding another set of X and Y coordinates to the original line or point file. These are produced by a program which reads the original coordinates, then adds a small increment — one point for lines, two points for points — type data, then processing as an area file.

The first entry in each master file consists of a numerical identifier derived from arbitrary numbers assigned to each polygon defined by the rail network during map preparation, followed by the digital coordinates of representative points along the line produced during the digitizing operation described previously. The numbers at segment end points — similarly assigned during map preparation — were also coded. Figure 3 illustrates the link identifier assignment process. Each link in the state rail network was thus uniquely identified and geometrically described.

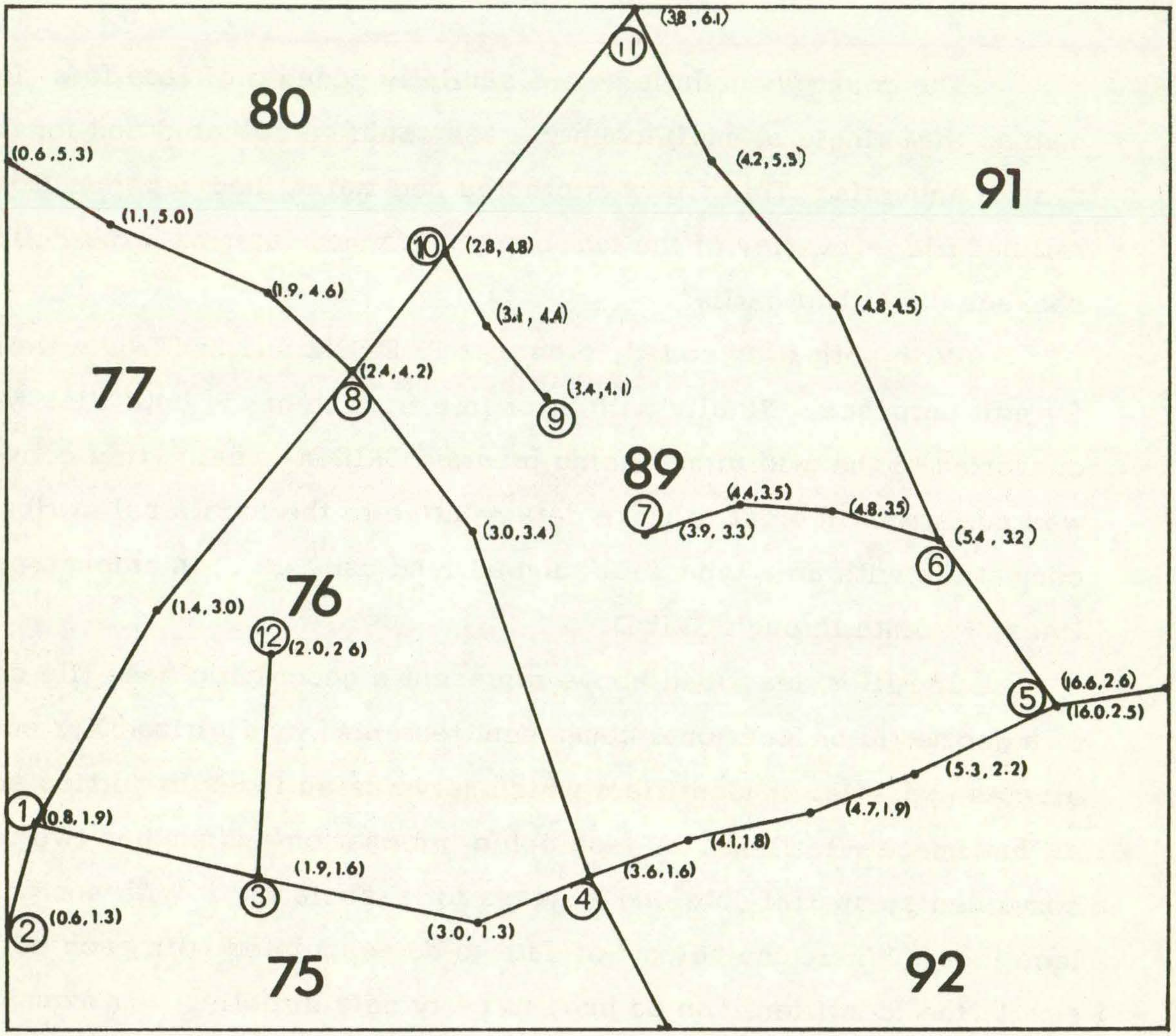

Figure 5. Link Identifiers, Junction Identifiers and Spur Identifiers

Circled numbers are junction identifiers. Large numbers are polygon identifiers from which link identifiers are derived, e.g., the link beginning at 1 and terminating at 8 is coded 76,77. Its full identification includes the digitized coordinates which define the link and its junction identifiers thus 76,77 (0.8, 1.9) (1.4, 3.0) (2.4, 4.2): 1,8.

Spur 3,12 would be identified as 76,76 (1.9, 1.6) (2.0, 2.8) 3,12. Both 9,10 and 7,6 would be coded 89,89, but one would be 89,89 (3.4, 3.3) (4.4, 3.5) (4.8, 3.4) (5.4, 3.2) 7,6 while the other would be represented by 89,89 (3.4, 4.1) (3.1, 4.4) (2.8, 4.8) 9,10.

The county boundaries were similarly coded digitized from the base map so that single or multi-county areas could be selected and for rail system analysis. This file was created and maintained separate from the rail net file — overlay of the two being performed later with the PLUS II package described earlier.

With both files coded, programs EDITONE and EDITWO were run for edit purposes. Finally with error free files in hand, both files were converted to the grid format using program GRIDD. Again, this conversion was performed in order to make data relative to the locational attributes compatible with area type data such as land use, etc., in order to process lines or points through GRIDD.

The files described above represent a geographic base file consisting of a geometric or locational component reprented by digitized X,Y coordinates and a set of identifiers which serve as an index to particular parts of that image - to links. A geographic information system has two principal components, spatial data and a means for associating it with appropriate locations. Where the volume of data to be associated with each point is small, the identifiers can be used to carry data directly. For example, land use mapping typically involves using a two or more digit code to classify parcels of land. These codes are typically carried as both the descriptor and identifier in the computer record. When the amount of information to be carried for each parcel is small and the number of parcels relatively large, attachment of small quantities of data directly to the geographic base file is efficient since any form of file search or analysis necessarily requires processing the entire data set to no additional costs or complexities result. This means of relating location and description becomes unsuitable as the volume of data to be carried becomes large — perhaps more than three computer words — or where a complicated data file structure is necessary. For rail planning and possible management purposes, the data base structure could become very complex since a large number of links are to be described and specialized needs may require further subdivision of links into segments making the creation of a new set of descriptor files referred to the geographic base file necessary. Also, the amount of description for each link could become quite large, thus requiring a lengthy file. Finally, some items might not be described for all lines due to differences in abandonment status, traffic and the like. The string of descriptors might then be spotty with a few items coded and a large number left blank.

The combination of the above factors makes inclusion of descriptive data as part of the geographic base file very cumbersome. For that reason separate records were created for the geographic base file, master file and abandonment sub-file. The location identifier in the geographic base file serves as the index to the other files. Figure 4 shows the relationship between the files. All three files can be stored temporarily or permanently on a disc so queries can be made interactively or quickly where PLUS II or other analytic programs are to be applied.

At this stage two file types are available: a grid image file and; the master rail and abandonment descriptor files. In order to perform analysis, it is necessary to search the descriptor file for links possessing selected attributes. This process produces a listing of identifiers from which the appropriate links in the gridded image file can be called up for analysis.

The fact that the analytic methodologies produced in the course of the overall research program were developed concurrent with the information system precluded direct utilization of the spatial analytic capabilities of PLUS. A number of such operations are possible. Generally, any application requiring the measurement of distances between two or more points is greatly facilitated, e.g., comparing a number of abandoned rights-of-way with regard to their distances from population centers in the context of their other attributes such as scenic quality and development costs as part of a trail system planning process. The files could also be used for network flow analysis, relating demand and supply for transportation. The authors anticipate further research in this area.

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7. Fuller, J.W., op. cit.

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10. See Swerdlogg, D.C. (1971), "Developing a National Network Model of Intercity Freight Movement in the United States," Freight Traffic Models - Symposium Proceedings, Amsterdam, for a discussion of large-scale network modeling.

11. See Dueker, K.J. and Horton, F.C., "Information Needs of the Continuing Transportation Planning Process," Transportation, Elsvier, The Netherlands.

12. Mazziotti, D., op. cit.

13. Tomlinson, R.F. (ed.), (1972), Geographic Data Handling, Symposium Edition A Publication of the International Geographical Union Commission on Geographyical Data Sensing and Processing for the UNESCO/IGU Second Symposium on Geographical Information Systems, Ottawa, for a detailed treatment of the various aspects of geographic information systems.

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15. See U.S. Bureau of the Census, Census Use Study: DIME Workshop: An Interim Report, Washington, D.C., (1973) and Goodchild, M., op. cit., for more detail.

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Appendix I

PLUS PROGRAM

1. EDIT/DISPLAY

DIGPT	Input: IC File	Output: plotted map
OPLOT	Input: PC File	Output: plotted map
GRID	Input: GRID File	Output: printed map
EDITONE	Input: PC File	Output: "Cleaned" file and diagnostics.
EDITTWO	Input: PC File as output from EDITONE and instructions for changes in specific PC records	Output: "Cleaned" PC file

2. FILE CONVERSION

GRIT	Input: IC File	Output: Grid File
GRIDD	Input: PC File	Output: Grid File
POLYSORT	Input: IC File	Output: PC File

3. STUDY AREA REDEFINITION

TRANS	Input: coordinates of three locations on the "old" map, coordinates of same locations on the "new" map. Output: scale and angular displacement parameters for GRID control cards.
WINDOW	Input: PC File, coordinates of desired study area boundaries Output: File for data located within specified boundaries.

CCORD — Input: PC Files, for adjacent areas parameters to convert "old" map coordinates to "new" map coordinates.

Output: A single PC file having common scale and coordinates

4. REPORT GENERATION

RPG — Input: PC File — Output: Areal measurement of polygons

5. ANALYSIS/DISPLAY

GRID — Input: Grid File — Output: Choropleth map

PLUS/2 — Input: Grid File (NOTE: This package may be used in batch or interactive; functions are described assuming interactive use.)

Functions Available in PLUS/2

HELP - Allows the analyst to list available functions.

CREATE - Allows the anlayst to create a new coverage by entering data from terminal. This task is more onerous than one might expect, and should only be attempted if the coverage has a limited number of cells.

COVERAGES - Allows the analyst to list the coverages available to PLUS/2. This function is especially useful after new coverages have been created.

DISPLAY - Allows the analyst to display a selected coverage for visual checking. Often it is necessary to display a coverage in separate pages because of limitations of the output device.

DELETE - Allows the analyst to remove a coverage from PLUS/2 when it is no longer needed.

TABULATE -	Allows the analyst to make a tabulation of cells in a coverage by type or value.
CROSSTAB -	Allows the analyst to crosstabulate two alphanumeric coverages.
OVERLAY -	Allows the analyst to logically combine two alphanumeric coverages by assigning new symbols to each existing combination of old ones and producing a new coverage as a result.
DTAB -	Allows the analyst to tabulate a coverage by distance from a specified point.
RECODE -	Allows the analyst to recode the values or symbols in a coverage.
POLYGON -	Allows the analyst to create a coverage in which the cells lying inside a specified polygon will be assigned a specific character or number.
CONTIG -	Allows the analyst to search through a coverage and determine areas over or under a certain size. This size constraint is input by the analyst.
REGRESS -	Allows the analyst to determine the degree of relationship between numeric coverages using a regression technique. It must be noted here that although it would be possible to perform sophisticated numerical analyses within PLUS/2 such are usually best performed by program packages operated outside the PLUS system.
COMBINE -	Allows the analyst to algebraically combine two numeric coverages using a wide range of arithmetic operations.
STOP -	Allows the analyst to exit normally from the PLUS/2 system.