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Regional Computer Assisted Cartography Conferences

Summary

Regional Computer Assisted Cartography Conferences

Summary

August 1988

Sponsors:

Federal Highway Administration

Washington State Department of Transportation

Washington State Transportation Center

Pennsylvania Department of Transportation

Rural Technical Assistance Program

Computer-Assisted Mapping Conference

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Overview

In the fall of 1987, the Office of Planning of the Federal Highway Administration (FHWA) sponsored two regional Computer-Assisted Cartography Conferences in Olympia, Washington, and Harrisburg, Pennsylvania. The Washington State Department of Transportation (WSDOT) and the Pennsylvania Department of Transportation hosted these "first time" events. Their purpose was to bring together cartographers from state transportation agencies to exchange information and to learn about new technologies, techniques, and programs in the transportation cartographic field.

The discipline of cartography has been changing rapidly, from pen and paper to computers, digital databases, and geographic information systems. Through presentations, workshops, panel discussions, and demonstrations, the participants shared with each other the challenges that face the transportation cartographer today.

This conference summary contains a wide variety of information. Both conferences were events where "you had to be there," each having its own accent and flavor. This document summarizes what transpired at the meetings. Frank Cooper's position paper served as a starting point for many of the discussions. Following the Washington State conference, a technical paper on geographic information systems was commissioned by the FHWA and is included in this document.

To host two conferences of this magnitude and scope required the assistance of a large number of people. While it would be impossible to name everyone, the following people contributed substantial time and expertise to developing and conducting the conferences:

Chris Fleet, FHWA
Dr. Howard Simkowitz, FHWA
Chuck Chappel, FHWA
Tim Trainor, U. S. Census Bureau
Barry Napier, USGS
Mike Sety, USGS
Duane Berentson, WSDOT
James P. Toohey, WSDOT
Gale LaBlanc, LDOT
Dan Wyly, TXDOT
Tony Pulliam, TXDOT
Art Wagner, Pennsylvania DOT
Rhonda Brooks, TRAC
R. Brad Harvey, Weston Consultants
J. Russell, Chicago Aerial Survey
Dr. Ken Duecker, Portland State University
Dr. Tim Nyerges, University of Washington
Frank Cooper, Cooper Technologies
Barna Juhasz, FHWA
Benjamin Ramey, USGS
Richard Kleckner, USGS
Sheldon Pietenburg, USCB
Norm Baker, Iowa DOT
Gaylord Cumberledge, Pennsylvania DOT

Gerald Gingras, Vermont DOT
Charles Groves, Ohio DOT
Ike Leistikow, Pennsylvania DOT
Ray McNoldy, Pennsylvania DOT
Woody McGee, Pennsylvania DOT
Thomas Slayton, Virginia DOT
Dr. Raza Wajih, Soft Cadd, Inc.
Ron Cihon, WSDOT
Catherine Swatek, Pennsylvania DOT
Bill Pogash, Pennsylvania DOT
The Pennsylvania DOT Cartography staff and recorders

Transportation cartographers greatly benefited from this opportunity to share information. There is much to be gained by organizing future events that will continue the dialogue. The time spent learning and sharing will have a tremendous and immediate payback for those who participate. The FHWA will support future meetings but cannot finance them. We can be self-supporting. All that is needed is someone to take the lead. Please contact either of the undersigned, and we will be glad to get you started. For additional information about the 1987 conferences, contact the Federal Highway Administration; Office of Planning; 400 7th Street Southwest; Washington D.C. 20590.

Sincerely,

Paul Moody, Supervisor
Cartography Section
Washington State
Department of Transportation

Tom Perry, Manager
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8:PR&PT11

COMPUTER ASSISTED CARTOGRAPHY

BY
FRANK F. COOPER, P.E.
COOPER TECHNOLOGY

SPONSORED BY
THE FEDERAL HIGHWAY ADMINISTRATION
PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
WASHINGTON STATE DEPARTMENT OF TRANSPORTATION
RURAL TECHNICAL ASSISTANCE PROGRAM

PREFACE

The following document is a position paper prepared in conjunction with two cartographic workshops sponsored by the Federal Highway Administration (FHWA). The first of these was hosted in Harrisburg, Pennsylvania, by the Pennsylvania Department of Transportation on September 15-17, 1987. The second was hosted in Olympia, Washington, by the Washington Department of Transportation on September 22-24, 1987.

The author would like to thank the staffs of the Washington DOT, the Pennsylvania DOT, and the FHWA for their assistance and cooperation in the preparation of this paper and the hosting of the workshops. A thanks also goes to the vendors for their efforts to make these sessions a success by providing state-of-the-art demonstrations. One last thanks to the many DOT friends with whom the author has had discussions at HEEP , AASHTO, and now the two conferences. Some of those thoughts and ideas are inherent and portrayed in this paper.

The workshops provideed the DOT cartographic community with an opportunity:

* To see and discuss with vendors the latest state-of-the-art in automated cartographic equipment and/or processes.
* To discuss with their peers the various approaches to the implementation of a Geographic Information System for Transportation-Cartography (GIST-C).
* To identify common actions or viewpoints among the DOT cartographers that will assist the cartographers in advancing their contribution to the DOT.
* To establish some recommendation that will establish the continuation of the type of forum associated with these workshops on an annual basis.

A Draft Position Paper similar to that presented herein was composed to act as a starting point for the conferences. Except for Section XII, the Position Paper presented herein is a composite of that Draft and additions/modifications gathered at the two conferences. Section XII, Observations and Conclusions, represents strictly an assessment of the observations of the two conferences by the author.

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GLOSSARY

AAP --------- Arterial Analysis Package - A model for designing and evaluating arterial control for traffic networks.

AASHTO ------- American Association of State Highway and Transportation Officials

ACSM --------- American Congress of Surveying and Mapping

ADT ---------- Average Daily Traffic

Attribute --- A defined characteristic of a geographic feature.

BPR ---------- Bureau of Public Roads

CADD --------- Computer Aided Design and Drafting

CIM ---------- Computer Integrated Machinery

Computer Assisted Cartography -- A digital spatial database that can be manipulated and edited to produce map products.

CPU ---------- Central Processing Unit

Database ----- Related subject information stored as a set of files.

DLG ---------- Digital Line Graph - An internal U.S.G.S. standard for planimetric map data.

DOT ---------- Department of Transportation

FAI ---------- Federal Aide Interstate

FAP ---------- Federal Aide Primary

FHWA --------- Federal Highway Administration

FIPS --------- Federal Information Processing Standards

GIS ---------- Geographic Information System

GIST --------- A transportation oriented GIS

GIST-C ------- A GIST that uses a cartographic map as its graphics base

GIST-D ------- A GIST that uses engineering drawings as its graphics base

GKS ---------- Graphics Kernel System - An international graphics standard for allowing workstations to be more vendor independent.

GPS ---------- Global Positioning System - A navigational technology that uses satellites for obtaining a geographic position

HEEP --------- Highway Engineering Exchange Program - An organization of transportation professionals that are dedicated to the exchange of computer software and concepts.

HOST --------- The administrative computer of the DOT where existing databases are maintained.

Host --------- The central hub of a network of graphics computers.

IGES --------- Initial Graphics Exchange Specification - A specification standard for the exchange of graphic information between different vendors

ISO/OSI ------ International Standards Organization Open Systems Interconnection - An international communication standard for establishing communication between various vendor's equipment

LAN ----------	Local Area Network - A high speed physical communication link that interfaces together various computers, workstations, their peripheals, and communication equipment.
MPO ----------	Municipal Planning Organization
NETSIM -------	A simulation program for analyzing various operational scenarios on a defined traffic network
NON-SPATIAL --	An attribute of a feature that is not necessarily reflected in the graphics representation of that feature
PDES ---------	Project Data Exchange Specification - A graphics exchange specification that is primarily geared toward the machinery CAD/CAM industry.
PennDOT ------	Pennsylvania Department of Transportation
ROW ----------	Right-Of-Way
SPATIAL ------	The geographic position of a cartographic feature.
TCP/IP -------	Transport Control Protocol/ Internet Protocol
TEAMS --------	Texas Automated Mapping System - An early 1970 automated mapping effort by the Texas DOT using photogrammetry techniques
U.S.G.S.------	United States Geological Survey
UTPS ---------	Urban Transportation System - A transportation planning model that provides for methods of analysis of multimodal transportation systems
XNS ----------	Xerox Networking System - A prominent communication protocol standard

SECTION I - INTRODUCTION

The Information Age proposed to be the bedrock of the twenty-first century is increasingly affecting our society through its insertion of ever changing high technological advancements into both our personal and professional life styles. These changes greatly impact our ability to trade in international markets, organize and manage our businesses, hire an efficient work force in both number and level of education, measure productivity, and compensate employees. A visible example of this AGE is in the area of Computer Integrated Manufacturing (CIM) and its impact on society, the machinery industry, and the machinist himself. This particular technological development has subtly become a dominant force and an industry accepted tool. CIM not only automates the machining of the part, but creates the numerical control instructions that drive the tooling machine during the design stage. Thus, more precisely tooled products are produced in larger quantities with reduced labor costs. Everyday, on television or in the newspaper we see the indirect impact of these technological advancements as they relate to the loss of jobs or to the ability of America to compete in foreign markets.

Cartography is undergoing similar technological advancements in the surge of digital spatial database systems. These cartographic digital systems are commonly referred to as Geographic Information Systems (GIS). Cartography as a profession is facing the same dilemmas as other labor intensive professions. A general correlation can be made between CIM and

GIS. The drafter parallels the machinist and the cartographer the designer. The impact on the cartographic drafting task may reduce labor requirements in the private sector. However, the impact on DOTs of a GIS applied to transportation will:

* Free needed resources within the cartographic units to improve production cycles and
* Provide a whole new methodology for addressing planning and engineering data management through improved "informational" technology.

Like the designer, the cartographer will have at his finger tips the tools to virtually complete his total production tasks. Unlike the machinist, the cartographer will have come full circle with GIS providing:

* A new "Beginning",
* A challenge for the professional cartographer, and
* An opportunity to reestablish and extend the visibility of his professional station within the DOT.

GENERAL HIGHWAY MAPPING

Prior to 1935, maps for most of the 3000+ counties in the United States were either non-existent or incomplete, particularly with regard to highway planning. In 1935, through a federal government program administered by the FHWA (then called the Bureau of Public Roads), state highway planning divisions began to prepare general highway series maps. These maps were intended to display all planimetric information needed for highway planning. In addition to the county map series, state, city, and special maps were also prepared from data collected for the state highway inventories. Inventories are

updated through limited field work and supplemented by data gathered from other government agencies and the private sector.

Proceeding from these base maps, DOT cartographic units have also produced maps meeting internal department needs. In addition, many of the maps are available to the public and have evolved as a "best" source for business planning. Through the years, the maps generated by the DOTs have become recognized as among the most dependable for timely and accurate information. The public has become accustomed to the quality and availability of the maps, particularly the county map. The DOT cartographic units have also become an excellent source of information for such agencies as U.S.G.S., the Census Bureau, other state agencies, and private mapping companies.

The present status of the cartographic units within the DOTs throughout the United States is one of decreasing manpower and expertise and an increasing workload. Field data collection units are generally below minimum staff levels, thus creating longer update cycle times for standard maps. It is important to note that DOT cartographic units are service organizations. There are no products that it produces for itself but it responds to the internal needs of the Department and of the public. Few DOT resources have been allocated to automate cartographic data collection or updating tasks. The move to CADD by the DOT's to increase plan preparation and design support has provided some cartographic units with access to equipment, but exposure is generally limited to replacing drafting tasks. This situation exists not from a lack of funding, but from a lack of interest by

either the cartographer or management or the cartographers failure to convince management of the long term benefits.

THE FHWA

Throughout the past fifty years, the FHWA has provided financial and technical assistance to state highway agency mapping activities. In general, the relationship between the FHWA and the states has been a good one. The program has certainly been successful with transportation maps having some semblance of standardization available on a nationwide basis.

In 1973 the FHWA published the "Guide for a Highway Planning Map Manual". This guide suggested features to be shown on the maps, map formats, and compilation procedures in order that generally uniform mapping practices would be followed by the States. It was meant to serve as a guide for each State to prepare its own manual with criteria based on its own characteristics and needs. The guide also contained a set of standard symbols for a wide variety of features which have traditionally been included on the planning maps. While these same guidelines can be used for automated cartography, they do not take into account the added capabilities and limitations of the new technology.

Today, the FHWA has again determined that it should be influencing the mapping practices of the States. The FHWA believes that its role should be that of a disseminator of information as well as a facilitator in the exchange of state-of-the-art information on mapping. To accomplish this goal, the FHWA

has funded the Harrisburg and Olympia conferences which are designed to bring State DOT cartographers together in an environment that is conducive to the sharing of the latest technical information. The FHWA intends to publish the proceedings from this conference as a statement of consensus of the DOTs. The FHWA hopes that this information exchange will continue. However, the agency has no intention of intervening in State mapping activities beyond an assistance level.

One of the major objectives of the conference is to identify common areas of interest among the DOTs. One of these areas is obviously standardization. There are two types of standards:

* Cartographic standards that address the presentation of automated cartographic outputs.
* Data exchange standards that provide for sharing of digital spatial and non-spatial data between cartographers.

Common action by the DOTs on standardization is warranted. Automated cartographic standards may effect productivity rates and aesthetic quality. Data exchange standards will become increasingly important as the nation becomes involved in GIS and the availability of digital data is more abundant. Section VIII is dedicated to the discussion of this topic.

SUMMARY

The technological advances that supply the catalyst for the automation of cartographic operations:

* Will provide the prepared cartographer with a golden opportunity.
* Will shortly change the way engineering systems are designed.
* Will require cooperation at all government and private levels for the transfer of information because of its ever broadening scope.

The existing partnership between the States and the FHWA has provided an important service to the nation over the years in the mapping area. This relationship needs to be renewed and strengthened. The sign of the times is to automate so "one can do more with less". The automation of cartography should be an integral component of any DOT's automative efforts. Planning carefully and keeping pace with the latest technologies and methodologies will result in improving engineering management and planning.

The following Sections will address specific topics such as computer assisted cartography, implementation, GIS, the subsystems of automated cartography, standardization, micro-computer mapping, and future actions available to DOT cartographers. These topics are to act as a reference guide and provide a common ground for thought from which to begin peer-to-peer discussions.

SECTION II - COMPUTER ASSISTED CARTOGRAPHY

The automation of DOT cartographic functions has been evolving since at least 1969 when Texas began a program, TEAMS, of digitizing county maps with its stereoplotters. A complete data collection, editing, and plotting system was placed into production. However, this system did not include "interactive graphics". At that time, an acceptable cost effective "interactive graphics" system wasn't available. This "interactive graphics" system was looked upon as a supplemental system to solve the "annotation" problem by allowing interactive placement and editing of text. As CADD systems developed and improved, Michigan addressed plan sheet production while Ohio and New York led the way in linking "non-graphic" information to graphics, i.e. traffic safety to the road network. By 1982, Louisiana's CADD plan included in it the full development of an "intelligent" map based on U.S.G.S. 7.5 ' quad sheets for depicting DOT engineering management data. Today, Pennsylvania and Washington are hosting this paper's associated workshops because of their dedicated effort in this area and almost all states are at least investigating the impact that computer assisted cartography developments may have on their operations.

The purposes of this section are to identify the components that define a cartographic operation, to introduce the concept of computer assisted cartography, to describe the relationships between the existing manual operations and an automated one, and to discuss the cartographer's role in facilitating cartographic automation.

DEFINITION

> Computer assisted cartography is the integration of automated mapping processes that input to, manipulate, and edit a spatial database in order to produce map products.

Computer assisted cartography had been initially developed to simply replace manual map making processes with the creation of digital maps that can produce existing hard-copy products. This approach may provide limited drafting productivity gains but will not achieve the long range benefits of expanded capabilities from a automated cartographic system that includes non-spatial attributes. However, present development efforts are evolving to utilize of informational technology which will expand the use of cartography beyond imagination. Section IV, Geographic Information Systems, will discuss more thoroughly these developments.

CARTOGRAPHIC OPERATION COMPONENTS

There are six components that define a DOT cartographic operation. These components apply whether the operation is manual or automated and can be universally defined across all DOTs as:

* Source Documents
* Basemap Database
* Map Creation
* Map Maintenance
* Map Production
* The Cartographer

Source documents and basemap database are "thing" components. Source documents represent the inputs and the basemap database represent the "storage area" for valid cartographic information. Map creation, maintenance, production are three "end result" operations. The last component is the most important, in that, it is the cartographer himself. The cartographer provides

the interaction between the other five components and brings the all important human trait of common sense and decision making to the operation.

Figure 1 illustrates the Pennsylvania Department of Transportation Cartographic Division when performing as a manual operation. Figure 2 depicts a system overview of an automated cartographic system design that incorporates the first five of the listed components. These components translate into three subsystems that represent the automated version of their manual counterpart tasks that create, update, and produce map products. The design simulates and improves those tasks by utilizing traditional source documents, as well as, new digital sources to create and maintain a masterfile of graphic and non-graphic information. The three computer subsystems are interfaced to the source documents, master-file, and map products with the cartographer providing the interaction among all the components. A brief look at each component follows:

Source Documents

Manual: Hardcopy documents such as maps, computer listings, newspapers, etc. Table 1 depicts some typical source documents from which stable material base map masters are updated.

Automated: Same as manual plus digital sources. These sources may be internal from the DOT's host computer, other agencies, or digital data collection systems.

The major source documents will continue to be those presently being used. Source documents include both those used increating the base map data and in the update cycle.

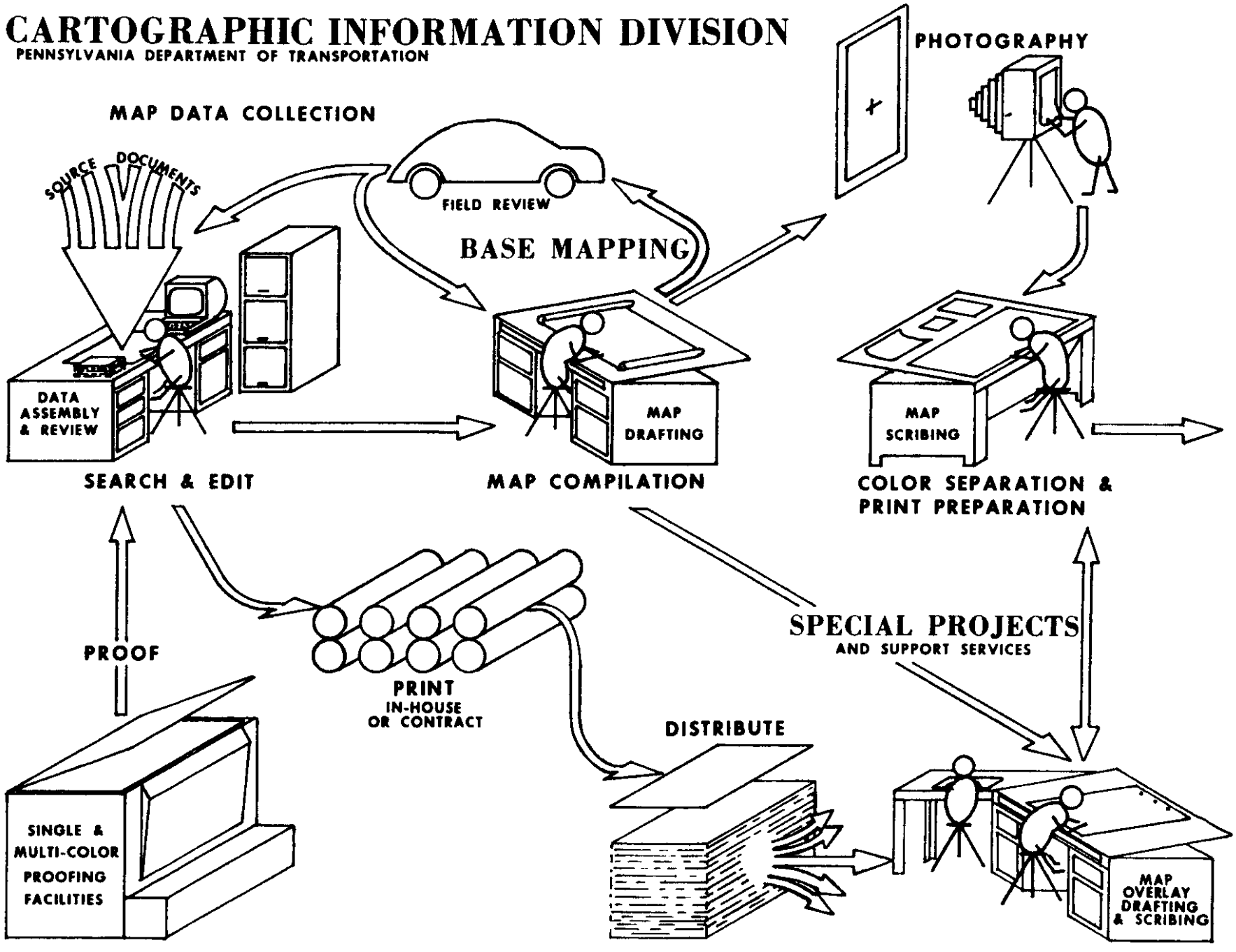

CARTOGRAPHIC INFORMATION DIVISION
PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
MAP DATA COLLECTION
SOURCE DOCUMENTS
FIELD REVIEW
BASE MAPPING
PHOTOGRAPHY
DATA ASSEMBLY & REVIEW
MAP DRAFTING
MAP SCRIBING
SEARCH & EDIT
MAP COMPILATION
COLOR SEPARATION & PRINT PREPARATION
PROOF
PRINT
IN-HOUSE OR CONTRACT
SPECIAL PROJECTS
AND SUPPORT SERVICES
DISTRIBUTE
SINGLE & MULTI-COLOR PROOFING FACILITIES
MAP OVERLAY DRAFTING & SCRIBING

FIGURE 1

Because of its importance in improving the update cycle time for reissuing a standard map product, every approach should be investigated to acquire data in digital form. One digital data source is the U.S.G.S. and its digital mapping efforts. Another major source of digital data is the existing databases on the mainframe. Surface types, bridge locations and other pertinent data exist. With proper development of the system, this information can be extracted and used in batch mode to automatically create map features, leaving normal clean-up tasks to interactive drafting procedures.

A point that needs reemphasis is the fact that additional resources need to be directed at data collection systems supporting DOT map making processes. This is an area where the use of data exchange between federal, state, and local entities as digital cartographic data standards develop across the nation. Again Table 1 is referenced as it illustrates some of the various source documents used by states to maintain their base maps and thus represent prime candidates for automation.

Basemap Database

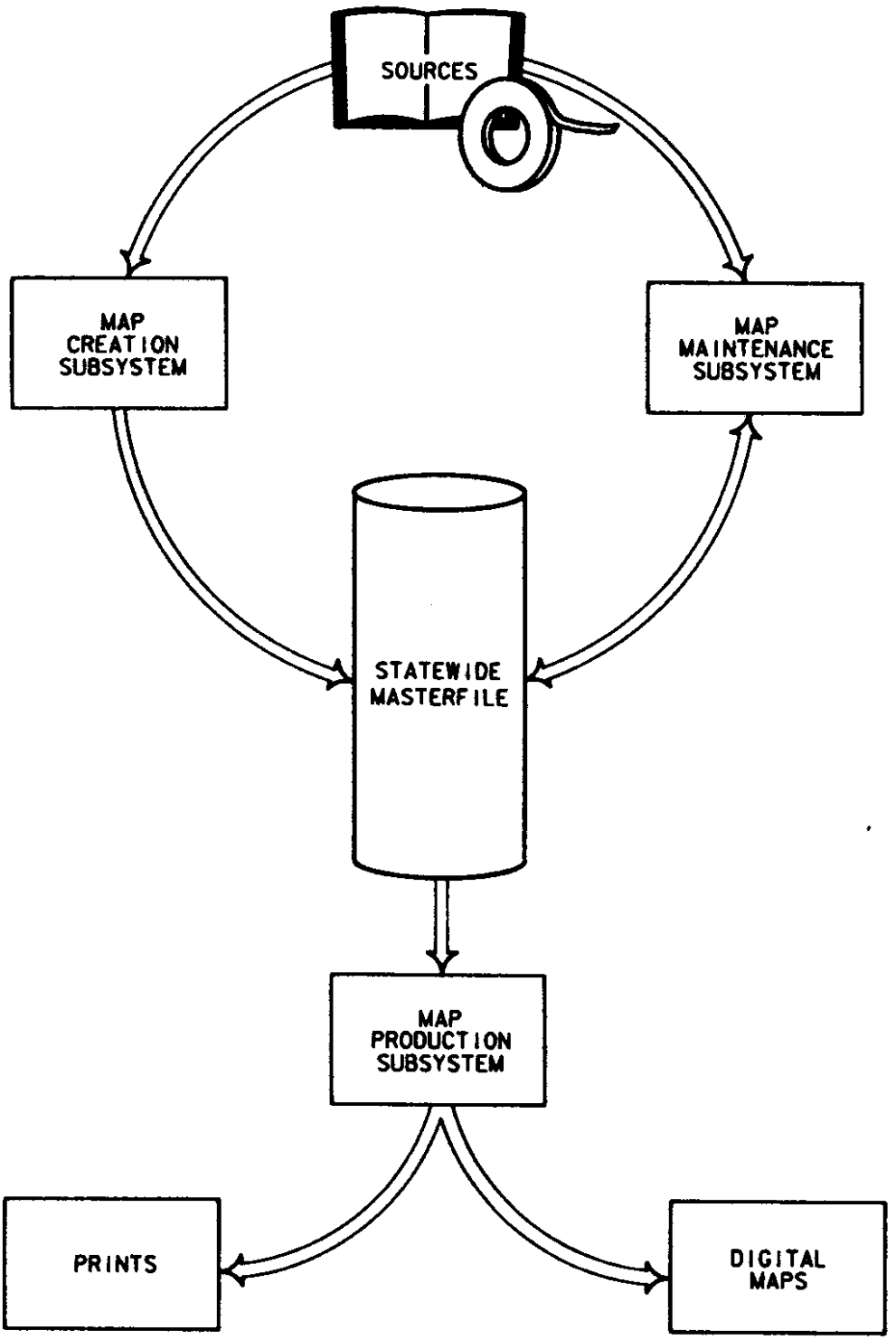
Manual: A stable base material, usually a scribing material, that represents a specific map or one of its overlays. The base is periodically updated and film copies reproduced for printing or modifications in the case of special maps.

Automated: A digital spatial database consisting of graphical features and/or non-graphical information.

Manual - Master Basemap

In the manual stage the base map was generally "created" in the early stages of the general highway map program. Over the

COMPUTER ASSISTED CARTOGRAPHY SYSTEM OVERVIEW



Pennsylvania Department of Transportation

FIGURE 2

years the map has been updated on demand or according to a cyclic time schedule. Important changes such as the completion of a new route are often added immediately to the base. Other changes are generally accumulated until the map is to be reissued or manpower becomes available to perform the update tasks. Since each base is for a specific map, the same updates are required for each map version of the same area. An important observation is that there is little if any "creation" of maps occurring under the manual system. There is little need to create new bases as updating tasks simply correct the stable base master. If a new map type series is required, the cartographer combines reproduction techniques with drafting skills to create the new stable base master. However, there is now one more map series to maintain in the update cycle.

Automated Cartography

1. Masterfile

The masterfile shown in Figure 2 is the hub of the automated cartographic system and its most important component from a design standpoint. To avoid technical definition arguments, the masterfile shall be defined to consist of all databases and files used to support the cartographic effort.

The masterfile contains the spatial and non-spatial map database information which correlates to base map file drawers and update source file folders of the

TYPICAL CARTOGRAPHIC SOURCE DOCUMENTS

USGS Quadrangles	Sub-division plats
Highway inventory notes and maps	Oil and gas maps
Highway reference logs	Political boundary descriptions
Route logs	Descriptions of wildlife preserves and refugees
Aerial photographs	Railroad logs
Federal aid maps	Airport manuals
Census population listings	Highway construction plans
Newspapers	Legal boundary descriptions
Maintenance logs	Commercial travel maps

TABLE 1

manual system. The masterfile constitutes:

* The graphics representation of the map features.
* The cartographic non-spatial attribute data.
* The linkage for the non-spatial user data.

It is important to note that the automated cartographic system will require significant manpower resources in the initial stages to create the digital database. The computer data structure will necessarily be in the file formats dictated by the vendor's software.

2. Physical File Convention

The file convention decision has three important parameters to take into consideration:

* Response time at the workstation,
* Work effort required in compositing or separating base maps for the user, and
* Database activity for maintaining the database.

The physical file convention that the cartographer uses to access specific areas of information may be controlled somewhat by the vendor's hardware or software but the cartographer should have some flexibility in how he structures the data. It is recommended that file convention be one of the geographical political subdivisions, preferably the one most used or system efficient.

The response time of the system, to the user at the workstation, is affected by the file convention because the size of files effects system efficiency. The smaller the files the faster the response time.

Another important criteria will be the long range uses for the system in modeling analysis or other transportation applications. For pure graphic output the selected geographical subdivision may not make a difference. However, for the analysis type applications where the political subdivision breakdown is too small, the cartographer will constantly have to merge together features to produce larger area maps. Large area maps require the opposite, the breaking down of the data to satisfy smaller area maps.

Ideally, the cartographer desires to maintain statewide databases. However, this will require software that is capable of easily extracting data from the masterfile for three purposes:

* First to maintain the masterfile using various geographical boundary definitions.
* Second to maintain the road network and other transportation features by graphic entity.
* Third to extract data from the masterfile to create a map product.

Grouping common features by files and controlling the extraction area, minimizes the file size the workstation will be using. Again, this is the critical issue for maintaining productive response times.

Map Creation

Manual: Originally, the use of compilation and map projections to create hardcopy base manuscripts.

Automated: A digital data collection process such as digitizing or scanning in combination with projection type software.

Map creation is the first of three "end result" components and defines one of the major subsystems in the computer assisted cartographic system. Creation tasks are least utilized in existing manual systems but will be most important for probably the first three to five years in the implementation of the automated system. Section V, Map Creation Subsystem, will discuss this phase in detail.

Map Maintenance

Manual: Update master basemaps using drafting tasks defined by update source documents.

Automated: A software program that provides for the updating of spatial and non-spatial data. This software must protect against user query during the process and maintain an audit trail for the map updates.

Map maintenance is the second of the "end result" components and represents one of the major tasks in the manual operation. Tasks in this area will necessarily have to be continuous maintenance operations. Presently, this appears to be the most overlooked element in the automated cartography system design. Failure to consider this area properly could destroy the data integrity of system in later years. Section VI, Map Maintenance Subsystem, will discuss this area in detail.

Map Production

Manual: Reproduction and drafting in combination to produce the final product.

Automated: A combination of extractions from the digital masterfile, CADD drafting tasks, and automated digital plotters.

Map production is the third of the "end result" components and represents the end product that the user will see.

This product is presently a hardcopy map resulting from drafting and reproduction processes. The automated cartographic system will produce both computer screen display and hardcopy products. These will be discussed fully in Section VII, Map Production Subsystem.

The Cartographer

Manual:	Cartographic skills and reproduction knowledge.
Automated:	Cartographic skills, an understanding of computer systems and databases, and he ability to adapt drafting skills to automated plotting.

Contrary to many espoused viewpoints, the automation of cartography is not a change in what the cartographer does, but a change in the tools he uses to get the job done. The automated system must still create the map base, maintain the map base, and produce products from the map base. The difference will be that the cartographer will make use of computer workstations, databases, computer files, and plotters instead of manual drafting, file drawers, and reproduction processes. The cartographer is the key to successful implementation of the automated project. Through interest and skill he can make a poor system a success; through improper management, he can make a good system unproductive.

THE CARTOGRAPHER'S ROLE

Although the cartographer has generally had little exposure to computer technology within the DOT, he is not as unexposed to modern concepts as many may think. The exploding field of computer assisted cartography has given any interested

cartographer ample opportunity to become familiar with the technology through his trade journals. The computer programmer or system designer may be worse off because he has had no exposure to cartography. Since the new technology is heavily dependent on database concepts, the cartographer has the advantage because the cartographers have always managed databases as a part of their day-to-day tasks. The difference being that their databases have not been digital but on film. Because of this experience the cartographer will already:

* Be cognizant of data integrity requirements
* Be familiar with database management procedural requirements.
* Know the relationship among data elements.

While the level of knowledge and expertise a cartographer will achieve in the technical aspects of databases will be dependent upon his personal interest in that area, there is a minimum level of interface understanding that is mandatory. The cartographer must:

* Participate in the database design because of his knowledge of data relationships and end products
* He must acquire the skills to be a knowledgeable user for he will be required to manipulate the data for special maps.

SUMMARY

As a DOT progresses from manual to automated cartography, the cartographer will remain the interacting catalyst for the success of the system. He must learn to apply his knowledge using different tools to attain the same or similar results to those of the past. Computer assisted cartography is equivalent to a more powerful set of tools with which to do a job. It also offers

additional capabilities that will allow the cartographic operation to project itself into the management, planning, and design activities of the Department. Its similarity to manual processes will make adjustment easy. The learning curve for this technology is long, under any circumstances, but the cartographer can play a more important role within the Department if he has patience and the perseverance to succeed.

SECTION III - IMPLEMENTATION TASKS

The implementation of a computer assisted cartographic system is not an effort to take haphazardly. Success requires a long term commitment by the DOT. This effort involves a substantial initial capital investment, training, annual operating budgets, budgeted funds for hardware and software growth and enhancements, operational support personnel, development personnel to improve productivity levels, and most important a full long term commitment by upper management.

Technically a computer assisted cartographic system is the integration of computer technology, communication technology, database methodologies, and the skillful handling of human resources and factors. In a DOT this integration is applied to automating the mapping operations and to assisting in solving transportation problems. There are four basic components that need to be addressed to insure the successful implementation of an automated cartographic system. These components encompass the definition of needs, the solution to those needs, the required support to implement and maintain those needs, and the people requirements to achieve success. These components are:

* JUSTIFICATION
* SYSTEM DESIGN
* HUMAN RESOURCES
* IMPLEMENTATION PLAN

Although almost 90% of the states already have CADD systems, not all DOTs have addressed automating the cartographic effort. Each DOT will fall into one of three conditional categories and SECTION III will be of varying value depending on a DOT's

existing situation. The three conditional categories are:

Category 1. **System procured and cartography actively involved.**
Category 2. System procured and cartography not involved.
Category 3. DOT does not have CADD

All categories should find Human Resources and Implementation components to be informational and useful. States falling into Category 1 may find the remaining components in SECTION III of little value, but are expected to critique the information and assist fellow States in the other two categories. DOT cartographers in Category 2 will find SECTION III of value if State policy requires justification even for a workstation, and in any case, the discussions on system design should be helpful for evaluating equipment configurations and options. Hopefully, those States in Category 3 situation will find SECTION III useful as a guide for their endeavor to implement an automated cartographic system.

Section III will discuss these basic components from primarily a cartographer's viewpoint.

JUSTIFICATION

Cartographers in those States presently evaluating CADD systems should make their presence known early in the process. It is a basic fact that the engineering design and drafting functions will provide the primary justification for the system. Therefore, it will be the dominant decision maker in the system design, configuration, and installation plan. Inputs at this early stage are critical, even if cartography is regulated to a

later installation phase. Cartography requires the longest time to reach a fully automated level of production. Every effort should be made by the cartographer to get at least one workstation in the initial equipment delivery.

Objective Statements

The first and most important step in preparing the justification of a computer assisted cartographic system is to define one or more overall objectives. These objective statements will establish the guidelines for justifying and implementing the system. They will in turn allow the cartographer to initiate a generic design of the system and target the internal organizational support he intends to solicit.

Each State will need to establish its own goals and may need to get application specific to convince management. Three general purpose objectives that are typical of those that a DOT cartographic unit might propose are:

Objective 1: To improve the responsiveness and workflow of map products by automating and integrating those procedures for which it is technically feasible and cost effective,

Objective 2: To expand the use of graphics as an automated visual communication tool for engineering management and planning through the use of informational technology, and/or

Objective 3: To improve the efficiency of iterative solution processes by improving the responsiveness and ease with which operational traffic and planning simulation applications can be accessed.

Justification Approach

Many states have established procedures and formats for preparing official justification. The best approach to preparing any justification document is to document one's ideas and first prove to oneself that the project is worthwhile through quantifying the facts. Once this is accomplished, it is simply a matter of formatting the findings to the required standards. It is important to build justification around objectives and target developments around high priority Departmental goals where practical. Using the three objectives listed above as examples, guidelines to support justification could be as follows:

Objective 1:
- A. Develop a 5 Year Plan for Automating Cartographic Operations
  - 1. Define Workflow
  - 2. Define Data Collection Sources
  - 3. Identify Automation Candidates
  - 4. Identify Resource Requirements
    - a. Budget
    - b. Skills
    - c. Manpower
- B. Productivity Measures
  - 1. Existing Productivity Measures
  - 2. Required Productivity Gains for Justification
  - 3. Expected Phased Productivity Gains

Objective 2:
- A. Identify Visual Management Application
  - 1. Upper Management Level
  - 2. Legislative Exposure
- B. Schedule Cartographic Automation Tasks to Accomplish A.
  - 1. Use Pilot Area Methodology (County)
  - 2. Invoke Imaginative Procedures for Inputting Source Data

Objective 3:
- A. Identify Simulation Processes Used by DOT
  - 1. Planning Models
  - 2. Traffic Models
  - 3. Emergency Management Models

B. Select Model
   1. Use Pilot Area Methodology
   2. Select on Management Interests

Benefits

The visual part of any justification lists items of primary interest to administrators, the benefits and benefit/cost ratios. The benefits over the short term are measurable, and unbelievably significant over the long term. The problem is to quantify such benefits into meaningful measures. Figure 3 lists some of the expected benefits a DOT can derive from automating its cartographic operations. The quantitative benefits for each of item in Figure 3 are State dependent and require each State to make its own cost/benefit analysis. One must realize, these benefits are achieved in a phased atmosphere over a long period of time. It is also important to note that for some extensive period of time the cartographic unit will have to maintain both manual and automated maps.

One avenue available for obtaining early visual benefits is the creation of minimally sufficient maps. Such maps will be acceptable for certain applications and can be developed in the early stages and then upgraded as the "official" geographic area is completed to desired specifications. This has several advantages:

* Visual exposure of automated maps to the user.
* Expanded familiarity with the automated system in producing maps,
* Experience in the use of the plotter or other output devices to produce map products,
* Early achievement of productivity gains.

COMPUTER ASSISTED CARTOGRAPHY

EXPECTED BENEFITS

1. More current maps through reducing the cycle time for states to update map information.

2. An increase in cartographic productivity:

   - The availability of new technologies and added capabilities.
   - The availability of digital data from existing DOT databases.
   - The availability of digital data from sources external to the DOT.
   - An increase in the flexibility of cartographic production processes.
   - An improved ease of making changes.
   - A common database for basemaps of varying sizes thus reducing data redundancy.

3. Creative opportunity for the cartographic unit and staff to contribute significantly in assisting the DOT in achieving its chartered responsibilities.

4. Improved data analysis capability through the availability of a spatial cartographic database that correlates spatial and non-spatial data. A spatial database provides for:

   - Better graphics presentation capabilities for communicating tansportation needs to the legislature and to the public.

   - Improved accessibility to modeling techniques for:
     — Excellent existing transportation models such as NETSIM and AAP.
     — Existing planning models such as UTPS.
     — The development of future models.

   - Improved management techniques for:
     — Pavement and bridge life cycle management.
     — Needs and priorities for the preparation of construction budgetary processes.

   - Greater data integrity for DOT databases.

FIGURE 3

All of these advantages help keep management in a supportive frame of mind.

SYSTEM DESIGN

The system design component for automating cartography is a time consuming effort. In general, it involves in-depth investigation of what is available today and what will be possible tomorrow. There are five factors that inherently comprise the system design component. These five factors are:

* Overall Design
* Informational Sources
* Computer Technology
* Communication Technology
* Database Methodology

Overall Design

Once a DOT has made the decision to develop an automated cartographic system, the State has three options available:

* Develop a system from scratch by configuring the hardware and software and supporting the system development and maintenance inhouse, or
* Procure a turnkey system from a vendor that supplies the full compliment of software and hardware, or
* Combine a turnkey system procurement with inhouse development for tailoring the system to meet specific DOT needs.

The first option is costly in manpower resources, and time consuming to the extent that the project is vulnerable to losing administrative support. It is one that is constantly faced with technological obsolescence. The second is impractical because no vendor's turnkey system will completely satisfy a State's idiosyncrasies and it would be costly in time and money to depend on the vendor to satisfy the DOTs ever changing needs. The combined turnkey/DOT option is the best solution for most DOTs. This option allows the State to take advantage of a vendor's turnkey system and enhance that system with inhouse support at a level that meets the DOT's capabilities, available resources, and

budget constraints.

Interestingly the vendors have packaged technology and computer components together to provide an acceptable turnkey package from which a State can launch the automation of its cartographic operations. Using the combined turnkey/DOT scenario, a DOT might typically approach the overall design as follows:

1. Vendor provides
   * The computer and computer peripherals,
   * The communication hardware and software,
   * The operating system software,
   * Language compilers and application interface software,
   * The database and database management software,
   * Basic application software
   * Documentation

2. DOT provides for
   * The operational support for the computer configuration,
   * The programming skills for attaining acceptable productivity levels,
   * Database creation and management skills, and
   * Cartographic expertise and skills

Regardless of the option selected the cartographic unit will find itself operating under one of three computer configurations:

1. Cartography is to simply be a user, having access to workstations and appropriate software but system operation is the responsibility of others,
2. Cartography is a totally separate system and responsible for the operation of the system with no integrations intended with the outside world, or
3. Cartography is a separate system operating as a node on a system network.

There is no technical requirement that CADD and GIST computer systems be the same, nor that GIST and the Administrative HOST be the same. It makes sense that the GIST computer system be identical or compatible with the CADD or the Administrative HOST for controlling operational costs and optimizing manpower resources. It is more likely that the

cartographic unit will operate as a user workstation or as a node on a network. In both of these configurations, the cartographer no longer can define what he needs, but must monitor what is available and do the best he can under those circumstances. While the role of the cartographer is important in all cases, this "likely" role will be more difficult and the cartographer should see that the designed system:

* Includes the hardware and software that the vendor(s) have available to support cartographic tasks,
* Is expandable for supporting additional workstations, memory and storage, and
* Supports multiple computer systems and communication gateways that allow accessing of other remote computer systems.

Informational Sources

Cartographers can seek information from four sources:

* Literature and reports,
* Vendors
* Vendor's clients
* Other DOTs

The best source of information by far is readily available from the more than 40 DOTs which have already installed systems. The cartographer should be able to find at least one state which is already using the selected or proposed system. Care must be taken when analyzing system installations that are not a DOT but claim or appear to perform similar activities. There is a large community of organizations whose perception of transportation cartographic needs is incorrect. Literature articles, and reports generally approach situations from an ideal point of view. While the information is valuable as a guide, most State procedures do not permit "ideal" or private industry type of evaluations and

procurement. Database design scenarios have in many cases already been established by the Computer Section and the cartographer will have to accept what exists and design his system within those constraints.

Computer Technology

Computer technology consists of both hardware and software to make the system function in a cartographic mode. Today this is available as a turnkey system from a single vendor. The cartographer need not be concerned about the central processing unit (cpu) manufacturer, but in the capabilities of the total system. The cartographer should check for the following points:

* The cpu should support peripherals such as tape units, disk drives, plotters and printers.
* The system should also support computer-to-computer and remote communications, multiple disk units.
* Memory size must be sufficient for the operating system and application software to function efficiently.
* The system must have a minimum of two disk drives.
* The system must be expandable in both memory and disk drives.
* The procurement contract document must outline expansion requirements and associated costs.
* The operating system software should be both multi-tasking and multi-user.
* The operating system software should be that of the manufacturer and the vendor must interface to and not modify that operating system software.
* User interface or ease of operation should be acceptable.
* Documentation and training must be provided.

Figure 4 illustrates a typical starter equipment configuration for a cartographic unit.

Communications Technology

Communication hardware and software should also be furnished by the vendor. It is important that the cartographer

TYPICAL EQUIPMENT CONFIGURATION
CATEGORY-3

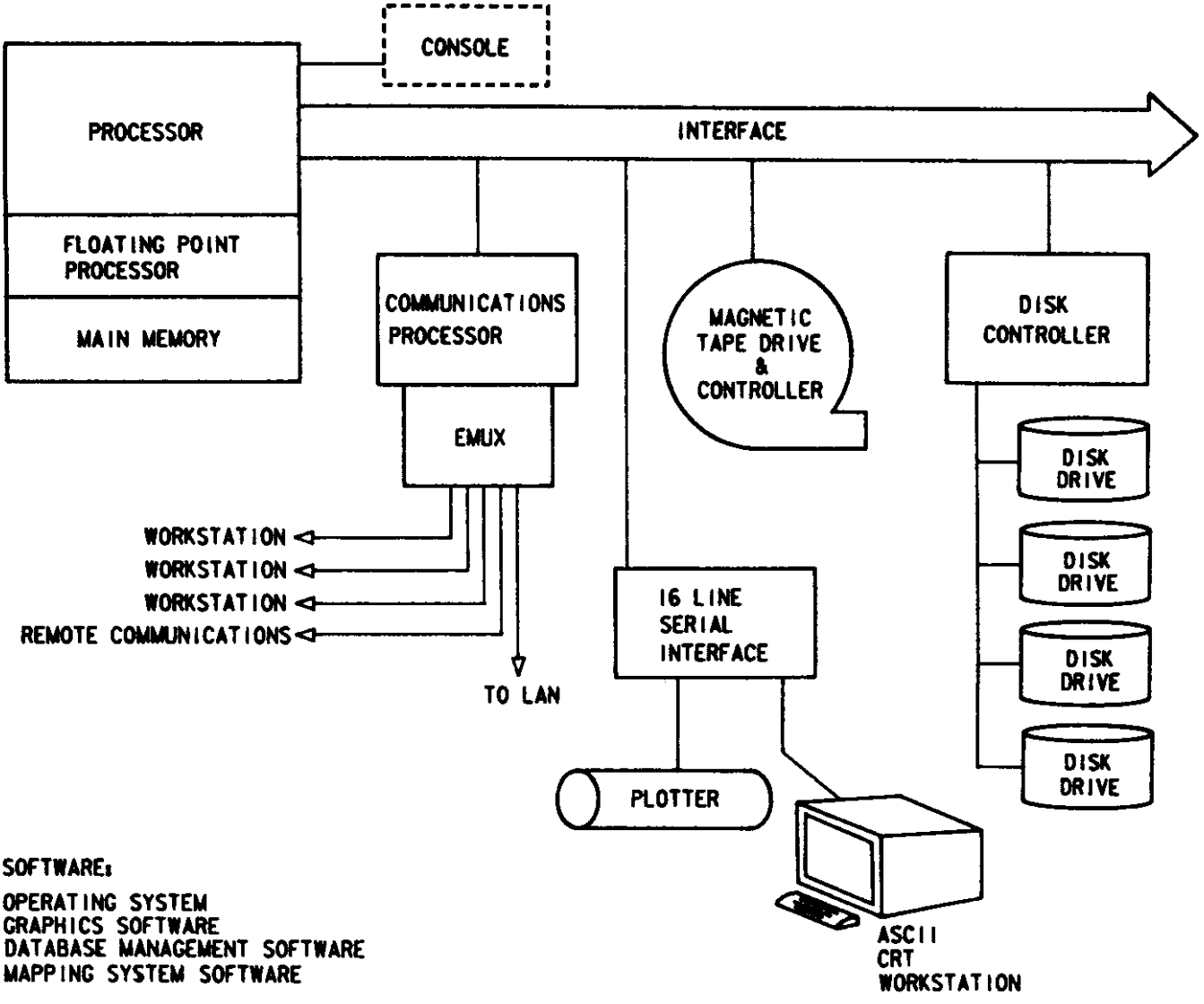


FIGURE 4

have a basic knowledge of what is happening industry-wide in the communication area. It is likely that the computer assisted cartographic system will be more sensitive to the need to exchange digital information with governmental and private organizations outside of the Department. There are three basic evolving communication standards that the cartographer should be aware of:

* Xerox Networking System - XNS (Ethernet)
* Transport Control Protocal / Internet protocal-TCP/IP
* International Standards Organizational's Open System Interconnection - ISO/OSI

The XNS should be a mandatory requirement in the specifications. Each of the other two will provide added flexibility. The ISO/OSI standard may be of more importance to the states bordering Canada, should the electronic transfer of information be anticipated.

The communication standards will become more important with growth and as file standardization takes hold. User workstations will be of particular interest. These workstations will be micro-computer based and it will be desirable to "download" road network data to the user for his further manipulation and analysis. This type of workstation will be a major growth component as the DOT cartographic system comes on line and geographic areas of a sufficient size are available. The full data management capabilities will have to be in operation prior to allowing update tasks to maintain data integrity. Table 2 lists items that the cartographer may want to inquire about during evaluation of the system.

COMPUTER SYSTEM EQUIPMENT

WORKSTATIONS

1. Microbases
2. Unix operating system V
3. Graphical Kernal System GKS
4. Terminal emulators
5. Compilers
    a. Fortran
    b. Pascal
    c. C

GRAPHICS SOFTWARE

1. Map projection system
2. Rubber/elastic band
3. Drafting
4. Geometric manipulations
5. Conversion software
    a. Other graphic systems
    b. U.S.G.S. DLG format

OUTPUT DEVICES

1. Printer
2. Edit plots
3. Color plots
4. Print copy plots

DATABASES

1. Graphic-nongraphic attribute linkage
2. Report generator

COMMUNICATIONS

1. XNS
2. Remote
3. Remote dial-up

STORAGE

1. Minimum two drives
2. Tape drive

TABLE 2

Database Methodologies

It is not mandatory that the cartographer be a database guru, but it is important that he have a working knowledge and the more knowledgeable he is the better. The Administrative HOST computer personnel will be interested in a "relational" database. This is not critical from a cartographic point of view but the cartographer must be interested in the handling of both the "graphic" and "non-graphic" data. The cartographer should insist on the following capabilities:

1. The building, editing, and manipulating of the graphic elements that comprise the graphic image.

2. The ability to provide intelligence to the graphic elements for easy generation of base map type products.

3. The ability to link non-graphic user defined data to the graphic images and to manipulate those elements through logical and/or mathematical operations.

4. The ability to generate reports from the database via report generator type software.

HUMAN RESOURCES

Psychology Aspect

Of all the components that determine the degree of success or failure of the cartographic function, none is more vital than the human component. At all levels, the human resource, not hardware or software is the cornerstone to achievement. This applies to both manual and automated mapping operations. However, at this point in the evolution of the profession -- the shift to new technology -- the focus on the human element becomes even more critical.

The pressures of change brought about by computer assisted mapping are exerted throughout the entire workplace. These changes must be effectively accommodated by the agency, the management, and the staff. If this is not done, the entire cartographic program can be put in jeopardy. If accommodated properly, the cartographic program can flourish along new levels of opportunity for expanded service to the agency and other markets.

Having established the importance of the individual in making or breaking the effort in the workplace, it is appropriate to note some of his or her concerns regarding a change to the new technology. Internally the cartographer may ask the questions:

* Will I be able to learn new techniques adequately and in a timely manner?
* What will be expected of me?
* What kind of training will I receive?
* How is this going to affect my career path?
* Will I appear incompetent?

The individual supervisors and managers are asking similar questions of themselves. They are also questioning the type of support they will receive from their management and staff. Cartographic managers and supervisors are suddenly faced with being given an expensive system to operate with an expectation of a demonstrative payoff. New goals must be established and proper staffing for effective, productive results must fall in line. The problem becomes a people problem. The hardware and software components are a neutral issue. The questions facing those responsible for the success of the system are:

* How can I nurture and develop a positive attitude in those individuals who must operate and understand the system?

* What steps can I take to help my staff feel ownership and responsibility for the new system efforts?
* How can I help my staff feel good about themselves and our mission?
* What are my options to successfully orient my present staff to the task at hand?
* Where might I be able to obtain new people with the skills and enthusiasm needed now?

* What steps can I take with upper management to develop some positive direction for the months ahead?

The effective answers to these human resource issues can be applied to the mechanical aspects of the new technology for successful results. These are, however, very human issues. They revolve around feelings, self-esteem, self-interest, attitude emotion, and ability. The issues are deeply rooted in the psychology of what motivates us as individuals --- the individuals who can determine failure or success in the change to automated cartography.

Training and staffing are two critical elements that will assist the cartographic supervisor in achieving results.

Staffing

Staffing will depend on the computer system configuration that the cartographic unit will operate under. The most likely configuration for DOTs, especially in the beginning, will be a user workstation linked to a system managed outside of the cartographic unit. The Overall Design points to cartographic units responsible for the computer system either as an independent system or as a node on a communication network. In this situation, professional computer staffing will be required. This will also significantly impact the cartographic managers as their responsibilities will now include a need to manage a technology and staff with which they are unfamiliar.

The key to effectively automating the cartographic operation is an integration of the vendors tools to accomplish the goals and missions of the cartographic section. This requires that the unit manager has access to or provide for himself at least one person familiar with programming techniques. This individual's work assignments and priorities must be under supervisory control of the cartographic unit manager, regardless of his or her administrative assignments. Only in this manner can the unit maintain some control of its destiny in reaching objectives promised to Management. An alternative is the use of consultants or professional service contracts. Because this automated effort covers a long time period, consultants should be considered as a supplement "to" and not a replacement "of" real staffing needs.

Staffing needs can be grouped into three areas:

* Workstation
* Application Software
* System Responsibility

Workstation

The workstation is primarily a CADD operation. The best results will be achieved by using experienced cartographers. While attitude is important, workstation personnel should be knowledgeable about cartography and the internal operations of the unit. It is a mistake to place inexperienced people at the station because they must not only learn how to do the CADD operations but also decipher what to do. A safe assumption is that those staff members that produce now will produce even more than the normal multiple with the new automated tools.

Application Software

It is likely that some application software will apply only to cartography. It will be imperative in those cases that some cartographic staffer become exceptionally proficient with that package and become the source of "expertise" for the unit. If the supervisor has the flexibility, it is a good practice to assign different application packages to different personnel.

The cartographic unit should treat use of the database like an application. Again some cartographic staffer should become a sophisticated user of the database. For cartographic operations that have a sufficient staff level, it is recommended that a database manager be considered to coordinate the flow of data between systems and outside users. An ideal support person should have database experience to optimize the design and development of the non-graphic database.

System Responsibility

This staffing requirement will exist only when the cartographic unit is responsible for the computer system. In most cases personnel to support this area must have computer skills and will transfer from other units or be hired. When cartography is responsible for the computer system, probably as a node on a communication network, the skill requirement will not change but the cartography manager will probably have unfamiliar responsibilities. Again a good source of information is a State that is

operating in that configuration. The Pennsylvania Cartographic Information Division operates as a node on a network.

Training

The vendor should supply training that includes workstation operational training, application software training and system software training as required. Expect to be disappointed by the vendor training, because his training program is necessarily directed at a broad usage of the system. A suggestion is to set up your own training program to focus on those interactive tools applicable to cartography. Documentation for the system is mandatory and should be considered as part of the training. Vendors are generally very lenient about making copies of their operator manuals for inhouse use. This makes manuals inexpensive and the appropriate manuals should be easily accessible to each operator.

IMPLEMENTATION PLAN

Ideally an implementation plan should be developed at the justification stage. Realistically that is almost impossible except to establish general direction. Some may consider the initial installation plan as an implementation plan, but at least for automating cartography, the implementation plan needs to be more extensive and will require that the unit acquire experience with the equipment and software. Since CADD systems by nature have a long learning curve, the development of a plan may need to follow 3 to 6 months after installation.

It is important to develop and maintain the implementation plan as a "living" document that constantly identifies goals, needs, and time frames. Objective 1 in the discussion on justification, identifies a need for an automation plan which can become the implementation plan. Regardless of the plan connotation, the plan should become the major support document for expansion of the automated cartographic operations. The plan should always:

* Reflect 3 to 5 years growth,
* Identify resources for budgeting purposes,
* Maintain schedules, and
* Document achievements

SECTION IV - GEOGRAPHIC INFORMATION SYSTEMS (GIS)

GIS's effect on DOT's is already impacting strategic "thinking", becoming a major topic for discussion in strategic planning. A symposium in March 1987, at Tempe, Arizona, was jointly sponsored by the AASHTO Subcommittee on Computer Technology, the Mapping and Graphic Task Force of the AASHTO Standing Committee on Planning, and the Highway Engineering Exchange Program (HEEP). This symposium was directed at the subject of Geographical Informational Systems (GIS) with the targeted audience of computer science staff and planning administrators. A request to the AASHTO directors to establish a GIS direction for the DOT's resulted from this symposium.

DEFINITION

GIS is the computer technology buzz word for the next few years and its definition varies from individual to individual and certainly between the various professional disciplines. The U.S. Geological Survey uses an acceptable definition:

> A geographic information system is a computer hardware and software system designed to collect, manage, manipulate, analyze, and display spatially digital data. Spatially referenced digital data are computer-readable, geographically referenced features or feature classes that are described by both geographic position and attributes.

Since a GIS can apply to various professional disciplines that have varying accuracy and detail requirements, the scope of the definition needs to reflect a transportation viewpoint and the GIS acronym is thus modified to GIST, Geographical

GIS DATABASE CONCEPTS

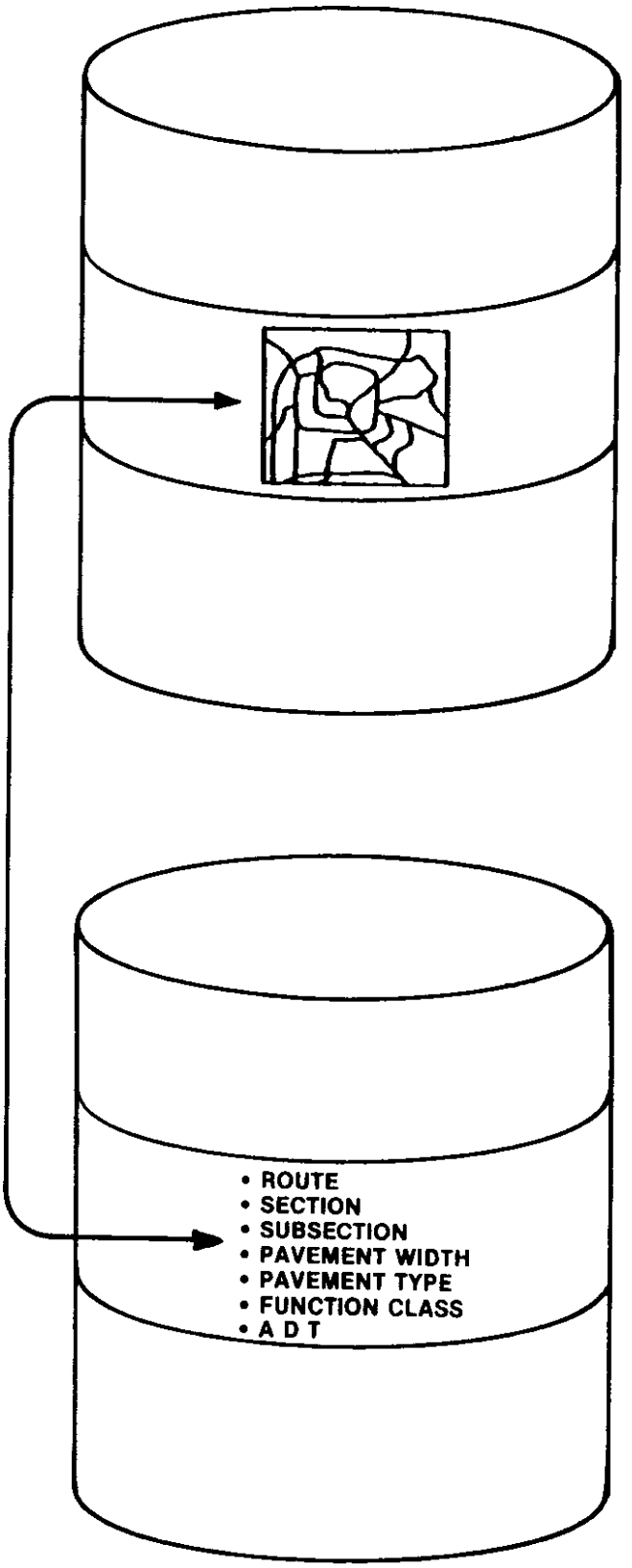


FIGURE 5

Information Systems for Transportation.

If the GIST definition is analyzed, one finds that it has six distinct components which are:

* Serves transportation
* Selected geographic features
* Feature location
* Geometric description
* Physical properties
* Owner

These components reflect information that can be either visualized graphically (spatial) or is simply a characteristic of the visualized data (non-spatial or non-graphic). These two data categories, graphic and non-graphic or spatial and non-spatial, provide GIS or GIST with two unique characteristics:

1. One may identify a graphic feature and obtain all of the non-graphic (attribute) data associated with that feature, or

2. One can select a set of characteristics (attributes) that define a desired result and obtain all of the graphical features that meet that criteria.

While the various vendors may technically address this association differently, a lay point of view is to think of the graphic and non-graphic data as physically separated. The vendor or developer must then provide the linkage between the separated data categories in order to meet the required GIS characteristics outlined above. Figure 5 is illustrative of that view point. The DOT cartographic unit will in most cases be the ideal organizational unit to develop, maintain, and administer the graphics component of the GIST-C. Most States will already have the non-spatial data operational, probably on the HOST.

GIST-C, A CARTOGRAPHIC GIST

GIST can apply to both transportation related cartographic or design based computer systems. To differentiate between the two, a GIST application involving cartography will be designated GIST-C and one involving transportation design will be designated GIST-D. This paper and the supporting workshops will be referencing only GIST-C related subjects.

Discussions of the six components for the definition of GIST-C are as follows:

Serves Transportation

GIST-C by definition focuses on transportation applications that are associated with cartographic products. Typical transportation areas are:

* Engineering Management
* Urban and Regional Planning
* Operational Traffic Management

These application areas are all map oriented with engineering management presently the forerunner in interest among DOTs. Since DOTs manage statewide transportation networks, the engineering management application provides for an excellent pilot project. This project would:

* Justify initiating the digital compilation of the state transportation system into a spatial database.
* Develop plans and establish procedures for providing access to the non-spatial data residing on the HOST computer facility.
* Create the linkage between the digitally compiled network and the graphics elements.

The linkage between the spatial and non-spatial data will necessarily be the existing Departmental road and bridge

inventory reference system. It is important to note that GIST-C will easily handle the correlation of data dependent upon multiple reference systems.

Urban/regional planning and operational traffic management appear highly adaptable to a GIST-C. Both can be major benefactors of GIST-C through reducing the time required to enter tedious input data. Both applications use iteractive analysis processes and would benefit from a database that generates input data streams and feeds them into existing simulation and modeling computer programs. In many cases micro-based systems will be designed for specific applications allowing further onetime manipulation of the digital map road network data. Examples would be arterial progression or freeway capacity modeling. Figures 6 and 7 show the adaptation of GIST-C to DOT planning and operational traffic analysis applications.

Selected Geographic Features

There is an unrealistic notion that a database of all features with all information is the ultimate solution. Present computer technology does not support that concept and real world conditions for applying computer technology don't require that capability. GIST is an excellent example describing this situation, as GIST-C and GIST-D applications will evolve from independently developed GIST systems. What is mandatory is that an application have easy access to all the information that is required to allow users to solve their problems.

The graphic component of a GIST-C will likely be maintained as a single system but will consist only of selected graphic

TRANSPORTATION PLANNING MODEL

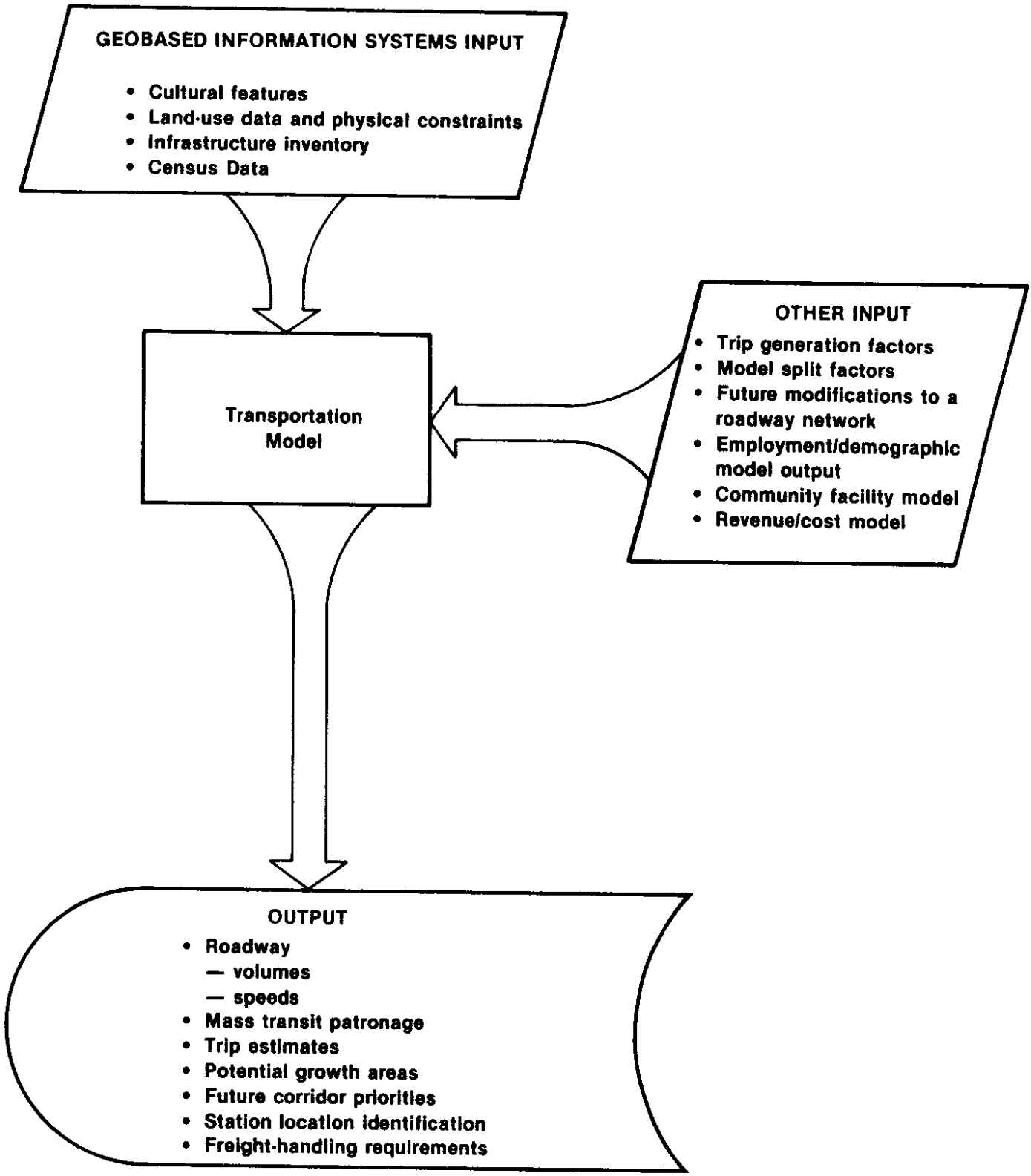


FIGURE 6

TRANSPORTATION OPERATIONAL ANALYSIS MODEL

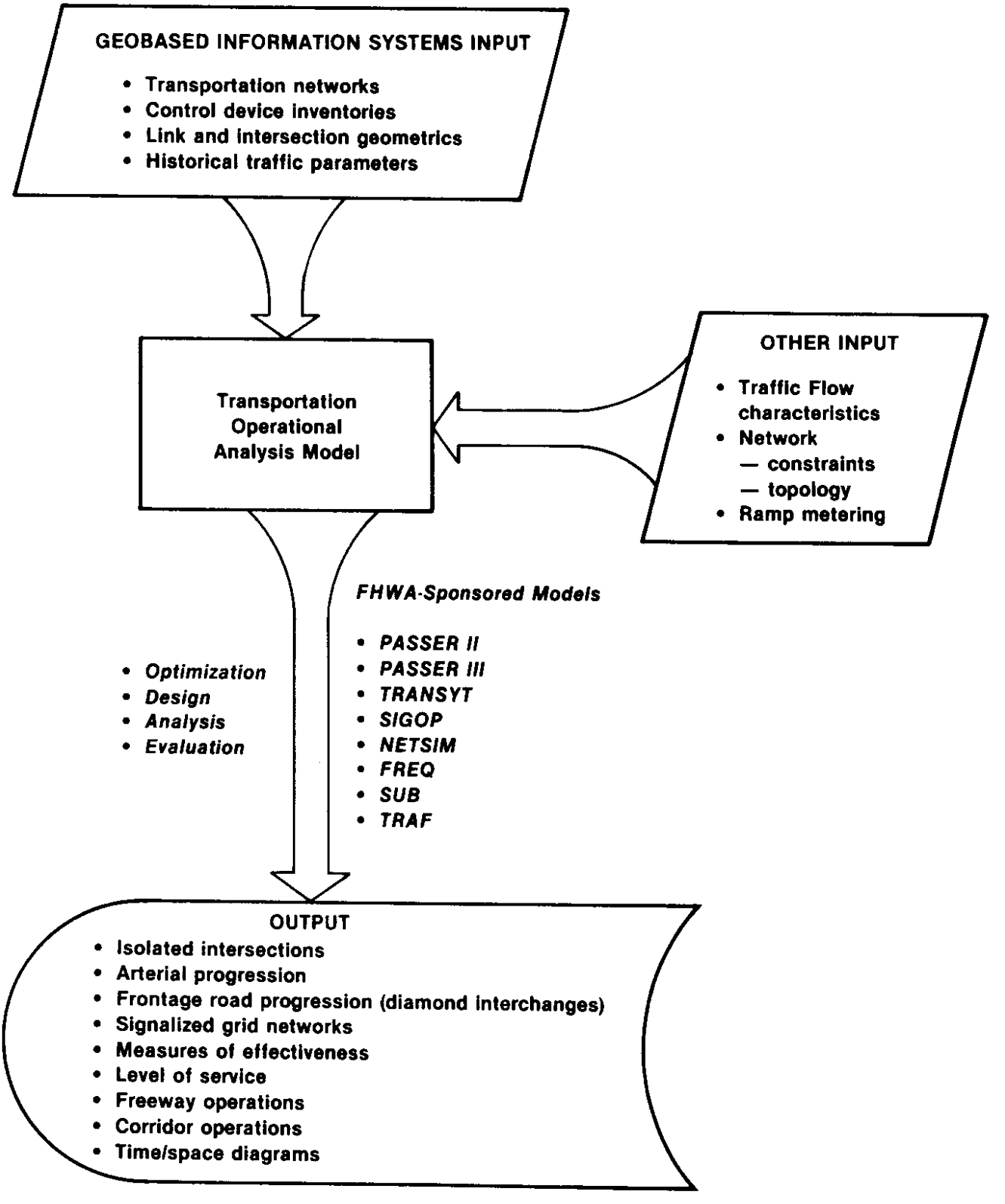


FIGURE 7

elements that:

* Are required as a part of a transportation network,
* Have an effect on the planning and/or design of a transportation network,
* Define a boundary of a political subdivision, or
* Represent a major cartographic feature essential to determining one's location or orientation.

The graphic image will be representative or symbolic of the feature at an appropriate map scale. The visual display of these graphic elements will be application independent and their appearance will be a function of the manipulation of the graphic element or database.

Feature Location

A location of a feature represents the spatial position of the geographic feature. Longitude and latitude are generally preferred in most GIS systems as each set of coordinates represent a unique geographical position on earth. GIST-C will generally follow suit but other coordinate systems may be more adaptable to specific applications. It is imperative that the coordinate system be defined or described for proper projection to other coordinate systems. The ability to include an elevation or "z" value as part of the coordinate set is optional but should become more important as the technology evolves.

Geometric Description

The geometric shape of a feature may be either a part of the graphic representation, a set of non-graphic attributes, or some combination of the two. An example could be that a roadway is graphically described as a line string, but attached alignment. This allows simple graphic representation of features for the map

scales typically used for GIST-C applications but if an application needs the actual geometrics, they are available.

Physical Properties

In some instances the physical properties of a feature are graphically displayed through color, line weight, line type or symbolic representation. Road surface type is an example that is often symbolically displayed on cartographic products. GIST-C will also carry this characteristic as a non-spatial attribute.

It is these types of characteristics that are generally analyzed to produce special maps. Typical non-spatial attributes are:

* ADT counts
* Skid rating
* Pavement distress factor
* ROW width
* Traffic accidents
* Maintenance rating
* Bridge length

These databases or files that maintain such attribute values will likely reside on the DOT's Administrative HOST computer. The ability to access this information and incorporate it into GIST-C is vital. The ability to access this information interactively will become increasingly important.

Owner

In nearly all instances it is important that the "owners" of a transportation facility be known. This may be accomplished through grouping together the graphic descriptions of like owners and/or include them as non-spatial data. The more specific the owner, the less likely graphic element grouping will be appropriate. In many instances, both group and specific owners

will be carried as attributes because of their use in the analysis processes. Typical owners for GIST-C products are:

Group Owners	Specific Owners
* FAP roads	U.S. route number
* FAI roads	Interstate number
* State roads	Route number
* County roads	Designation or Street name
* Operational railroads	R.R. company
* Major culture features	School name
* Bridges	Structure number

COMPUTER ASSISTED CARTOGRAPHY AND GIST-C

GIST will have a revolutionary effect on the future development for automation of transportation applications. The most practical and beneficial way to implement a computer assisted cartographic system is to approach it from a GIST point of view. Designing the automated cartographic operation around a GIST-C, will allow the cartographer to take full advantage of the capabilities inherent in a digital spatial cartographic system.

GIST is an important concept for the cartographer to become at ease with because he will be associated with it in two ways:

* As a key tool for generation and maintenance of base maps. By selecting non-graphic attribute parameters, base maps can be created depicting only desirable information and thus allowing data for which the map is being created to be more easily emphasized.
* As a vehicle for user type information to be transferred and linked to the graphic system for special analysis and display.

The second way will require some thought on just how the user and the cartographic unit will interface. The major components of this interface are:

* The digital base map
* The validity of the user data
* The analysis of the data and/or creation of the special map
* The review of the map product
* The finalization of the product

Digital Base Map

The cartographic unit should be responsible for making available to the user the most current applicable map. This map may be simply a graphic file or a full GIST-C complement.

User Data Validity

The user will always be responsible for the validity of the user data that is to be attached as non-spatial attributes. Where the data is to be first extracted from the HOST, the user is responsible for that extraction. The wide variety of applications prohibits this activity from being a cartographic responsibility.

Analysis and Special Map Creation

This is the primary area where decisions on responsibility must be determined because it affects staffing and training. In reality this will probably be application dependent with some users capable of using the database. However, for transfer of the full GIST-C capabilities across the Department, the cartographic unit must have expertise in this area. Two major reasons for this requirement are:

* Cartography already prepares many special maps and will need the knowledge and expertise just to carry out its responsibilities.
* There will be infrequent or new users. It will not be practical or economical for those users to become "experts". New users may not have evaluated their benefits from GIST-C or will be in the learning stage.

Review of the Map Product

Review of the analysis and/or product is a mandatory responsibility of the user. Where the user is dependent on the cartographic unit for the execution of the database processes, a joint effort will be required between cartography and the user.

Map Finalization

Generally this should be a user responsibility. However, the user may not have access to a workstation or, historically, the cartographic unit has produced his product.

One prevalent misconception is that GIST-C is a data processing function. In reality, GIST-C provides a set of tools that can be adapted to computer applications. GIST-C utilizes computer technology and database methodology to provide a new approach for automating effectively. Actually, GIST-C allows the cartographer or decision maker to interactively make decisions at the workstation and have the visual products (displays or hardcopies) simultaneously produced. This man/machine interface will alter the skill requirements of the cartographic unit by diminishing the need for pure draftspersons or tracers. DOT's that successfully implement a GIST-C will:

* Aggressively pursue technological advancements in digital data collection of cartographic data,
* Apply the technology to transportation life cycle management, traffic applications and planning activities,
* Recognize that their cartographers have some unique skills, and
* Have cartographers that recognize and nurture their changing role.

SECTION V - MAP CREATION SUBSYSTEM

Section II, Computer Assisted Cartography, discussed the automation of cartographic operations. Section IV, Geographic Information Systems, discussed the use of new technologies and methodologies to accomplish this automation. The result is a geographic system that addresses cartography in the field of transportation, GIST-C. The design, development, and implementation of this system requires the same attention to cartographic procedures as do the manual processes and must therefore accomplish the same tasks. These tasks are:

* Creating the base maps,
* Maintaining the base maps, and
* Producing cartographic products.

Section V, Section VI, and Section VII will discuss each of these respectively.

PLANNING THE SUBSYSTEM

Figure 8 diagrams the Map Creation Subsystem. This subsystem is the primary focal point for early GIST-C development. The subsystem objective is to convert both traditional and automated source information into a digital masterfile. To accomplish this objective, the Creation Subsystem must:

* Create the graphic features for the GIST-C database.
* Structure the data for the Maintenance and Production subsystems.
* Build the cartographic non-spatial database.
* Establish the linkage for the user non-spatial database

Two early steps the cartographic unit manager must take to assure a systematic implementation are:

* Develop an Action Plan
* Develop a Procedures Manual

MAP CREATION SUBSYSTEM

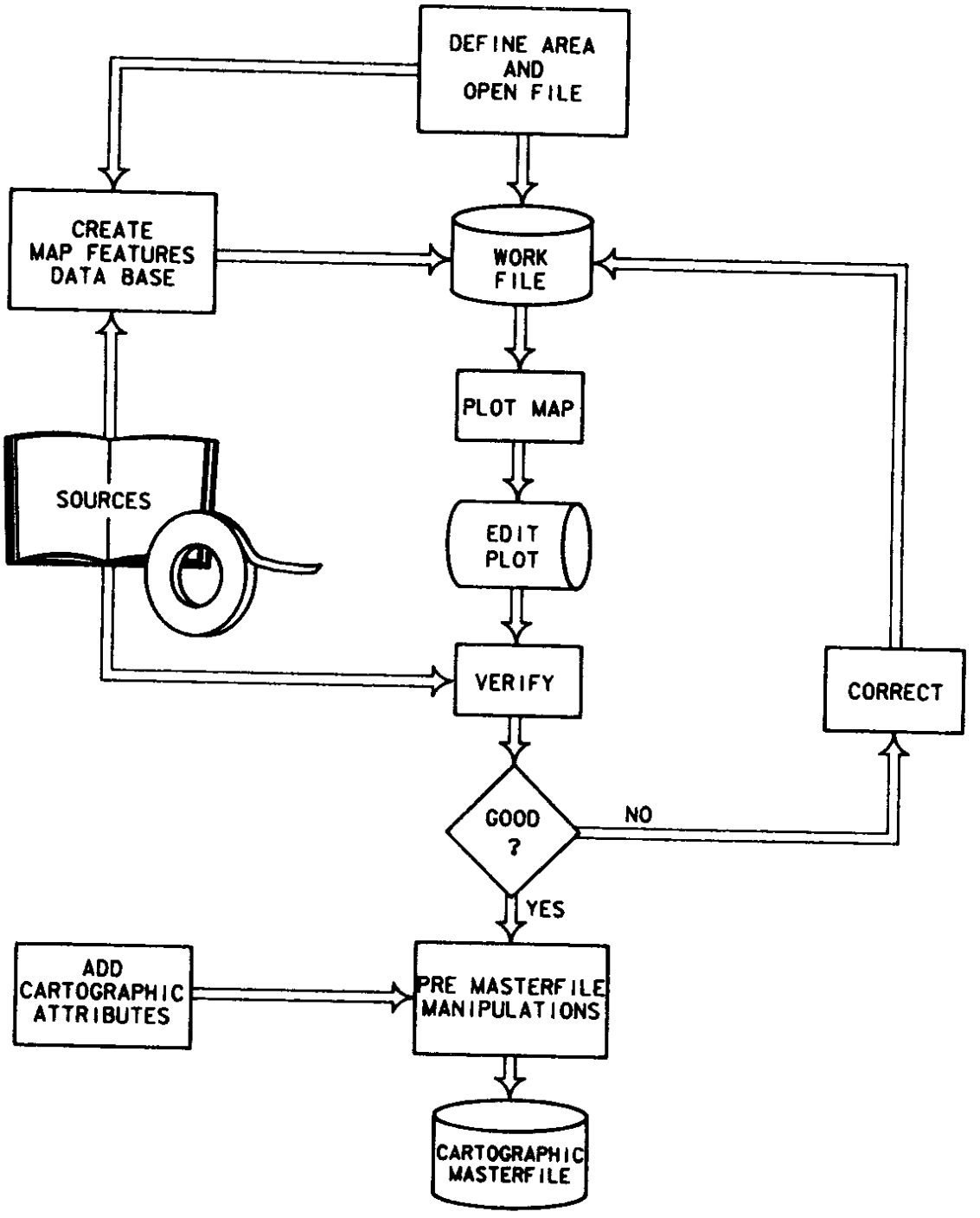


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FIGURE 8

Action Plan

The cartographic manager's Action Plan must address several factors:

* Establish steps for longterm commitment to produce General Highway Series maps.
* Focus short term objectives on one or two cartographic products.
* Coordinate automated and manual cartography tasks during system development.
* Determine what users want/can do with GIST-C.
* Commit personnel to development efforts.

The cartographic manager should be aware that early exposure to the user is paramount in maintaining administrative support. It is also wise to get early feedback from users. Short term development plans should be integrated with the long term objective, the general highway series map. This optimizes development resources while still advancing early success scenarios. User interest in specific applications will also impact the data conversion decisions and cartographic products selected as pilots should have statewide implementation. The preparation of the plan requires the evaluation of several options:

* Create base map by political subdivision (county, district)
* Create base map by road network (FAI, FAP, etc.)
* Use U.S.G.S. quad sheets as data capture source.
* Use existing base maps as data capture source.
* Initially build graphics only base maps.
* Initially collect non-spatial attribute data while creating base map.
* Initially capture the full complement of graphic features.
* Initially collect selected features using a phased approach to eventually achieve the full complement of graphic features.

Large area maps, graphics only data capture, and selected features support the early completion of map products. The penalty paid is in redundant data capture procedures but

technology may make this postponement not so costly. As stated earlier, the expectations of GIST-C by users will influence the manager's decisions. Road network accuracy is directly proportional to data conversion effort. Accuracy standards are determined by the need to make area/section analysis or point location analysis. Pavement management is a typical example of "section" type analysis, while traffic accidents are a good example of point location requirements.

Automated and Manual Coordination

The development of a GIST-C will be accomplished over a long time period and should be achieved in phases. Careful consideration must be given to the dual map responsibilities that occur during this period. The cartography manager must be constantly aware of the development status in order to make reasonable decisions on user requests. The manager may choose to generate the request manually, by automation, or by a combination of the two.

DATA CONVERSION

Data conversion will be the primary task in the Map Creation Subsystem. The cost is high in time and effort, but keep in mind that it is a "one" time effort and it is better to progress steadily and precisely than having to repeat the data capture process. This is not to say that "planned" redundancy is disadvantageous, but unplanned is catastrophic. The unit manager has access to several choices for executing data conversion:

* Digitizing
* Scanning
* Existing digital data
* Kinematic global positioning

Digitizing

Digitizing collects data in a vector format and is the most popular procedure for collecting the graphics database. While scanning, existing digital data, and GPS technology talk a good game, they have yet to reach a consensus level of acceptance. Digitizing is still considered the most reliable because:

* The cartographic manager is in control of his product from both a quality and scheduling standpoint.
* In many instances the desired sorting of features is not apparent on the source documents causing increased post data conversion efforts. On the other hand, separating and grouping of features can be easily accomplished during the digitizing of the source document.
* The work effort can be done inhouse on existing workstation equipment.

The importance of establishing data collection procedures, is again emphasized. Once data conversion procedures are established, production digitizing is a good third shift operation. Digitizing procedures should cover:

* Data preparation,
* Data conversion, and
* Data edit.

These documented procedures will not only provide inhouse quality assurance but will be useful for the same purpose when contracting digitizing to the private sector. A typical set of operational procedures is:

* Preparation of source documents for digitizer.
* Digitizing of source documents
* Digitizer's edit
* Corrections
* Supervisor edit
* Corrections
* File structure merge
* Product edit

Scanning

Scanning is an area where the cartographic manager should evaluate the economics of purchasing equipment as compared to contracting for a scanning service. In addition to the normalcost evaluation criteria the evaluation should consider:

* How can the State utilize the equipment upon completion of the map data conversion project?
* What technical and operational support level is required?

There are two scanning techniques:

* Raster scanning
* Vector scanning

The raster and vector representations of geographic data both have their strengths and weaknesses such that neither data type can adequately replace the other. Raster data are easily acquired and used extensively in remote sensing applications. Raster images, however, require large amounts of storage and can not reliably resolve objects that are smaller than the image grid cell size. Vector images, on the other hand, can afford a very high spatial resolution due to the greater storage efficiency of the format. Vector data has proven to be exceedingly hard to generate automatically and most vector data sets are the result of laborious human interaction and editing. The same difficulties involved in automatic vector data generation also make raster to vector data conversion a difficult problem, whereas vector to raster data conversion is a well established routine process.

Raster Scanning (Harlow and Hill)

The raster encoding scheme divides the image area into a regular grid whose cell size resolution may vary over an

extremely broad range. Cell sizes of several square kilometers down to less than one square meter each are typical for remote sensing. Document scanning equipment has resolutions from 25 to 100 microns. Each grid square is represented by a number that signifies some characteristic of the image. The collection of numbers from all grid squares form a rectangular array known as a digital image. Raster data sets are typically quite large.

There are two modes for scanning:

* Binary
* Continuous tone

Binary scanning captures only the presence or absence of information. Continuous tone scanning captures photos, printed multicolored maps, and other continuous tone or halftone materials, by assigning a numeric value to each pixel in the document raster file.

Companies have attempted to overcome raster weaknesses through raster/vector conversion procedures. Selective data scanning can be somewhat addressed through the scanning of map separates. The conversion processes attempt to minimize the disk storage and to make the data more feature oriented. One should never expect raster scanning to achieve 100% conversion results to recognizable features. A more realistic expectation is 90% to 95%. Typically the raster-/vector conversion has several steps:

* Capture the data
* Vectorize the data
* Recognize the data
* Interactively edit the data
* Validate the data
* Convert the data to GIST-C format

Vector Scanning

A vector scanner uses laser technology to automatically scan a photo negative. The scanning technique incorporates an operator interface to provide selection "intelligence". This makes the process very similar to standard digitizing techniques but much faster. It allows for selective data conversion from a single source document, thus reducing source document preparation time and never collecting unwanted data. Although the process has many automated features, the operator's override capabilities provide flexibility for unique data capture situations. Editing and quality assurance of the converted data would follow the exact procedures common to digitizing. This system is exceptionally adaptable to the data capture of highway networks, streams and contours.

Digital Source Data

The use of existing digital data takes two forms:

* Graphical element data that has already been digitally converted.
* Feature information that exists on currently available Departmental databases or files.

The best source for feature oriented digital data is probably the U.S.G.S. They have recently digitized the United States for the Bureau of Census at 1"=100,000 scale. The usefulness of this data, as it applies to DOTs, is still in question. Some states find it satisfactory while others find it unacceptable. The Wisconsin DOT is a state that has found the 1"=100,000 acceptable. They felt that the benefits of the immediate availability of the data were greater than the

liabilities of the 150 ft. accuracy. Each State will have to determine its value to their objectives for a GIST-C. In any event, the cartography unit can expect a significant manual effort to organize the data.

States seeking digital 7.5 minute quad sheets to use for the geographic basemap are probably out of luck. This program was a casualty of the 1"=100,000 digitizing program. The 7.5' program is again active. A state should check to see the scheduled compilation date for quad sheets in their state. A state's interest could have an impact on U.S.G.S. scheduling.

DOTs may find the U.S.G.S. geographical name files useful. They can, at a minimum, reduce errors and time for inputting annotations. Each DOT should investigate the availability of digital data from other state agencies and local private industry, such as utilities. The unit manager should be alert for any unique situation within the State area, that might provide data in a digital form.

A good source for digital data that can significantly assist in the development of a State's GIST-C is its own HOST resident databases. Once the road network has been captured and edited, the capabilities inherent to the GIST-C can be used to assist in the data conversion of features residing in the highway inventory, bridge, and other HOST files. This procedure will require:

* The database linkage between the graphical road elements and the statewide reference system(s) used by the HOST data files.
* A digital road network of relative accuracy with respect to the HOST data files.

Using the reference system as a linkage key, graphics can be generated or non-spatial attributes added to the GIST-C database. While in most instances this will not be 100% acceptable, it will eliminate some tediously laborious data capture and the cartographic task will be reduced to one of clean-up.

Kinematic Global Positioning

Global positioning technology is an evolving technology that promises to provide a positive impact on a wide range of transportation applications. Static GPS is already being successfully applied to control type surveys. Kinematic GPS promises to be the base nucleus for an ideal data collection system in support of cartographic operations.

GPS is a satellite navigation system. Present plans call for three equally spaced satellites in six different orbits. Each satellite will complete an orbit in 12 hours. Using "ranging" techniques, positional coordinates can be computed from three satellites and three dimensional positioning computed from four satellites. Today there are only 12 satellites orbiting which limit the coverage to approximately 3-5 hours. In addition the window slips two hours per month. Until the full complement of satellites are in orbit, the productive use of the system will be limited. The shuttle accident has delayed the deployment of additional satellites and therefore 24 hour coverage is not expected until 1990. However, the opportunity for development of techniques to utilize this technology are here and the DOT

cartography profession should push for that development.

Present accuracy for kinematic global positioning is approximately 50 feet. This correlates to both the informational data collected on the highway network and the digitizing accuracy for the U.S.G.S. 7.5 minute quad sheets. Data can be collected at highway speeds with the restrictions being data density and speed limits. The integration of a GPS receiver unit in a van or automobile could make the vehicle a "digitizer". One application for this concept would be the collection and/or verification of the off-system road network.

SECTION VI - MAP MAINTENANCE SUBSYSTEM

The automation of the map maintenance functions will vary widely from state-to-state as they are dependent upon:

* The Cartography unit's charter within the DOT.
* The state of automation within the DOT.
* The update source media available for maintaining the base map database.
* The aggressiveness of the Cartography manager in seeking automated support.

As the DOT completes the creation of each new geographic area, the success of the GIST-C project becomes more dependent on the Maintenance Subsystem. This subsystem will ultimately be the major component of the automated cartographic operation. Realizing that each State may operate differently, Figure 9 represents a typical automation scenario for the map maintenance function and Section VI will discuss the Map Maintenance Subsystem as outlined in Figure 9.

PLANNING THE SUBSYSTEM

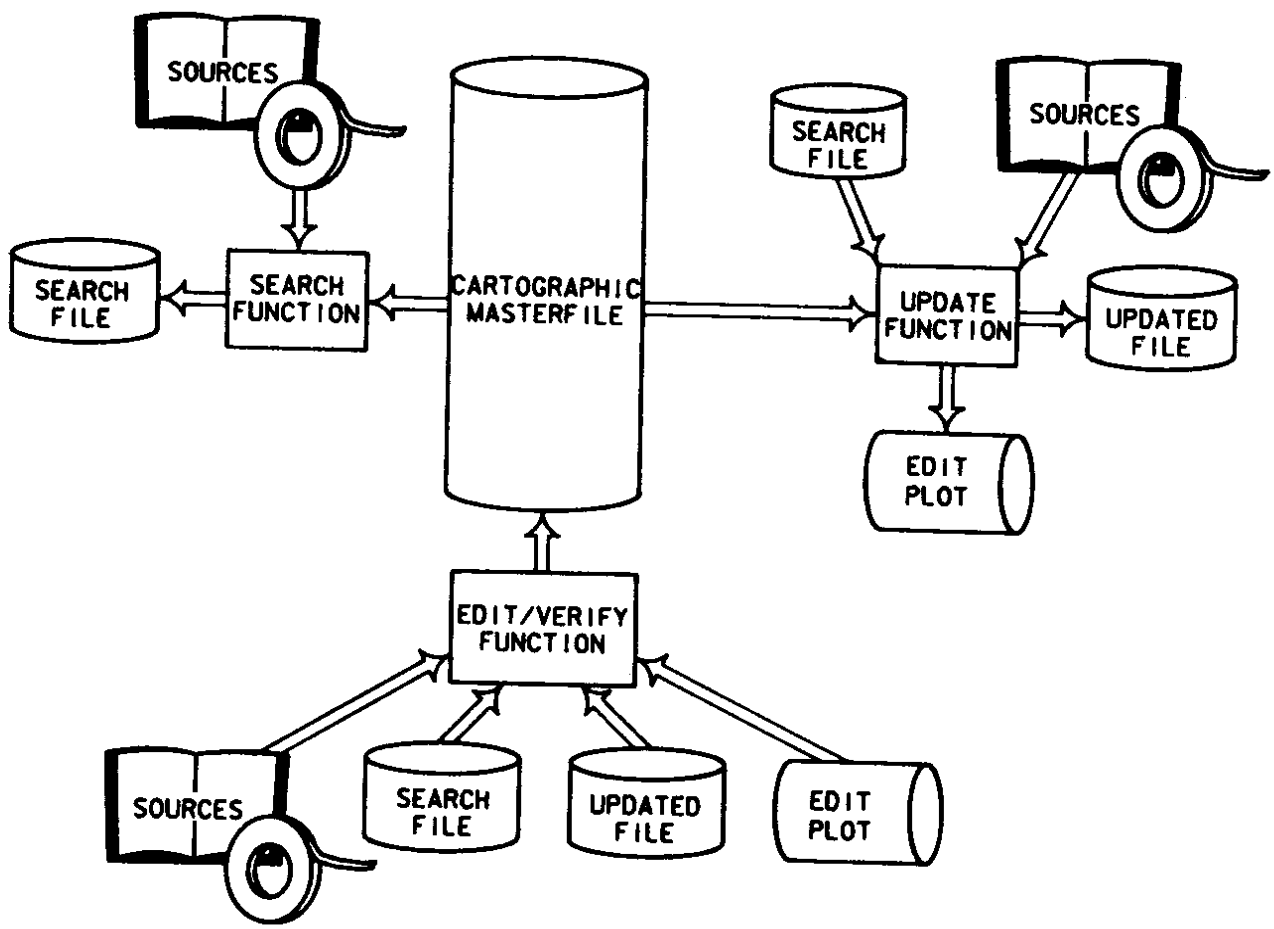
The objective of the maintenance subsystem is to maintain the data integrity of the GIST-C masterfile. To accomplish this objective there are basic functions that must be performed:

* The data must be gathered from the different sources and converted into a digital format.
* The edited converted data must update the masterfile.
* The masterfile update must be verified.
* The data must be valid and current

These functions translate into three sub-subsystems that integrate together to formulate the Maintenance Subsystem. The three sub-subsystem can be defined as :

* Search
* Update
* Edit/Verify

MAP MAINTENANCE SUBSYSTEM



Pennsylvania Department of Transportation

FIGURE 9

The extent of automation for each of these sub-subsystem will function upon execution of its small automated tasks by the cartography staff. The trigger mechanism for producing a cartographic product will initiate one of two activities:

* The extraction of an existing digital product for modification and finalizing.
* The execution of the complete maintenance subsystem for producing a current GIST-C database of a specific geographical area.

The first activity is strictly the execution of the Map Production Subsystem which will be discussed in Section VII. The second is a product initiated by the execution of the Map Maintenance Subsystem.

The ideal Map Maintenance Subsystem provides:

* The extraction of data by a boundary defined area.
* The extraction of a specific feature or feature groups.
* The protection against multiple update activities of the same feature or area.
* The creation of an audit trail for update activities.

Maintenance of the masterfile includes:

* The graphics database,
* The cartographic non-spatial attributes, and
* The reference system linkages

Data integrity of the masterfile will be measured by:

* Is the data current?
* Is the data valid?

The cartography unit will be responsible for:

* Keeping the graphics database current and valid.
* Keeping the cartographic attribute values current.
* Keeping the reference linkage current and valid.

Other DOT units will be responsible for:

* Keeping the HOST databases current and valid.
* Extracting and providing valid data for special map requests.

The continuous interaction between the cartography staff and the tasks will be designed to keep a GIST-C masterfile current.

A key capability of Maintenance subsystem will be the ability to extract data by geographically defined boundaries or by a specific feature. The boundary definitions may be county lines, city limits, political boundaries, quad sheet limits, etc. These extractions:

* Simulate present manual update practices.
* Organize the update procedures for better management

Extraction by feature will be more efficient in certain instances such as the updating of a particular transportation link or network. This procedure will be more adaptable to specialized applications where interaction between the HOST and the graphics database is needed.

Since the Maintenance subsystem activity is by geographical area, different stages of the system may be active for different geographical areas. These extractions are represented as the search file in Figure 10. The subsystem should handle multiple boundary extractions for or within an area. The following is a brief description of the three sub-subsystems.

Search

The search function is a continuous activity. The cartography unit collects update source material and maintains the search file. Update source material consists of:

* Present source documents,
* Automated digital sources,
* System generated turnaround documents, and
* HOST database extractions

As update information is received, digital data is processed and other data converted to digital format for the search file. Source data captured from a hardcopy media is converted via any of the data conversion processes described in Section V. The search file accumulates new digital data until the update process is triggered. Trigger mechanisms can be:

* Scheduled time cycles
* Spontaneous requests
* Published map inventory level
* Cartographic unit workload

Presently, published map updates are based on cyclic time schedules. One problem facing the cartographic unit is that manpower restrictions can lengthen that cycle to unacceptable levels. As the GIS concept spreads to other Federal and State agencies, many of their applications will be dependent upon the transportation network. Current and accurate information will be more critical. Automation of the cartographic processes gives the cartography manager an opportunity to be innovative and evaluate alternatives to the conventional time cycle schedules. Pennsylvania is considering a published map inventory level to trigger the revision cycle for map series to be published.

Update

Once the search sub-subsystem is complete, the update sub-subsystem becomes active. The update process extracts data from conventional search files, adds any digital files and commences update processing. The work effort for this sub-subsystem can vary depending upon assigned responsibilities. Alternate scenarios between the search and update responsibilities are:

* The search effort strictly collects and records the source information, identifies it for the update function, and performs the update edit for completeness.
* The search effort collects the source data and performs the data conversion functions in the search file. The update function moves the data into the masterfile and performs the update edit.

Edit/Verify

The Edit/Verify sub-subsystem again is a conglomerate of small automated tasks supporting:

* The edit tasks of the Search and Update sub-subsystems.
* The verification of the data updates to the masterfile.

DOT cartography units having database managers on their staff will want to make the masterfile verification one of their responsibilities.

UPDATE SOURCES

Realistically, the update source types are the same as for the Creation Subsystem previously discussed in Section V. Digitizing will continue to be necessary because some hardcopy documents depicting graphic data come from non-DOT sources and such sources are not automated. Scanning should have little impact on the capture of revision data. Digital sources and GPS technology should have an ever increasing positive impact on the map maintenance process.

The major cost of any database system is the initial cost of data collection to create the database. The success of any database system development is measured by the integrity of the maintenance for that database. If the collection process is simple, fewer errors will occur and more valid data will be the

result. The earlier in the collection process the data is converted into digital form, the more economical the collection process and error free the data.

The DOT cartographer should seek the automation of field data collection and office conversion tasks. The DOT cartographic community should support applied research activities for the use of new technologies for digital data gathering tasks. Many industries use data collectors which could be an interim solution to automating existing DOT cartographic procedures. New technologies such as kinematic GPS indicate a capability of collecting positioning data while driving at normal highway speeds. The adaptation and inclusion of this technology to collecting highway inventory is an exciting concept for making data more current. A single field crew could collect update data at a rate of 3000 miles a month instead of 6000 miles a year. Other technologies such as the extension of photologging technology, to perform roadway measurement calculations, show as much promise as GPS.

SECTION VII - MAP PRODUCTION SUBSYSTEM

This Map Production subsystem is the subsystem that produces the cartographic product from the masterfile. It is the visual result of the GIST-C system. The Creation and Maintenance subsystems are primarily internal to the cartographic unit. The Production subsystem is the interface module with the user. Figure 10 is a flowchart description of the Map Production Subsystem and depicts the subsystem supporting two categories of cartographic products:

* Standard products that are the responsibility of the cartographic unit.
* Special products that require interaction with the user and HOST databases.

Section VII will discuss the generation of cartographic products as detailed in Figure 10.

PLANNING THE SUBSYSTEM

The objective of the Map Production Subsystem is to produce cartographic products from the GIST-C masterfile. To accomplish this objective, the subsystem must support certain design criteria:

* Extract data from the masterfile by geographical boundaries.
* Customize the extracted area through the use of the non-spatial attribute data.
* Prepare digital maps for workstation display.
* Prepare hardcopy maps for presentation.
* Prepare separates for printing of cartographic quality maps.
* Interface to a variety of plotters to produce maps having varying quality requirements.

In support of above design criteria, the Production subsystem must perform the following tasks:

* Extract specific feature groups from the GIST-C masterfile based upon a geographically defined area.

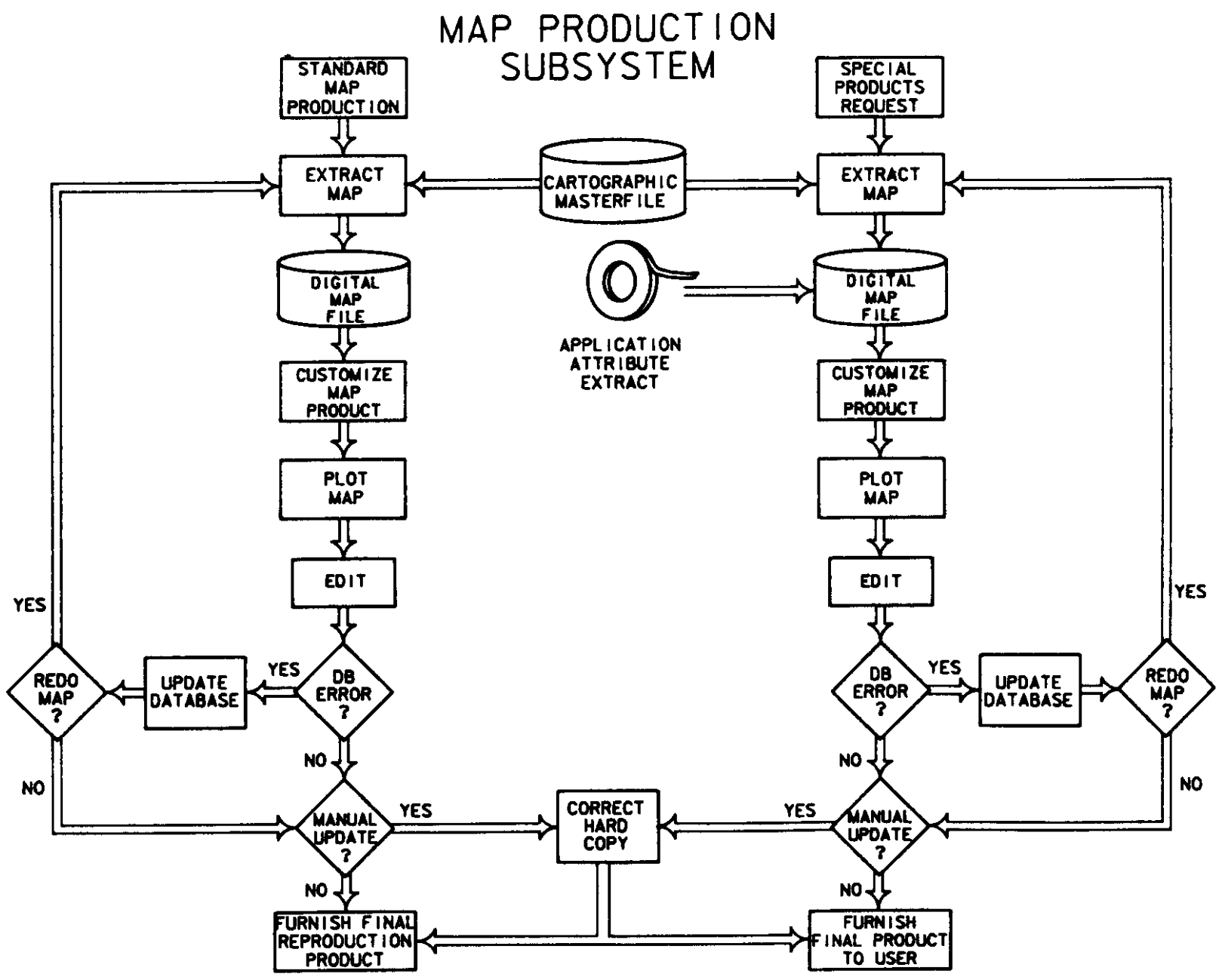

MAP PRODUCTION SUBSYSTEM
STANDARD MAP PRODUCTION
SPECIAL PRODUCTS REQUEST
EXTRACT MAP
CARTOGRAPHIC MASTERFILE
EXTRACT MAP
DIGITAL MAP FILE
APPLICATION ATTRIBUTE EXTRACT
DIGITAL MAP FILE
CUSTOMIZE MAP PRODUCT
CUSTOMIZE MAP PRODUCT
PLOT MAP
PLOT MAP
EDIT
EDIT
YES
YES
REDO MAP ?
UPDATE DATABASE
YES
DB ERROR ?
DB ERROR ?
YES
UPDATE DATABASE
REDO MAP ?
NO
NO
NO
NO
MANUAL UPDATE ?
YES
CORRECT HARD COPY
YES
MANUAL UPDATE ?
NO
NO
FURNISH FINAL REPRODUCTION PRODUCT
FURNISH FINAL PRODUCT TO USER

FIGURE 10

* Customize the extracted product at the workstation using the spatial manipulation and non-spatial analysis capabilities inherent in the GIST-C system.
* Deliver the completed requested map product.

Standard Maps

Standard maps are defined as those maps that are the scheduled responsibility of the cartographic unit. In most cases these maps result in a published map that is available to the public. Other standard maps may be annual or periodical maps the cartographic unit has "contracted" to do for a specific user. The common characteristics of this type map are:

* The map has a basically consistent content and format.
* The production of the map is controlled within the cartographic unit.
* The map will generally have a digital display counterpart that is used within the Department.

The digital version of these maps represent the published maps of the existing manual system. Presently, DOT personnel use the printed products as "base maps" for a variety of special purpose maps. The latest version of this digital graphic display map (like the printed "county" map in the drawer) must be accessible to the DOT user. The user must be able to copy and manipulate the map for his own purposes. The Washington DOT has stressed "user friendliness" to allow the user to do as much as possible and will demonstrate their system at the Olympia workshops.

As procedures for producing these standard maps become well defined, further automation can make them more responsive and

economical. Many of the steps in the production process can be designed to be taken during the night shift in batch mode. Eventually the production process for many of the standard maps will simply consist of:

* Setting parameter values,
* Executing predefined computer procedures, and
* Performing map finalization drafting tasks.

Standard maps in general will require high quality hardcopy output to meet cartographic specifications. Available plotters from the market place are discussed later in this Section.

Special Maps

Special maps will require greater interaction between the cartography unit and the requestor. The primary characteristics that make the special map unique are:

* The requestor of the special map is responsible for extraction of the non-spatial data and its validity.
* The request is for a one-time only or infrequently produced map.

Once the HOST extracted data is merged into the GIST-C database, the requestor will have to assist in the non-spatial analysis of that data. This will probably be accomplished in cooperation with the cartography unit personnel at a workstation. In some instances the requestor will be self sufficient in the use of the database management tools and will not need cartography unit assistance. DOT cartography unit managers should not expect this to be the normal occurrence and should plan upon this being a needed service. Special maps in any case will be dependent upon the use of the basic interactive tools available through the workstation. Further automation of the process is not likely.

PLOTTERS

Various plotters will be used to generate final map products according to the quality desired. Characteristics of plotters available today are:

* Electro-mechanical, electrostatic, photo-sensitive and laser
* Electro-mechanical, electrostatic, photo-sensitive and laser

* Digital data can be transferred to paper, vellum, mylar, coated scribe base, or film.
* Digital data can be recorded onto hardcopy media in ink, ball point, felt pen, electronic sensitization, scribed, or photo-sensitized.
* Plotters can support sheets 8.5" x 11" to 60" continuous roll and beyond.
* Plotters can produce black and white or multi-color outputs.
* Plot quality can vary from high cartographic standards to printer type resolution.
* Plot systems may be interfaced directly to the graphics system or configured off-line.

A general rule of thumb is that plotter system cost is directly proportional to required line quality. Most cartographic operations need the full spectrum of plotters. However, reality requires the unit to evaluate its needs and procure plotters that are cost beneficial. Points to note:

* Edit and check print plots will constitute a minimum of 50% of the total usage.
* GIST-C with its non-spatial analysis capabilities will increase the need for color plots.
* Immediate access to plotter output is an important productivity parameter.
* Laser plotters appear to have the best through-put speed to quality ratio.
* The plotter output support provided by the vendor is an important system evaluation factor.
* Off-line plotter configurations have greater flexibility and are more adaptable to a production environment.
* For high quality plot requirements the use of a plotting service may be a very good alternative to procurement.

SECTION VIII - STANDARDIZATION

A critical need in the implementation of digital mapping on a national basis will be the establishment of cartographic standards. The DOTs will need to address two types of standards:

* Cartographic standards addressing the presentation of automated cartographic outputs.
* Data exchange standards that provide for sharing of digital spatial and non-spatial data between cartographers.

CARTOGRAPHY STANDARDS

Cartographic standards are those that define the graphics representation for a specific feature. DOT cartographers will be well acquainted with this type of standard as it is also required in the manual process. The FHWA manual map guidelines published in 1972 include suggested cartographic standards. DOT cartographers have not established standardization for automated cartography but clearly have two choices:

* Maintain the same standards as established for manual maps.
* Create a new set of standards that is compatible with automated cartographic operations.

The first choice is obviously the easiest to make as it requires no effort on the cartographer's part. However, some of the graphic symbologies are not very adaptable to automated equipment. In fact certain types of symbologies will affect the efficiency of the system. Examples of this are:

* Shaded symbols
* Complicated repetitive symbology

Since there is nothing requiring the use of the manual map standards for automated cartography and since the purpose of symbolization is to communicate to the user a description of a

geographical feature, it makes sense to at least evaluate the second option.

To establish a good set of standards for GIST-C generated maps, the cartographer must become aware of the capabilities and limitations of the vendor supplied system. His study should include:

* The graphics display workstations,
* The plotter equipment,
* The software that supports the graphics display, and
* the software that supports the plotting system.

Using common sense, the cartographer will need to strike a balance between those symbologies that have become so established that a change would be detrimental to the overall operation and to those where a change will make little difference but add efficiency to the process.

DATA EXCHANGE STANDARDS

The exchange of digital data in general will be an unfamiliar area for the cartographer. It is important that the cartographer become:

* Familiar with ongoing standardization efforts.
* Involved in the development of digital standards.
* Aware of what agency or firm has digital data.

There are many standardization efforts being pursued in the United States and on the International scene. This Section will discuss three digital graphic standards that DOT cartographers will hear mentioned with respect to transportation. These three are:

* IGES - Initial Graphics Exchange Specification
* DLG - Digital Line Graphs
* ACSM - American Congress of Surveying and Mapping

IGES

The first IGES standardization efforts were initiated in 1979. AASHTO has been officially participating in the establishment of this standard since 1985. The Wisconsin DOT has been active since 1984. The AASHTO Subcommittee on Computer Technology has endorsed the IGES standard for the exchange of engineering drawing data. The standard is primarily in support of CAD/CAM applications and has been dominated by corporations such as General Motors. Future developments will evolve the standard into one called PDES which will be even more manufacturing oriented. The latest information on the status of IGES as it relates to DOTs is in Appendix A.

DLG

The U.S.G.S. has been involved in automating cartographic operations since early 1970. It established quickly that the automated version of cartography would require more systematic rules for interfacing the various capabilities offered by geography with "intelligence". U.S.G.S. also observed that the printed map offered less than an adequate guide for digital standards. Because of these operational needs, the U.S.G.S. has been actively developing in-house digital cartographic standards. The Survey has published a series of circulars that describe some of these standards. These digital standards include:

* Digital elevation models,
* Digital line graphs,
* Land use and land cover data, and
* Geographic names.

The primary standards of interest to a GIST-C system will be

the DLG standard and Geographic Names Information Systems for geographic place names. The DLG standard has been used since 1980. The digital planimetric data is produced and distributed in a DLG format as two types:

* 1:24,000 - U.S.G.S. Quads
* 1:2,000,000 - Small scale

Many find the DLG standard:

* Cumbersome
* Too detailed for DOT needs
* Transportation attribute data incorrect or not DOT oriented
* Work effort to modify greater than collecting the data themselves from the 7.5 quad
* Availability does not serve their purpose

However, this is a source of digital data and most vendors will support its conversion. The Idaho DOT has an agreement of understanding with U.S.G.S. for a joint project. The Idaho DOT will digitize the state to U.S.G.S standards.

The geographic names are part of a GNIS system being developed by U.S.G.S. DOTs may find this a labor saving way of getting place name text into their system. The U.S.G.S. will sponsor a workshop for dissemination of information and discussion at the Harrisburg and Olympia sessions.

ACSM

The most promising standard being developed is one that is in its final development stages under the auspices of the American Congress of Surveying and Mapping. A National Committee for Digital Catographic Data Standards was established in 1982. This working committee is the result of mandates from the

National Bureau of Standards to the U.S. Geological Survey to the Committee. There have been 8 reports published by the Committee and two public hearings. This standard specifically addresses digital cartographic data. The ultimate goal of the ACSM standards is to become a Federal Information Processing Standard (FIPS). Participation in this effort by the DOTs and the FHWA is noticeably absent. It is not too late - ACSM would welcome active participation by the DOTs and FHWA to initiate the implementation of the standards by a user.

The Committee work is to be finalized this summer and presented in the fall with approval likely around the first of 1988. A form for obtaining information on this standard is in Appendix A.

SECTION IX - MICRO-COMPUTER MAPPING

Micro-computer mapping acting as a PC workstation will have a definite positive impact on the the use of the GIST-C system. This impact is the result of:

* A technology trend that envisions PCs increasing in computational speed and mass storage capability.
* A vendor trend to incorporate PCs as the basic cpu unit at the workstation.
* A result that provides computational power at the point of user/machine contact and provides for special application development

PC ROLE IN GIST-C

The PC role in a GIST-C development is as an extension of the system:

* To provide for the processing of special applications.
* To provide maintenance update information at the source of activity.
* To act as a data transfer media for map systems external to the DOT.

Special Applications

The GIST-C concept will necessarily require maintenance of the masterfile on a central site computer system. A logical extension of that concept and role of the PC is for extractions of the road network from the masterfile to be downloaded to the PC. The PC could then extend the GIST-C database to fit special applications. This will make GIST-C available to remote DOT operations. An assortment of vendor PCs can be addressable through a LAN communication network. A wide variety of users can be reached, ranging from the use of existing PC equipment to specialty micro-computer systems. The PC extends an excellent opportunity for inhouse and private development of analysis type applications addressing:

* Traffic simulation applications
* Transportation planning modeling
* Oversize routing
* Emergency management

GIST-C Update

As GIS matures and GIST-C systems become operational on a statewide basis, PC mapping will likely extend its role into capturing update type data at the field source. In many instances the update data for maintaining the masterfile comes from outlying DOT offices. PC workstations will provide an economical methodology to collecting and editing update data close to the source. In many instances the use of a map menu would simplify the data entry thus increasing data integrity.

Data Exchange

A growing use of the PC for mapping will be as a medium for digital data exchange. The exploding growth of GIS will create an extensive market for PC mapping and will expand the need to exchange information between all levels of the government and public sector. Small state agencies and local communities will not need or be able to economically justify the purchase and support of larger and more sophisticated systems. The DOT must be prepared to take advantage of any digitally collected data and prepare itself for easy access to the exchange of data.

CONCERNS

The evolving hardware technology and software development for the PC as a workstation provides computer power to the professional beyond his imagination. The above discussion hinted only at benefits but there are concerns. These concerns are not

technical but people oriented:

* Will the PC proliferation manifest itself into a large duplication of effort?
* Will the user tire of the PC after the novelty wears off and cause poor utilization of equipment?
* Will the user cease to use the graphics Host and develop separate databases?

These are management questions that can be handled through the proper development of policy and people management. These concerns are no different than many of the concerns by the Data Processing unit, as they attempt to distribute computer power to their users. The important factor is to integrate the PCs as workstations into the overall system development. If a user, particularly a remote user, becomes isolated from the overall objective, he will develop and maintain his "own thing".

SECTION X - PRECONFERENCE POINTS FOR DISCUSSION

One of the purposes of this paper and the workshops is to stimulate thinking and to initiate a forum where cartographers can openly exchange information and ideas with their peers. This Section is dedicated to stimulating that interest and is attempting to provide a platform for further discussion and critique at the workshops. The following ideas are those of the author and are basically the result of the preparation of this paper and "bull-sessions" with many of you over the years.

GIST_C provides this new and exciting opportunity to assist all levels of the DOT operations. This brings to the forethought:

* How do I generate interest within the DOT?
* How do I sell cartography as an important and vital participant to ongoing GIST efforts?
* What are other DOTs doing?

GIST-C is not just a technical system - it reaches into policy and into selling ideas to others. GIST-C will require cooperation with federal and local governments never before encountered. The answers to the above questions are best found in communication with your peers. This situation leads to the first and major point of discussion:

* How do I keep this forum active on an annual basis?

In addition to this major point there are specific points whose answers vary from state-to-state. Where policy has dictated the answer, the cartographer may not be in agreement with that decision and is looking for solid arguments to change that policy. Other topics will have a common interest across all states. It would appear that a consensus opinion by the cartographers on any specific topic when presented to AASHTO or

the FHWA could have some influence on establishing or changing a policy. Some of the questions that may be of common interest are:

* What should the role of DOTs be at the National level?
* What is the role of FHWA in assisting the States in implementing Computer Assisted Cartography?
* Do we need special automated cartographic standards?
* What digital data exchange standards should the DOTs support?
* Are there any common areas for joint development or joint funding?

WHAT SHOULD THE ROLE OF DOTS BE AT THE NATIONAL LEVEL?

The DOT is an already established source of dependable maps and map information. The state is situated as a central political subdivision in the nation's governmental structure. The DOT in each state is recognized as a doer and is respected. The State DOT is therefore a logical entity to coordinate the transfer of digital data between the federal and local levels of government. The State will also be the best source to maintain the latest transportation network and its critical non-spatial attribute data. Political subdivision boundaries are also important to many states as they allocate funds based on some mileage criteria.

WHAT IS THE ROLE OF THE FHWA?

The relationship that began in 1935 between the DOTs and FHWA in the development of good planning maps has been a beneficial one for the nation. The cycle has come full circle and it is time to reestablish a new stronger relationship between DOTs and FHWA. If the State is to take an active and participating role in GIS and digital data exchange, the FHWA must also take an active and participating role at the federal level so that transportation has a voice in standards and

policies for digital data. The exchange of digital data will be increasingly important and essential to a successful GIST.

DO WE NEED SPECIAL AUTOMATED CARTOGRAPHIC STANDARDS?

In 1973 the FHWA published a manual that set out the standards for cartographic produced planning maps. Naturally, these standards did not take automated cartography into consideration. The FHWA and DOTs should collaborate in establishing a set of standards that recognize the capabilities and limitations of automated cartography. This could be accomplished by:

* The FHWA forming a committee of DOT cartographic supervisors to develop a proposed standard for automated cartography.
* The standard act as a guideline for the State cartographic efforts.
* The FHWA reevaluate its mapping needs based on GIST-C concepts.

WHAT DIGITAL DATA EXCHANGE STANDARDS SHOULD THE DOTS SUPPORT?

The standards developed by ACSM National Committee for Digital Cartographic Standards appear to be by far the best set to be adopted. The general objective for the standard is to make it easier to use databases developed by other agencies. The specification contains four basic elements:

* Create a set of primitive graphic elements.
* Develop a data exchange mechanism.
* Develop data quality specifications.
* Define a set of cartographic features.

The basic difference between the proposed ASCM standards and the IGES standards accepted for design are:

* IGES requires the translation of graphic symbols i.e. the interpretation of the graphic elements making up the "scalloped line" and then the viewer understanding that the "scalloped line" is a

woodline. The ACSM standards would pass the data as a "woodline" and the receiving system would graphically display the woodline according to the symbolization defined in its graphics system.

* The ACSM standard also supports the transfer of raster and grid cell representations which may well prove valuable in the future.
* IGES does not carry spatial referencing system data.
* IGES does not provide for data quality information.

ARE THERE COMMON AREAS FOR JOINT DEVELOPMENT OR JOINT FUNDING?

At first glance it is difficult to see enough commonalties between the States to focus on joint development efforts for GIST-C. There are so many parameters that would have to mesh to support computer development. However, there are two areas of common interest that could be beneficial to all parties.

* The automation of data collection processes to facilitate the digital conversion tasks.
* Develop a subset of the ACSM standards for DOT transportation applications.

An excellent area for investigation and development is the kinematic GPS technology. This technology can:

* Provide for a van or automobile to act as a digitizer.
* Collect highway inventory and management data while moving at highway speeds.

Because the ACSM has a set of standards, a "compiler" type of software could be developed to meet the DOT subset and still maintain overall ACSM standard conformance. This would be machine independent and optimize the transfer of data between DOT data users.

SECTION XI - SUMMARY

Cartography and the DOTs are entering a new and exciting era, the Information Age. Combining the power of automated cartography with GIS concepts, formulation of GIST-C, a computer system concept limited only by the cartographer's imagination. This FHWA sponsored paper and its associated workshops provide a forum for cartographers to become aware of the latest technology and to exchange their ideas and experiences with their peers.

GIST-C combines hardware technology, cartographic software, and database management facilities to provide a spatial database for engineering and planning tasks. The interrelationship between spatial and non-spatial data allows for presentation scenarios and responsive modeling that support engineering applications. More important are the added capabilities for analyzing pavement management, construction budgets and highway needs. The expansion of GIS systems to many professional disciplines and political entities will require cooperation in the collection and exchange of information never heretofore experienced. Many applications outside of the DOT require knowledge and status of the transportation network in order to carry out their responsibilities.

These automated systems may become a reality because of technology, but they are successful because of people. Cartographic managers and their staff will have obstacles to overcome but the rewards are worth the effort. The cartographic manager must manage his human resources with compassion and leadership. Aggressive cartographers can provide added value to

planning and management activities within the DOT if:

* They accept the challenge of change,
* Exert themselves into the DOT operations, and
* Advertise their skills.

Changing times do not allow conditions to remain static. In the mid-thirties the states and the FHWA joined forces to address a national need. Once again time has come full circle and the States and the FHWA must reestablish an even stronger bond for providing new concepts for better management of the nation's transportation networks.

Webster's Dictionary defines gist as " the grounds for legal action" or "the essence or main point, as of an argument". The gist of GIST is opportunity - take advantage of it!

SECTION XII - CONFERENCE OBSERVATIONS AND CONCLUSIONS

The primary conclusion of the two conferences is that they were successful beyound anyone's most optimistic projection. Approximately 40 of the 50 states were represented plus FHWA staff, U.S.G.S. staff, Bureau of Census, interested Pennsylvania and Washington state agencies, and the academia world. The resulting conclusion is that the DOT cartographic community is enthusiastically alive and mentally prepared for GIS technology. The prominant theme at the end of both sessions was " Let's develop this as an annual event where the cartographer and his computer support personnel can gather and discuss GIST-C with our peers".

OBSERVATIONS

A review of the presentations, demonstrations, discussions, and workshops at the two conferences provides the following observations:

* The definition of "what GIS technology is" is no clearer to the Transportation profession than it is to other professional disciplines.

* The type of conference planned for a "first conference" was perfect. Both states did an excellent job of promoting a relaxed atmosphere and providing the opportunity for attendees to seek the level of information that matched the state of their GIS development.

* As a group, the DOT attendees were attentive and enthusiastic about the potential of GIS within their Departments.

* The FHWA got a first hand view of the DOTs. This should help identify the various support needs required because of the wide range of state of development of the GIS technology within the DOTs.

* While the various DOTs and Federal agencies were on their own GIS paths because of internal mission

needs, there was a strong desire and realization that the cooperative sharing of digital data was the only reasonable long term solution for a cost effective system.

CONCLUSIONS

The author reached the following conclusions as a result of the conference:

* There is an extensive desire and need for an annual meeting of DOT cartographers and their computer support personnel. The conference should remain independent of other computer meetings to assure that the cartographic community will be able to attend.

* The short term success of having an annual conference will require the support of the FHWA. It is only through the approval of such activities by the FHWA that many DOT cartographers will be permitted to attend.

* Because of the need to share similar data, the DOTs and the Census Bureau will become cooperative partners in the exchange of road and planning data.

* Because of the early development stages of GIS technolgy, their is a need for the state DOTs to determine their role in this nationally developing technology and to establish some common "definition of terms" for better communication of the definition and characteristics of a transportation oriented GIS.

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Western Region Computer Assisted Cartography Conference
September 22, 1987
Christopher Fleet, FHWA

Before I begin my remarks, I would like to just take a little bit of a head count so that I can tell who's out there in the audience. I would like to see a show of hands of those of you who are cartographers or in some way involved in developing map products. That's just about everyone. Good--you're in the right conference.

Now, can I see a show of hands of those of you who consider themselves as transportation planners. Half a dozen or so.

Now, thirdly, can I see a show of hands of those of you who are cartographers working in some way in the mapping field where your unit within the state DOT is part of the Planning department. About three-fourths of you out there.

Now, can I see a show of hands of who the feds are. That's good, thank you.

I think that is instructive to me and perhaps to those of you in the audience. Whether you realize this now, I hope that you will realize it by the end of this conference, that work that you do--and I'm speaking to the cartographers now--the work that you is a very important link in your state highway program and all of the processes that support that program. What you do today and what you will be doing with the new technology, as it develops so rapidly in digital mapping, is very critical to the highway decision-making process.

You might be wondering why the Office of Planning in Federal Highways is co-sponsoring this conference. Some of you might have relatively little contact with planners. Perhaps only the stage at which you provide the many maps that are requested, such as system maps, traffic flow maps, county highway maps, and so on. But I think that this is about to change. For some of you, I think it already has. Your roles and responsibilities will be changing in light of the new technology. Technology that enhances your capabilities to supply the information needs of the planning process and other key functions of the highway program.

Planning has played a significant role in the highway development process since the 1930s. Rapid growth in automobile ownership and highway travel placed increasing demands on inadequate highway systems. These growing problems required the collection and analysis of information on highways and their use on a more comprehensive scale than ever before. Beginning with the Federal Aid Highway Act of 1934, the Congress authorized the use of 1½ percent of the highway construction funds apportioned to each of the states annually for planning and research purposes. Eligible activities included surveys, plans, and economic analyses for future highway construction projects. The act also created the cooperative arrangement that we see today between, at that time, Bureau of Public Growth, now the Federal Highway Administration, and the state departments of transportation.

When the highway planning surveys were first begun, they included a complete inventory of mapping of the highway system and its physical characteristics. Traffic surveys were undertaken to determine the volume of traffic by vehicle type, weight, and dimension. Financial studies were made to assess the state's ability to finance the construction and operation of the highway system and to indicate how to allocate highway taxes among the users of that system.

State highway planning departments today routinely perform many of these same activities to support the states' highway development program. They monitor existing routes to determine their physical condition and capacity. They determine the types and volumes of vehicles using these routes. They predict traffic as a result of future population and economic growth. They forecast future highway needs. They perform safety studies. They determine sources of revenue and compare this to future highway needs, and they develop a schedule of projects.

Improvements in the implementation of these activities will depend to a great degree on the state's mapping and geographic information system's capabilities. Shifts in government roles imply greater state responsibilities and flexibility today for transportation analysis than in the past. At the same time, resources that each state has are subject to competing needs. Fortunately, I think that the progress of technology is on our side today. What used to take months to do by hand can be done in days or even hours using computers. In many cases, the work can be performed at a work station on someone's desk rather than relying on the central

computer at some distant facility. Advances in the hardware and software that we will discuss the next three days enable us to accomplish things that we had never dreamed about five or six years ago, whether it's for updating a map or running a complex, sophisticated forecasting process. I think the technology is getting better, less expensive, more sophisticated, and easier to use all at the same time.

Some states have acted quickly to adopt this new technology. Other states not quite so quickly. Out of 40 states responding to a survey that was sent out recently, about half of the states do no mapping by computer and only two produced all their maps by computer. The responses to the questionnaire indicated wide differences among the states. Some states felt the new technology resulted in better maps and a better product while others disagreed. Training time to become familiar with the new technology varied considerably from 1 week to 30 weeks. About one-quarter of the states are using USGS data and products, the others are not. For your information, we have summarized the results of this survey in a handout, and I think there are enough copies for everyone. If you have not received a copy, be sure you do before the day is out.

The wide variance in the responses raises some important questions that I hope will be addressed and answered--hopefully will be answered--during this conference. For example, how steep is the learning curve. Is it a difficult one to get through? Why aren't more states taking advantage of USGS products? What happens to existing staffs as this new technology is introduced? What happens to the level of productivity and quality of the output? Are their significant hidden costs associated with this new technology? And finally, perhaps most importantly, what is the best way to improve coordination and communication among all of you who are involved in this rapidly changing technology?

At the federal level, we are sensitive to the need for improved coordination with other agencies. These include USGS. The geological surveys' most familiar product, of course, is the 7½ minute quads. But the work that they are doing with the Census Bureau and the 1 to 1,000,000 scale mapping for the TIGER System is also of significant interest to us. We will learn about the USGS products in the workshops to come.

I mentioned Census and the TIGER System that they are producing. We foresee a major advancement in the way inputs to the transportation planning process can be handled once TIGER becomes available. The census folks, I believe, are also here to speak with us through the workshops and during the breaks.

The URISA, Urban and Regional Information Systems Association, has been interested in geographic information systems since the 1960s and proceedings from their conferences include articles on this topic all of the time. Most of their focus though I think has been on natural resources and land record systems. The ASCM, American Congress on Surveying and Mapping, guided the National Committee for Digital Cartographic Data Standards. At AASHTO, the American Association of State Highway and Transportation Officials, the most recent event sponsored by that outfit was held in March 1987, in Tempe, Arizona, to do several things: To evaluate hardware and software available to the states with regard to geographic information system, to gain insight into how GIS technology may be applied to transportation problems and to discuss the potential for joint development of GIS software for transportation applications. As a result of that symposium, AASHTO is developing a forum for further study, making it a high priority item among the states. We also believe that state mapping activities should be carefully integrated with the agency's database to create a full-function geographic information system. We will be coordinating closely with the AASHTO activity and you, perhaps, at your state level may wish to do the same.

One of our roles at FHWA is to encourage and assist technology sharing among the states. This can take many forms, such as courses, conferences, site visits, and any other means that will help ensure that the professional staff has access to the state-of-the-art. This conference is a good example of technology sharing. We have seen this conference grow from the earliest perceived needs to one which you see before you here today and are about to take part in it. This would not have happened without the hard work and devotion of a group of key individuals from Washington, and I would just like to mention several of those people. Bill Hordan was the initial contact at Washington State when we first started working on this conference. Rhonda Brooks who you've met, no doubt, has done an outstanding job in the overall conference coordinating. Professor Scott Rutherford has provided important guidance along the way. Jim Toohey, Assistant Secretary for Planning, Research and Public Transportation, has been very supportive of our effort. And I

would like to thank also Paul Moody and Ron Cihon who have spent countless, countless hours in pulling this conference together and providing their guidance. I hope that I have not left anyone out.

We had three broad objectives in mind for this conference. First of all, to provide a forum for transportation cartographers and others responsible for state mapping to exchange information and address issues on the use of computer technology, and the conference has been designed to give you ample opportunity to discuss these issues among your peers. Secondly, to afford state DOT's the opportunity to provide input to the future direction of computer-assisted cartography. The results from this conference, along with the results from the Pennsylvania conference held last week, will go together with Frank Cooper's paper that you will see in the next session to form the proceedings of this conference. We ask that each of you participate in the workshop sessions and lend your expertise to the discussions. And the the third objective, and perhaps most important I think, was to emphasize the critical role of the cartographer in the overall state highway planning program.

Vendors have been invited to demonstrate their hardware and software, and I hope that you will grill them on their products, how their products will do the job that you need to have accomplished.

Maps have always been an important planning tool; however, I think we are just beginning to realize the potential of new technology to expand their usefulness. With data tied to a physical coordinate system with a wide variety of statewide data accessible by the same database engine, states will be able to realize the potential to fulfill a wider variety of highway information needs. GIS that will allow a range of planning analysis requires a data structure that makes possible both graphic display and spacial analysis. But without a good base map, the glue that holds the database together, these geographic information systems are not possible. This, I think, is a key role that the cartographers need to play.

No longer can mapping be thought of as primarily a service function to other parts of the state's DOT or local agencies. While your concerns in the past may have been with accuracy and detail of alignments and intersection geometries, we believe that the future will challenge you to move into new areas and to produce new products. Discuss with the planners and others involved in the highway

departments their data requirements and keep these in mind when you are designing your mapping systems. We have found that other agencies in state governments and in private sectors, for example, utility companies, are building complex GIS's. USGS and Census, too, should be considered for what they have to offer and what you can provide to those agencies in return. The accelerated change in technology is not going let up. We can look forward to effortless data transfer between computers of different architectures, higher resolution screens, better user interfaces, and stand alone desktop micros hooked up to a CD ROM or laser disk that contains the entire state geographic information and all the attribute data associated with them. Managers will want to have this capability on their desktop so that they can make real time answers and make real time decisions. Only you can ensure that your state's mapping and information system needs will meet the needs of the future.

Thank you.

2:PR&PT10

Western Region Computer-Assisted Cartography Conference
September 22, 1987
Frank Cooper - Cooper Technologies

Paul didn't cover all the announcements. The people that were in room 205 last night--you are excused from the lecture if you should desire. I don't think we're going to uncover anything. I think we've turned the tables on about everything there was in that session last night. And also for a matter of information for Mr. Gendrich in Nebraska, I'm trying to prepare a second edition of that paper so you can sleep better on the way home.

Let's see. Now here it is. I guess we'll get down to what I'm here for--a little power to the projector. Do we need to do something with the lights--do you all see that? There seems to be a slide missing. I'll just ad lib this then.

One of the things I started the other session off with and I'm going to start this one off with is a few discussions; first, about experts having been with the highway department, I always look forward to experts willing to listen to experts in my field. And I awaited them with anticipation of what fool they would make of themselves, so I've come prepared for this.

The other thing is the GIS expert. I would like to capture something from Gerry from Vermont in that there is not such a thing as a GIS expert and if you find one that so claims, hold on to all your pockets. We can't even define GIS as far as it applies to various disciplines. I went to the ASCM conference and I see this brochure that says "local GIS system, 2 million scale photography, remote sensing type applications" so that anybody who reads that if they'd been hearing about GIS, it would have seemed no immediate application for GIS and their discipline. So GIS has a lot of meanings to a lot of different people and I think part of the problem that we have in the Department of Transportation is that we have a lot of experts that have never done a cartographic map for a DOT, have never done the applications necessary for the DOT cartographers that are telling us what it is that we're supposed to be doing instead of asking us what it is that we need and I think that this is what this conference is all about. That's the reason we're trying to

bring the federal agencies and the state agencies and eventually, all the communities together so that we can get a better communication technique between ourselves to describe what it is that we need and what can we do for you and what can you do for us, and to build that communication because we are entering this GIS technology that is ever encompassing. It is going to change the way things are done at all levels in the area of data processing. It so happens that in this area of cartography and in this area of decision making, that you are on the front end of those things.

As far as the conference, we will start with what the purpose of it is and while we welcome all of the guests, you'll notice that most of my remarks about this conference and in the paper are directed at the DOT cartographer. I think the discussions with Tom Perry, and I think Paul mentioned it earlier, he could not remember any conference that was put together that was specifically aimed at DOT cartographers where they can get together and talk with their peers and talk about their problems and find out from people if you're not doing anything, find out that people are doing something and maybe for the first time be able to talk about GIS to another mapper instead of the data processing person or some of the engineers or whatever the case may be and I know that means a lot. It feels good to see that someone, that you're not the only person in the world that has these problems. These problems are shared by many.

The second thing is this is your conference and I know that this is the way FHWA feels, it's the way I feel, it's the way Washington feels. We knew that in two and a half days we could not create from scratch, so we said, "Okay, we'll start with something." People have something to start with, it's very easy to say, "No, I don't agree with that, I do agree with that." It triggers a thought or whatever the case may be and we want your participation in these workshops. We're going to have people there to lead and try to bring out discussions--and we want your comments, your feelings. There is no such thing as a dumb idea or a dumb question. It is many of the dumb ideas that are in the applied areas. We find that a lot of times that a person who's down in the trenches has an idea says, "Well, you know, if I could just do this I could produce something," and he's afraid to bring it forward. Well, here's your chance. Bounce it off somebody that probably has the same dumb idea and is afraid to bring it forward also. For the latest technology, we've tried to bring you speakers and we're bringing you experience of people doing things.

The vendors--we've tried to cover a base, I'm not sure if all the vendors are here, but I know that we have some of the system vendors here. We have some of the output people here that are producing, you know--a lot of people don't understand that once we get all this beautiful stuff on the screen, that it has to get over here at some point in time on a piece of hard copy to distribute either to the public or something of that sort. There's a lot of internal situations where we can give them a digital map, but we cannot at this point in time do away with a hard copy map. As of today, I do not know of any households that are carrying digital systems prepared for maps. That may not be too far in the future--especially in cars. I guess the most important thing, I think, of the conference, is the peer fear business. You are going to meet people--your counterparts--that are working in other states. Get their names, get their ideas, get their telephone numbers. The next time that you get this weird idea that you don't know who to bounce it off, bounce it off one of them. Or if you remember something they said that they were doing or trying to do or they thought they'd have done in six months, give them a buzz. That's what this is all about. A lot of you probably talk to by phone, but now you've met them, you've got a face connection with a phone number and that's probably one of the most important things you will get out of this conference.

And the last is the fact that this is--there's two things--one, we hope that this conference is a starting point. I think one of the things that we'll talk about for the next two and a half days is when is the next one. What can we do to have this as an annual event or whatever you all feel is a likely candidate? And the other thing was that the paper was basically a starting point. Again, we knew that we couldn't come in here and create everything in 2½ days, so the basic purpose of the paper is to kind of give you all the idea of what's going on and a point to start with at the conference. Again, it's a lot easier to say, "Yes, I agree. No, I don't agree. I wish that you would add something," and things of that sort, and I would like to mention on that if any of you have comments on the paper either in one of the workshops or if you want to write it down, just make sure it gets to some of the Washington people so we can get those comments incorporated.

What do we want to be accomplished? We want you to leave here feeling like that you know more in the technology area than when you came. That maybe you'll see a piece of equipment or you'll hear an idea or you'll hear something in the area of technology that you want to keep up to date on or that you'll find a service that

may be available that you didn't know was available before you got here. I've already mentioned the peer contacts and I think it's so important to find people that maybe are ahead of you or maybe at the same level that you are in this process of evolution--this cartographic mapping system--and that you have somebody that you can bounce ideas off of, that you can talk to about resolutions of problems.

I guess I like this one best of all--stimulate discussion. I put that in there because it kind of gives me the right to do whatever is necessary to stimulate you all to do the talking. I can agree with you, I can play devil's advocate, make you mad, or anything of that sort to get that idea, that stimulation of what we need to do and what you think out on the table and in front of everybody so that we can . . . because this is really an important part. Cartography has an opportunity to expand itself into the operations of the DOT that it's never had the opportunity to be and it is an opportunity and we have got to get you out there with your ideas and pushing.

Common interests--one of the things that we want to talk to even though each state operates separate, there's got to be some areas of which we have common either interests or common concerns and maybe through this forum we can begin to get together on some common ways so that we don't have to solve the problem, the same problem, in 50 states. If we can come together and either through AASHTO, through the FHWA, or whatever vehicle we can find necessary to get some of these common things going so that we're not all doing the same thing. There is enough to do without us all repeating the same thing. If we can beg, borrow, and steal from each other, we can get down the path a lot faster.

And then the last thing, there is a future forum. I think at least I'll cheat a little bit here. I think from the Pennsylvania Conference if there's any one theme that came out of that is when are going to meet again, how are we going to meet again, what do we need to do to set this in motion that annually we can get together as cartographers and discuss particularly the GIS thing and of course, its related aspects such as data collection will come forward in the future. This is an important thing for every one of you to remember as we go through here. Everything I say will be agreed upon and disagreed upon because there are 50 viewpoints out there and everything that you say will be agreed upon and disagreed

upon and while we have to talk in generalities, remember that your statement has some unique circumstances and what you have to be aware of is to quiz these other states that are doing some things that you don't really understand. Why they're doing them and why you have such diverse opinions, such as in the area of the 100,000 digitizing that has been going on. You have some states that are totally rejecting it I think you have Wisconsin who is using it, they feel successful, and I think what you have to do, and unfortunately Wisconsin is not here, but there may be someone from the other states that are doing that, is why are they able to do this? And you have to pick out of the reason. Just the fact that they're doing, doesn't make it viable to your situation because you've got more states saying they aren't. Is it because they're behind or do they have a legitimate reason. And I think what you'll find is that the decision made by each state is because, in their situation, they have a unique situation that either allows them do that or on the other hand makes them feel like that it is not the thing for them to do. In the area of digitizing, we'll talk about collecting quality at the digitizing stage. You have some states that are going to use the 7½ minute quads to digitize from and after that point they don't intend to use the USGS quads because they feel like the information that they maintain on their maps they already get better than they would be through USGS. And then on the other hand, fortunately, you have Idaho who has an agreement with USGS to digitize their state to those standards. So those are the things you have the opportunity to discuss with the people and to get from them why they made that decision or why they made that decision not to do something.

I'm not going to read the paper as you all probably see is obvious. What we do want to try to discuss as we go through the talk this morning is the cartographer's role in computer-assisted cartography, GIS, some standards, microcomputer mapping and some points for discussion. The cartographer's role is, of course, the most important aspect in the entire theme of things. Machines just perform activities and it is the cartographer's role as the human being involved with these machines to develop the machines that can provide them with decision making vehicles for DOT administrators that will make the project a success. Any of you that have dealt with automated systems and know that I can create the finest system possible when judged by my peers, but if it is rejected by the user it is a failure. And I have seen other systems which I thought were really rather "Mickey Mouse" but the user was so intense on using that system that he made it work--that he was happy with it.

He wanted improvements, but it is the cartographer's role as a user and developer of the base for these decision-making processes to get active in that area. There's actually two parts to the cartographer. They have a supervisor and it is important that supervisor provide the overall direction and we have to look at these things realistically. If you're going to solve problems and get to the answers that need to be done, we have to realize that we're dealing in an engineering organization that is primarily run by construction engineers, maybe some design engineers. Planning exists because it has to. These people tolerate planning as a necessary evil, in most cases. Some states it may be different, but I'm not sure too different. Mapping is even further down over here in the end of the planning area and so that this man has a job, he's got a selling job. He's got to find the technology, he's got to put it together and let his administration understand the importance of his involvement in the development of this GIS system and in providing that base map. It would be kind of scary if we asked ourselves the question if the federal government was to pull funding away from mapping, how many states would still be mapping? I won't ask that question. I won't embarrass anybody. I've talked to enough of you to know that there would probably be very few because we're not viewed, we're not visible at the top in the administration. What we as cartographers in the near term have got to do is change that answer to "that we wouldn't be gone." Because we have become such a vital force in the decision-making processes, that we are an essential ingredient for the overall operations of the Department of Transportation and that is not done without selling, without you participating, without you knocking on doors, without you finding who in your department is really interested and who is going to support. It's a job.

The second thing, I guess, is harder. How are we going to get the cartographer involved in the development and the implementation of the GIS. And the other is the leadership. You've got to move up to the forefront or you have to find somebody in the organization who will be that forefront. Let him know how important cartography base in the development of the GIS is from their viewpoint. And enthusiasm. Nothing gets done if you don't believe in what you're selling and you have to be enthused, not only to the people above you, but that is very important to the people that work for you. If you're enthused about automating cartography in the development of the GIS system and what it can do and the opportunity that it will provide to the actual cartographer doing the work, then you have to get that message across that you want. And he has to understand. He is

going through a major, major change. He is changing his profession. In fact, in the last session, David Green suggested in the paper that probably the most important issue is: It is the cartographer that is in the changing role at this point in time. There will be other professions that because of this development will also enter into a changing role, but at the present time, it is the cartographer that is in a changing role. And in that changing role, he has an opportunity to not only increase his impact on the DOT, but also will further his profession. The other part is human resources and I will talk just briefly on this because there is a talk on it, but the psychology aspect, and I have to say, according to the paper there, it is almost verbatim from Mr. Moody--he has very strong feelings in that area. I thought it was really well done. It is very important in that enthusiasm that your people underneath you feel that you have sympathy and understanding, but you also have to get the job done. That's part of a supervisor's task to make sure the job gets done, but if he can get his people going with him he's going to get it done better and faster. And then, of course, staffing will be discussed. What type of people do I use and that type of thing and then training. Do I train the operators I have or go to the outside? How do I train? Of course, the vendors supply some training, but I think in general, you'll quickly get into it and find you need the kind of tailor-made training that fits your particular needs.

The next thing we want to move to is computer-assisted cartography. This is my definition and I guess personally I have a hard time separating computer-assisted cartography and GIS or GIST as it would be in the paper, but I think the purpose here in the discussions with the people from Washington and Pennsylvania was to realize that there's a lot that we can do even if we don't attach attribute information. That if we just automate the cartographic applications themselves there is an awful lot that we can get accomplished because of the fact that we have a very sophisticated graphic systems available to us today that let's us do a lot of things that we do manually, in a automated mode even quicker and better even without the power of GIS. What we really want to do in computer-assisted cartography is not just digitize the road and throw it out there and bring it back. We need to look at automating the entire processes and that goes all the way from the data collection aspect where we have field people out collecting information; that organization or its existence will vary from state to state. In many instances, the mapping and the highway inventory type people are together. Sometimes they're in different organizations. It really doesn't make any difference. I think

one of the next major efforts that you're going to find with technology is the ability to collect this information digitally. In this business of collecting it in a vehicle, people come back and punching into the machine, is a source of errors and that type of thing and the technology is on the horizon for us to relatively cheaply automate that process so that we can do what seems to be common today--do more with less. Not only do we have to get the data gathered, we have to get it into the system. That's not only the creation on it, we have to maintain the system as we know we have information coming in from all sources--construction plans, plats, newspapers, name changes; there's all kinds of sources that a lot of people do not understand that cartographers at the DOTs use to try to maintain that excellent map that the public buys, and what you have to do is to automate those procedures, too. Part of the process is after we get it built, we have to get it out of the system and we have to get it out in a quality manner, so we have to look at plotters. We probably can use all kinds of plotters in the cartographic area. We have a lot of edit plots in which we would just like to see things come out as quickly as they can so we can do the edits. We have colored plots, which means we may use pen plotters or may even use electrostatic color plotters. Technology has come along; we get cheap enough we can use those kinds. And then what a lot of people keep saying is that we're going to have this digital map internal but we still have to print the map for the public, so we've got look at quality type plotters. And in the past, of course, that's been photoheads and scribing type machines, and the new technology today, I think what looks very promising to all of us is the laser technology that can get the fine lines to do the types of maps that cartographers think are necessary. And this may be if you're a rich state, maybe you can buy one or the services--there are a lot of--I forgot the word--anyway, the people that provide reproduction services are buying this equipment and some of it is pretty unbelievably reasonable. So, here's an opportunity and a method to get that data that you're going to capture and get it digitally on the screen and get it out into the system. But you have to look at all of those aspects to really get a system which you would say is a computer-automated cartographic system.

What do we want to do? What we want to do is to produce maps. We want to produce all kinds of maps. The mapping you see is a county map of Louisiana and it's called a parish. We want to produce that type of map. We want to produce what we might call regional map. This is a regional district state highway system map. In other words, it's I don't know how many counties, parishes, but it is 6 or 7

and we don't have all of the detail, but we have the important information that deals with that particular map in that area.

What we want to do is take the sources and automate those sources so the we're either creating the map or that we're maintaining the map. We want to keep a master file or a set database of that map so that, hopefully, one entry of the information will satisfy multiple sizes of that map. And then of course, we have to extract information from those maps to either produce digital products that others within the organizations use or that we go to either some type of hard copy output.

What are we going to do that with? We're going to do that with the computer system and some of the things it has to have--it has to have storage devices, and output devices, and workstations so that the users can manipulate it.

Back up. One of the maps that we want to produce is smaller-area maps say, such as townships or cities. We want to extract that information with the same database.

All right. Let's talk about geographical information systems. This is a definition of--my definition of geographical information system and it has already been tailored a little bit towards transportation, but I think the key aspect about a GIS system is that you are talking about the feature and you're talking about its location. If you look at, I guess, a GIS system in the broad sense, what we're basically talking about is the big picture, is the graphic feature and some non-graphic information attached to that feature. And I guess what makes the general category kind of separate in the GIS aspect of things is the fact that we have that location. But there is no reason why you cannot use two other coordinate systems. It's just that in the transfer of information, maybe even between yourself, and certainly between other people, they have to know what that coordinate system is to be able to use your information. So what we have is, we have a description of the features, we have its location and then we may carry other information about it such as description, what some of its physical properties are, and its owner. That owner may be the highway system that it's on, it may be the property owner, it may be a class of urban area in which we want to analyze information. That's just a rough down, taking that and using the bullet points such as the database and features and geographic locations, the description, properties, and the owner.

What is GIST? GIST is basically just a GIS that is specifically directed at transportation and in the paper I discussed two types. One was a GIST-C and one was a GIST-D. To just briefly touch on GIST-D, that is looking at the design aspect of things and that will be the area that will follow. Already in Louisiana we are collecting surveying information that has a GIST base to it, that is, when we collect a curve or a fence with our digital collection systems, we know that is concrete, we probably know that it is barrier curb. We know that the fence is 4 to 6 feet high, we know that it's a Model R fence, and we've already gone into production with some of that and the power that lies in collecting that information in the GIS formatting that could have an effect on the design in the future and what they will be able to do quickly as far as preliminary estimates and some early analyses is that they tune that design to fit the needs of the project, it's really--it's almost unbelievable. And as that moves into the design area, that we will find the development of plans taking to this changing role by those people and, hopefully by then the cartographers will have already mostly made those changes in moving onto higher things.

I like to use this diagram. It doesn't necessarily fit all vendors and that's not the purpose of it but it's kinda; people with limited brain power like myself, I can break this thing down and I can think of the GIS system as a graphic database file here and a nongraphic database file here and the vendor has made some way in which I can attach that information. And what I want to do, is I want to go and look at a piece of graphic data on my screen, whether it's a road or a feature or an area, where ever that may be, and ask the system about its characteristics. In other words, if I took the road, I may want to know what highway system it's on, what it's surface type is, what it's pavement distress factor is, whatever kind of information I'm interested in, I can respond on the screens of the graphics feature and have that information come back to me about whatever that particular point is or segmented areas that might be in some of the pavement systems. The other thing that I want to do, is I want to describe certain criteria. I want to say, "Show me all of the parts of the road that have this type of characteristics," and I want to turn them green or red or give them a line symbology or whatever it is to do so that I can begin to make analysis of that system and then as I go forward and since most of the DOTs--the other reason I like this--most of the DOTs have separate systems, I'll refer to them as a host system, in which their databases are already carried and they're already maintained and there's inquiries going into those systems all the

time that have nothing to do with graphics. And what we want to be able to do is to go into those systems and extract that information out and link it to our graphics system. I guess make a subanalysis on the extraction that I'm only interested in these certain characteristics and then when I bring them over to my graphics is to use the various scenarios about "what if the maze meter reading is less than this and the pavement distress fact or is this and this, and the ADT is less than this," turn all these red. Those are critical conditions and I want my highway budget to address those areas first until I see that its needs are twice as much as the money I have available and then I have to go maybe to some subjective or further analysis to come up with those needs conditions.

There are three major areas in which I feel that GIS of today should address: engineering, data, and management. This is related to the decision-making policies of the people at the top and it concerns the scenarios that we were talking about like needs and priorities. It concerns with what they take to their legislatures and to the public. But with all we have to do through this analysis is to get the penny added to the gasoline tax. If they increase the construction budget $50,000,000, this will pay for all of the equipment that would ever go into the cartographic area. And it is the way that we have to make things visible to the people at the top that this system is valuable to them as a decision-making tool and it is through those efforts that we will no longer be dependent upon what kind of funding that will be an integral part of the organization.

This section is to the transportation modeling area and this is getting down to where the workers are as we build the GIS systems, then there are a lot of simulation programs that are really quite good that exist. The Federal Highway Administration has spent a lot of money on it in the past and the problem is that we no longer have the troops to fill out the forms and gather the data to get it into the system. One particular program I think is very good is NETSIM, but it takes a lot of work. But through GIS systems, or maybe through some skeleton type of planning and evaluation models, we can actually get the operational analysis into this needs area so that when we see that we have to, say take a four-lane road and we're going to have to go to six, that maybe through some left-turn lanes and computerized signalization that we can only spend 25 percent of the money and that will help us four years on down the road. And when those leads outstrip the money available, maybe that's an important factor. We don't have the time to get

those things into our needs analysis today. We don't have time to automate in the area of--a lot of the states are behind in their early network analysis and the MPO planning analysis. It's just a matter of manpower and funding and in most instances, I think you're going to find these areas in the DOT cut down to the minimum to the point of well, there's no need cutting that person anymore because what I'm going to be losing is 70 to 80 percent of the federal money. I think they've already taken all the surplus away. The story that you can hear is that we've gone from 17 to 6, we've gone from 12 to 5. We no longer have a field crew and all these types of things have just been stripped to the bone and what we have to do is work ourselves back up. And then the other, of course, is transportation design which I just touched upon as it enters into the design criteria.

One of the interesting things that in the design area one knows at the point of design what type of pavement is there and it is carried on through the construction and we end up with asbuilt plans. We already have the data digitally collected.

It would be nice if it is already there. If it is already built in as a database and just transfer it forward into our maintenance management systems. And I think that's where we're heading. We're looking--what we're really heading for is life cycle management systems and I think there's been some interesting papers--one of them by Jim Porter out of Louisiana talking about life cycle. We have the design and we have the construction and maintenance of the operation, but they still work independently. Design is trying to cover a lot of problems through design specifications, but no one tells, say in the bridge situation, no one lets the maintenance people know that that bridge needs to be painted maybe in 5 years and if we have to paint it in 4 or did we not have to paint it in 7. Those are the types of management information that a GIS system is going to slowly develop. I know in talking to the people of Oregon last night, it was a county or city that is looking at something similar to their aspect, I forget what it was, but it was either some type of spray that they were using and did it work last year or did it not and those are the types of things that a GIS system developer are going to provide our organizations.

I think one of the things that is least understood, and I think certainly by the vendors and by many outside agencies that deal with the DOTs, is our reference system. We basically have two types of information that we are interested

in--there is the planning area where we're interested in land use and things of that sort--but, as a whole percentage of the overall situation of the DOT operation, that is less than what is generally dealt as far as the needs of priorities--and what is in pavement management and maintenance management in all of the systems. What we are primarily interested in there is the road itself and the condition of that road and we look at those pieces of information in two types of ways. One is by segments or by linear elements. For instance, in pavement management, we don't look at each pothole. Most management systems like that, they got so many potholes per mile or half-mile or whatever they want to use in the system and in Pennsylvania they made the decision that their pavement management system can be managed roughly on the half-mile segments. So your state has come up with some type of thing that it wants to do pavement management or whatever it is; you're looking for types of statistics that look over that linear element. These are the types of things that where the intersection is and some details about the map itself do not necessarily have to be correct, exactly, because no one is actually looking at a point-to-point situation. What they're after is that these are segments of road that are red and blue and green and whatever the legend tells them that means. And what we do is we start at some point on that road and we go down it, and there is no way at this point in time, maybe technology will get there, but you give a maintenance man a longitude and latitude reading and tell him that that's where his culvert is--I mean, that just absolutely has no meaning. Then you tell him to go down .15 miles from the intersection of Route 6 and 7, you know, he can grasp that and you know he can go down there and said, "Well, I checked that out. It really looks okay. But the problem really seems to be some drainage built up for some reason at log mile .25 further on down the road." And those are the type of things the man in the field--any record system--this is one of the things the DPers are getting to jump on you a little bit--one of the things you have to remember is the man, we're building databases, we're building graphical databases, we're building informational databases, and the data, if we're going to make a decision on it, we want it right. And the easier that it is for the man in the field to collect the information, the better the data. I don't care how sophisticated the computer program is, you can always find a programmer smart enough to write anything. Although what it might cost you to do that might be another story. But you cannot develop a system that the man in the field cannot use and that he cannot use realistically and the man you are dealing with in the field doesn't have a Ph.D. And he may have, in some instances, been lucky to graduate from high school, and so

you have constantly got to think about who is collecting the information because what we are trying to do is to build a system that management will rely on and once we get the data linked between the graphics and the information sets that is in agreement, then its users are going to make decisions on it. And all we have to do is tell ourselves one time to the state highway engineer to make a poor decision based on information because we didn't make it reliable.

The other thing is point elements. Now point elements are going to require more work on your part, because if I'm going to make an analysis of an accident situation and I'm going to look at say, 5 accidents, and they're happening around the intersection of the road, it would be nice if they all bunched together around the intersection of the road so the relativeness of that intersection or the relativeness of the beginning of the curve becomes important in the map so it's not only the each individual segment has to link together, the segments have to be relatively accurate. That doesn't mean that their longitude and latitude has to be exact, but again more relative. In other words, if I'm going to make point analysis, then my data has to be relatively correct. Now what a lot of people also don't understand is that the DOTs have a lot of this information already available to us on the computers. We have bridge systems, we have highway inventory systems, we have all types of systems in which that data is out there. So if we can build the road network so that it's in agreement, then we can actually create our map and verify our maps as we go on by extracting that information out of the databases. For instance, we can locate bridges if we have the row--we don't have to digitize it. On the state maintain system. All systems are a different story. But we can actually extract those bridges out and locate them where they should go provided we have our databases and our graphic systems in synchronization with each other.

This is another map we were trying to produce--you remember when we got confused with the slides. This is a typical GIS application in which the--can you read that top at all--what that legend up there is telling us is the type of service and the condition of that service. So through the GIS system where that information is linked, not only do I get a picture of that particular curve and of what type of surface is at that point, but also what the rating of that surface condition is at that point. And that's done through a combination of colors and line types which is easily depicted if you're trying to get your point across to somebody. What this is is just what I talked about in the design area of which you cut your

piece of information and get its attributes out of it, for instance if you have a segment of road, what you're looking here is the ADT and the highway speed, its capacity, or you may be interested in some just general characteristics of it in which its functional class--and this happens to be and this is Louisiana and they use a deficiency system for their needs study. And they have, I think it's 6 areas in which they rate for deficiency. The only problem is that the needs for the area are so great that they really only get to look at the pavement type in condition as far as doing that needs. But they could use these 6 characteristics and they come up with that needs, they could have a sophisticated formula, or it could be a subjective thing or it could be an objective thing. In other words, you as a cartographer are not really interested in how the engineer or the planner makes the decision, but you're providing him with a tool to analyze what he thinks are the conditions and to come up with some presentation materials that will effectively allow him to get the point across.

This is what I wanted to talk to you about as far as the power of GIS. I'm sorry this is disorganized. It's maybe what I am, disorganized sometimes.

In the Louisiana system, and you'll be able to look because Gail has brought along some sample outputs, but what you have here in their system is a list of characteristics at the bottom that, in essence, represents the attributes that are attached to the information. Each year, Louisiana has to prepare a system that goes to its legislature to get its construction budget, so this is an annual thing that has to be done. The subsections in there vary from year to year, so they use a control section system, which some of you may do. A control section, subsection may be different this year than it was the previous year. So we're keeping the data historically so over time we can make some historical analysis about the road. But what this does is through the fact that we have the graphic description of the road in the map in which they create the district map to show to the public and also to show to the transportation committee as well as the House and to the Senate of the state. But because this information is linked together in batch process, these manuals are created and you will be able see that. Gail has brought one fresh off the press for the 1987 data and we are able to look at the attribute information to see if it has any columns that it actually analyzes the window area in the graphics to see if it can put that particular control section up there. You'll notice here there's two, separated with a mark there kind of tells you that information. The

one on the left there is strictly a straight mark. In other words, the area fit fine into the window. You'll notice the one on the right, the arrow is pointing in a northwest direction. The system automatically rotates the window and it sounds like scissor drafting and that, in essence, is what it is. It's automated scissor graphic. So we can optimize the number of control sections that go on the sheet. We can place them, we can rotate them. If they still don't fit, we can scale them. We can do all of these types of things. This is because we have a GIS system built that tells us both the attribute information which is the lower level and the graphic information which is the upper level. Do we have any design engineers in here? You will see that this is an awful lot like a plan profile sheet--just that the two levels are slightly different information, but as far as the process is, you can see it is very similar.

Transportation operation analysis--this is the type of thing we see as we build the GIS. You can see some of the simulation programs, I think this is one of the figures in the paper, but it's the type of thing as we get this network built, and this is one of the things that I've been trying to talk to the vendors about--they're addressing a lot of the applications which is wonderful. What we need to do is to build the road network. We need their assistance in digitizing and getting the information built faster so we can get to some of these little neat applications. And if we start digitizing and all of a sudden we're off and doing certain things for certain areas, we're not going to get the whole state done. We're not talking about doing something overnight. We're talking about a commitment. We're talking about a commitment that can either come from the top or from the internal of your organization. The most important thing is the persistence of constantly moving forward and getting something done and that's the only way that you're going get there. The other thing, of course, is in the planning. It's the same thing as we dealt with network analysis and we have these planning models out there. We have sketch models out there that we can use, and if we can use these GIS systems at first to just create the input into these existing simulation models, then I think we will also give some incentive for some more research into maybe models that are specifically designed to utilize a GIS type of system. And one of the areas we do need to reactivate is the research area because it appears that our eagerness in which to get things built that we're just not doing the research necessary in many areas in which to advance in the future. And we are going to suffer.

Okay. In the development of the GIS system, there is basically three phases which are just almost exactly like what you would do in a manual operation. The first thing you have to do is create the map. Now in many instances, in the manual situation you, the supervisor, may be the only person who knows how that map was created because this was done a lot back in the 30's and what you do now is you pull out the manuscript and add things to it or you pull it out and you rescribe it. You don't go back to the creation of that map, so there is a little learning curve. You have to pull out the old notes and some fond memories about some things that you did to put that system together back in the days when that map was actually created. And in that, there are two types of attribute informations that we're looking at in the GIS system. One we call cartographic. The cartographic attributes are those attributes that you want to tie to the graphic features that help you produce maps. There are certain attributes of information that you desire that help you build a better map faster for your users. The other attributes we deal with we call user information. And that is that data in which you probably are not an expert on and the user must be the one who actually defines that kind of information he wants to link to the road network or to the area that is to be analyzed. And through this process, you're going to build a database, you're going to build a master file of how that's organized whether that's by county. One of the things we're looking at in Pennsylvania is looking at statewide features in many files because of the continuity we want through routes and some other things. This is the important part about data conversion. You're going to have sessions on nearly all of this. Of course, I think the biggest effort going on right now is just digitizing. Manual digitizing the information to get it into the system. One the of the things that everybody has been hoping for as long as I can remember over the last five years is that scanning would someway miraculously come through and provide us the information. And while the scanning systems have gotten better, most of the states have gone to two-color separates for most of their maps. The data cannot be scanned in any way that allows them to break the data down like they want to maintain it in their file. And so what you find in many instances, you might be able scan the data, but the work effort necessary to take the scan data and do something with it is more than if you just set down and digitized it yourself. The same thing may be true with existing digital data at this point in time, but this is an area that is going to rapidly improve. One of the things that we are looking at is the GNIS field name files from the U.S. Geological Survey. Oregon is even a little bit further ahead of us on that. We're finding that that is going to be maybe

the most useful piece of information because if it does nothing else, even if the man has to move the names around physically on the screen, it's going to keep you from typing in all the location names and maybe even some of the features names.

The last one, of course, is something that I personally am very excited about and that's geocentric global positioning. GPS is quite well known in the surveying area as far as control, but Tennessee has done some preliminary work. There are other people that are looking at a GPS system that will reach us, with 50-foot accuracy while moving down the highway at 50 to 60 mph and if we can get that, then than means that we could even use this vehicle as a big digitizer. We might go into our off systems and actually collect the alignment of the road sufficiently to put that onto our maps and to link that with our highway inventory systems in this correlation--today that is not a system to put into production because it is dependent upon the number of satellites in the air. That is not sufficient and I think the windows are somewhere between 2 to 4 hours across most of the nation, if you could collect information. But it is the time to do research. Research does not have to have a production limit and now is the time for us to look and encourage research in this area to see if this is a viable device that we get some work done and see if we can add it to our repertoire of weapons to get the job done.

The second system of the three systems is the map maintenance system. I guess some of the more advanced states are just now just getting into this area and if you just got your system, you've got your hands full getting the map created. But as time goes on, you're going to find that this is the most important system that you're going to have because if you stop and look and what you do today, you basically do maintenance and as you get the map created then it is this system that is going to become the important thing in which you maintain both the digital cartographic database and that cartographic information which you tie to your attribute. Depending upon how you organize things, in Pennsylvania we're going to always be dependent upon the user to be responsible for that attribute information that he is going to extract from the host databases. You basically have the search and the edit and the thing and want to automate those processes. You want to be able to go into the master file and extract the area in which you are performing maintenance. You want to have some type of audit in that area. You want to not have somebody else go in and do some of the things, do something to that area

while you're maintaining it. Not necessarily with the products, but you don't want them in essence changing that database. So those are some of the characteristics and they are relatively simple to say; they may not necessarily be simple to do and you need to knock on your good vendor, whoever he may be, and let him know that that's where you would opt for him to put some efforts.

The last is the map production subsystem and we basically try and produce digital maps to transfer to our district offices and our maintenance offices and for internal use so that they can produce maps. And then we also have special maps that are going to come to us from users that don't have a system--I mean, they don't have access to stations and they don't have access to the expertise to generate that and you're going to have to help them or else somewhere in the organization you're going to have to have somebody who is familiar to utilizing the database capabilities of your vendor's equipment in order to create those special maps because you're going to have to be provided with an interface. Those maps may be colored maps that are showing information or they may be some other type of special map. But the map production subsystem, in essence, is what gets it out of the system to the user whether it be on the screen or whether that be on the film, or whether that be on the paper. It is whatever that end product is and you want to be able to go in and extract that information, give it to him, the user, if he's the one doing it or if you're doing, do what you want to do with that and then either throw it away or if it happens to be one of your standard maps, I think that what you are going to find is that you're going to have a digital version of that standard printed product of which you're going to make available to use. And of course the nice thing with the things being layered in that map, you can turn levels on and off so that whatever it is that he's trying to bring home as the point will only have the information displayed that he's interested being displayed and it won't necessarily have a lot of superfluous information and that's what happens to him now. He takes one of your printed maps. He takes the one that best fits what he needs to do and he gets out his little crayolas or his stickum colored thing and away he goes.

I'm going to talk a minute about standardization since I'm going to be chairing that; there's not much need for me to spend too much time on it--we'll get that in the workshops. There are two types of standards that I see that are important to us. One is the cartographic standards, that is the symbologies. That is something that

you've dealt with in manual maps and I guess the point there as we move into the automated world, have we selected, are we using symbologies that fit the automated world quite well or is something that we need to look at? How important is this standardization? Does it need to be something universal? Or just let everybody do their own thing? And of course, something that is going to be new to many of the cartographic community is the data exchange standards and it is the hope of the future and it is very important and we will deal with it very much in the workshop because as we build systems and as other state agencies build systems and as our counties and our cities are able to acquire systems as they come down cheaper to meet their needs, we've got to have vehicles in which to exchange information and it is unrealistic to think that everybody is going to have the same system, so we've got to deal with different systems, big systems, small systems and we have to pick a data exchange method. One I'm very partial to is the new specification coming out under ASCM. I think those people have done a tremendous job and we're going to be fortunate enough to have chairing the next speaker that is going to talk to you a lot about that. And the other thing that I think it's essential that specification be one that is a FIPS, part of the Federal Information Processing Standards, because those are a lot of the people we will be dealing with and I think that if we select one of those standards, the vendors themselves will of course have to be addressing that FIPS specification to deal with federal government.

PC Mapping. You know I would probably say that a conference or two from now we may address PC mapping almost as a theme of that conference. It is something that is quickly growing. It has a lot of the capabilities. There's two areas that I see that it's going to primarily affect. One is when we get these maps, base maps built that as a work station it's going to be able to take the analysis and its going to be able to take the application and actually take that base map and do with it what it wants to do for that particular application and so the user is going to use it as a sophisticated analysis, special analysis, or whatever you want to call the system of that data plus whatever information that he feels needs to be added. And the second thing is that it's a small system. I think as this technology advances you know today, maybe only a few of the counties and cities are able to afford or able to even get into this area, but as time goes on this may be an accepted part of the city government or a small community and they are not going to have expensive systems and many of those systems are probably going to be PC based, and so we

have to be prepared to address that and transfer that information because they can be almost totally dependent upon us for their base map and then add to it what it is they need to know.

Points for discussion. This, in essence, was the last chapter in the report. There was even some debate about whether to put it in or not, but I guess we kind of felt that if we didn't bring some points out and get you thinking either that you agreed or disagreed or this was more important that we didn't mention that we might have difficulty in two and a half days with the timeframe that we're in in that being an object and so these are just some of them. An annual forum that I mention, I think it's at the top of the list. I think it's something you'll find you'll discuss almost every day as this conference is just going to be so much worthwhile, you're going to get so much out of it that you're going to want to do it again. And what we've got to do is to address the vehicle with which we want to get that annual forum going. Cartographic standards, the next session, the workshop this afternoon is going to address that and that's both the cartographic and the data exchange and I have the fine desire of FHWA support probably much to their chagrin. I know what their position is. I think that's addressed from the fact that the upper end of AASHTO is taking the leading role and I'm not sure that in this area of the GIS that's cartographic that we feel a little bit different about a total back off of FHWA. I think that we need them as partners and as we go on, this is one of the things that we want to discuss. You know that the people here maybe cannot make that decision, but they can certainly carry on back and if we get that information to AASHTO, then I think between the two of them that they will see that if we do need further FHWA participation, then that is the agreement with AASHTO, then I don't think there is any problem with FHWA wanting. It's not a matter of them not wanting to help us in this area and they will. We just have to help them define what it is that they want us to do. And I guess I would like to finish with this since everything that I've said is unique with every state and the key for you to do, you're not going to find that the state of Washington does what you want to do, or the state of Louisiana does what you want to do or the state of Pennsylvania or any single state does what you want to do. But between them, you're going to find that each of them do some things that you want to do and you're going to find out why they do them that way and as you pick up those pieces and put them together, then you can come up with a system that best fits your needs. And, once again, the importance of the cartographer is to step forward and become a leader. And as I

finish the paper, the written paper for those who stayed awake long enough to read it, the last sentence says, that the gist of GIST is opportunity. Thank you very much.

5:PR&PT11

Western Region Computer-Assisted Cartography Conference

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September 22, 1987

I would like to thank you all, and especially FHWA and WSDOT, for giving me the opportunity to share with you some of the trials and tribulations of the last five years of digital cartographic data standards efforts that have been going on.

I would like to start off by giving you a brief history of the five-year effort in about five minutes from an organizational perspective. There are a lot of people that have committed a lot of time over the last five years to developing digital cartographic data standards. To start out with, let me say that in about 1981, the National Bureau of Standards went to the U.S. Geological Survey (USGS) and said do something about earth science data standards. We are going to come into some real big problems here in the country if something is not done. So USGS said, okay, we do a lot of mapping but maybe we are not the ones to head up this thing. So Rupert Southard, from the National Mapping Division, went to the American Conference on Surveying and Mapping (ACSM), for which Joel Morrison at the time was president, and said, Joel, will you take on this effort and get together a nationwide effort consisting of personnel from federal, state, local, and private representatives in the cartographic community. So a call went out for people to participate in this effort, and out of this call came the formulation of the National Committee for Digital Cartographic Data Standards.

In 1983, staff of the Office of Management and Budget wrote a report titled "Duplicative Efforts in Computer Mapping" for the federal government. An April 1983 memo from David Stockman motivated another committee, the Federal Interagency Coordinating Committee in Digital Cartography. And so, in 1983, then with the national committee already being under way for about a year or so, this committee started on a process also developing standards for Digital Cartographic Data. The two committees sort of informally got together in various discussions and conversations and agreed not to duplicate the effort of each other. But the Federal Interagency Committee was only a federal committee. It represented about 10 federal agencies of the U.S. government and did not take into consideration as much the local, state, and private interest as did the national committee.

The National Committee for Cartographic Data Standards completed its task in March 1987. We submitted a document to Lowell Starr, Chief of the National Mapping Division at USGS. He took that document and formed a new committee

called the Digital Cartographic Data Standards Task Force. Joel Morrison was appointed the head of the new committee. That committee was comprised of the national committee and the federal committee members. So in a sense, it formally got together the two committees. So what we have now at the current time is a document which will now go to The American Cartographer, which is the journal of American Conference on Surveying and Mapping (ACSM), for publication in January 1988. So if you are not all members of the ACSM or do not get ready access to that journal, do look for this particular publication.

The areas that we focused on were four: cartographic objects, data exchange, data quality, and cartographic features. One of the main areas of focus that ran through all four of these areas of work was something we call the terminology effort. I would say that at this particular point in time, these terms perhaps no longer are the best terms to describe the particular areas of work. At the top, we might now label that one "Spatial Objects," rather than just strictly "Cartographic Objects." The data exchange went from "Data Exchange" to "Data Interchange" and is now called "Data Transfer." The dataset quality, because it has such an IBMism to it, the committee chairman wanted that to read "Data Quality." And the last one, we call it "Features Group." These four areas are the main areas of work for which standards were produced, and those are the areas that you will see addressed in the specification that will come out in January in The American Cartographer.

I have this slide and several other slides here to point out some of the organizations who were involved. Just reading down the list here, not names of individuals, but names of organizations: Ohio State University, the National Ocean Service, Defense Mapping Agency, Bureau of Census, Oak Ridge National Laboratories, Equa Associates, Environmental Systems Research Institute, Kansas Geological Survey, Consultants, University of Saskatchewan, University of Washington, and State University of New York at Buffalo. There was somewhat of a wide range of representation in the steering committee. I was the chair of Working Group 1 and a member of the Steering Committee.

Working group 1, when we started out, was called Data Organization. That was too broad of a topic. We knew that the main focus of why we existed as a committee was not to try and standardize data structures. The real need there was in Data

Interchange, Data Exchange, now we call it Data Transfer. So again, we have a wide cross spectrum of individuals that helped in this effort; University of Washington, Xerox, Special Information Systems, University of Saskatchewan, State University of New York at Buffalo, the Jet Propulsion Laboratory in Pasadena, Geological Survey, National Ocean Service, Defense Mapping, Eros Data Center, USGS, and Information Interchange.

The second working group was Data Quality. That was chaired by Nick Chrisman of the University of Wisconsin, and I happily say he is now with the University of Washington, my colleague. The members represented the Defense Mapping Agency, Ohio State University, Kansas Geological Survey, National Ocean Service, Bureau of Land Management, Survey Engineers of Boston, Geological Consultant, Bureau of Census, and the USGS.

Working Group 3 is Cartographic Features, which was chaired by Warren Schmidt of Digital Mapping Unlimited. We had representatives from Virginia Commonwealth University, USGS, National Ocean Service, Maxima Technologies, Tennessee Valley Authority, Naval Oceanographic Office, Defense Mapping Agency, the National Ocean Service, and Syracuse University. Since it was a volunteer effort that lasted over five years, we have probably more federal and university types than we have state, local, and private organizations. So it was all up to those organizations to give the time available to their individuals to participate in the effort and that is why we had the same types of names coming up over and over again. The National Ocean Service and USGS probably by far were the two most active federal agencies in the group.

Let's start off here, in the areas of work I have discussed. I would like to broaden out a little and tie in the notion of what we said was called a cartographic feature. A feature we defined as a defined entity that can be represented by an object. So a feature in a sense can almost be anything out there in the world that you really want it to be. It could be anything to do with physical, cultural, social, economic--any kind of entity that is out there. So all we have here with the term "entity" is that if we can agree that we are not going to subdivide this thing out there in the world, then we can give it a feature name perhaps, it being the same feature name that someone else might give it. If it is at another sublevel, you don't give it the same feature name, give it another name. It can be all or part of that more

compound feature, or in this case, an entity. It is important not to confuse the aggregations of elements. We have talked about the term feature as being the covering term in a sense for entity, and now let's talk about "object as being a digital representation of a feature." So in a sense, an entity is the real world thing; an object is its digital representation in the computer. Now there are a lot of terms out there that perhaps are not consistent or at least they're not consistent with these definitions. These are sort of the words that we came up with. So if you don't like the definitions for these particular terms in the transportation area, I am sure that you have an opportunity to do something about it to make it more specific for transportation.

First of all, I would like to talk about the generic elements as just done. There are five generic elements that I am going to say something about. The first is "entity." It is important that we get this idea across as to what Working Group 3 was doing. Working Group 3 title was "Cartographic Features." What they wanted to come up with was a set of terminology that referred to things out there in the world regardless of how they were represented on maps. So this got us away from the symbolic problem. We wanted to call something or agree upon something as to what it was out there in the world, and then everyone can figure out how they want to symbolize that. It has been discussed in the standards workshop that there is a lot of symbology, different symbology perhaps used to represent the same entity in the world. So the entity is a real world phenomenon that is not subdivided into phenomenon of the same kind. For example, here is a bridge, fortunately enough, a transportation example. A bridge is a bridge is a bridge. In this instance when we call it a bridge, of course, it might have a finer definition, or in fact, the term that is used. If bridge happens to be the standard way one would want to refer to a given class of information, then use B-R-I-D-G-E as that label, then it simply becomes a standard term. And of course, all of these standards as any standards are agreed upon conventions and that is all.

The second term here "attribute," that is a defined characteristic of an entity. So in terms of characteristics of things out there in the world, we simply label those characteristics as being attributes. We have not distinguished between cartographic, nongraphic, graphic, or any other types of attributes though there would perhaps be even finer classes yet of attributes. Attribute is just that characteristic that you use to describe something. And in fact, name is simply an

attribute. Name has no importance to it other than giving something the best label, or the best handle on something. So N-A-M-E as being a word is no more than an attribute for some entity that we have. We called it maybe the name of a bridge, something like that. Attribute value; that's a specific quality or quantity assigned to an attribute. So the value is what you have stuck into the computer inside this category for this thing called attribute. It's attribute value that we use in order to really create the databases. So it has a particular value in effect here. "Steel" is a value that we would use to instance what the composition would be of perhaps a bridge. And that is why the bridge compositions and steel up there are the examples. If we were going to have a data dictionary or a catalogue to describe all of these features, which is what we gave as a beginning right now, we would use the standard term as perhaps the most common label. That is really all that standard term means. It is perhaps the most general and is used to refer to these entities most often. Included terms, are those terms that perhaps are subsets of a standard term, or in other words, you might think of it as an alias form. A nonstandard label of an entity or attribute is cross-referenced to a standard term of an entity or an attribute. A nonstandard term is something that the standards committee did not agree on as being the standard term; it is just an alias form.

There are about 200 definitions now in the document that the U.S. Geological Survey has as a starting point. I think there is an opportunity here for the transportation sector of the mapping community. There weren't very many transportation terms in there, except for perhaps what might appear on U.S. Geological Survey maps. We all know, of course, that one organization's interest doesn't completely cover another organization's interest. We need some better terms for subareas or the application areas within the standards. I think that transportation is one of those areas that is in need of some work. There is a lot of opportunity for those of you here sitting in this room to participate in the creation of a standard data dictionary that you might have for your own systems, or for the data that you might transfer back and forth between one another.

The standard feature in this slide happens to be "inlet." The definition is an opening of the sea into the land or of a lake into its shores. The source for that particular definition is modified from the dictionary of geography published by Monkhouse. A very old dictionary, continually edited and kept up to date, but of course, no dictionary is by every means the final word or the entire word on a

definition. It just happens to be that in the committee's deliberation, they decided that this particular definition suited the feature "inlet," the best. The attributes of an inlet are name, location, size, shape, width, depth, and solidity. The included terms here are anse, arm, bay, bight, closed bay, cove, estuary, firth, fjord, gulf, rincor, and sound. Okay, those are the less common terms. But they, in any case, refer in some way to inlets. There is a cross reference here between the terminology. That is of course very important for a standard data dictionary as well. For those of you that have your particular terms of interest in transportation that may not coincide with somebody else's view in transportation, if you happen to be the one in the committee meeting who has your term that you feel that is definitely the term that should be used but the committee effort does not quite go along with your view, have it included in this included terms. There is always a way to get to your particular term, especially in the case when these things are automated.

Here is another case for stream. It has the definition, the source, perhaps an alternate definition, a list of attributes, a few more than were in the last example, and few more included terms. Here we have some other examples of attribute values which might be given for attributes for certain features. A buoy having a location with a latitude and longitude position. It has an attribute for color, it has a value that has black, it has an attribute for color pattern, the value is solid, the attribute for shape and so on. There are several standard attributes which may have standard values which go along with them as well, but that is not to say of course that that is the entire domain of values. This just gives you a representative example as to what they might be. In terms of a standard dictionary for transportation features, one could come up with or use a similar formula here.

Now we are getting into the cartographic objects. As I said before with the three terms entity, feature, and object, they sort of play a triumvirate role where as an entity is the thing in the world, the feature is something that may also be used as a term to cover the term entity, but a feature can also cover the term object. By that, what I mean and what I said before is that feature is the covering term that when we talk about a feature, we have never distinguished before as to whether or not we are really talking about the thing out there in the world or whether we are talking about the thing in the database. And of course, when we get into different

scales of mapping, it is very important. Because out there we drive on road ways which have some thickness and which have some width to them, wherein maps, of course, we don't see those things. So it really has an effect on what the character of a database might be.

In this slide, we have all of the objects or the digital representations. The terms we are using for the digital representations might not exist in any particular system, but more importantly, they might exist in the data interchange. There are perhaps a number of objects that aren't represented here that may be peculiar to, or idiosyncratic to, a particular vendor system. We couldn't vote to do all systems or incorporate all terms. But what we want to do is come up with what seems to be by convention a set of terms for which we can begin to talk on common grounds rather that using three different terms which mean the same thing or using one term that means three different things. We have come up with some set of characteristics here that we fit these terms into. There are geometry characteristics of these objects and there are topology characteristics of these objects. By geometry, what I mean for the most part, is the coordinate part of the data. By topology what I mean is the connectedness of objects. That is, whether they are zero dimensional, or one dimensional, or the zero dimensional things that are tagged on to one dimensional things, and one dimensional things are composed of two dimensional things, and so on. So it is the relationship in space that one could make explicit without having to use coordinates. So they're in a sense spatial relationships. Topology is no more than the primative spatial relationship of the elements stored in the database. So for the first classification, we have zero dimensional cartographic objects. They are different in a sense because the point zero dimensional object is something that only represents the coordinate, or the location of the feature. The Census Bureau has done some experimentation with producing maps that didn't have any coordinates where they were able to actually generate the geometry just out of the spatial relationships with the topology. There are several people that have done that, and actually that might be of some use to people coming along here at some point in time when we find out that some areas don't have the adequate control we need. When we know how far it is from here to there, we can generate the actual geometry from those distances.

There are some objects that are special for a point; these are the feature point, a label point, and an area point. So they are just in a sense variations on a theme of

a point. A feature is a point used principally for identifying the location of point features, such as towers, buoys, gauging stations. A label point is a point principally used for displaying map and chart text to system feature identification. An area point to the point within an area carrying attribute information about that area.

The one dimensional cartographic objects fall into the generic category of line information, and we define the line as a one dimensional object. Some of these things I don't feel as of yet the committee actually did true justice to the nature of the concept. But, after five years of effort, we sort of said that it is fine for right now until we get another Einstein, or something like that who has a completely different view of the world and clarifies everything for us. We'll just go over this. So a line being a one dimensional object has a more specific line, something called the line segment. That is a one dimensional object that is a direct line between two points. A string is a sequence of line segments, an arc is a series of points that form a curve that is defined by a mathematical function. A link is a one dimensional object that is a connection between two nodes. They are an alias of edge. Actually this is an old slide. This is perhaps about one year old. The aliases have now dropped out of the standard. There are no aliases for any of these objects, because, of course, we could come with any number of aliases. A directed link is a link between two nodes with one direction specified. A chain is a directed sequence of nonintersecting line segments, references to left and right identifiers are optional. A ring is somewhat a new term for many mapping personnel. It is a sequence of many nonintersecting chains, strings, links, or arcs with closures. The four terms that we just used would produce a closed boundary. This is called a ring. The term is used because it is mathematically defined, and what we are trying to imply is both the mathematical notion of closure, as well as the notion of boundary. A complete chain is a chain that has node identifiers, and left and right identifiers. So now we start to distinguish between perhaps those data structures which are only graphics oriented and those data structures which are topologically oriented. If you have nodes on each end, and left and right identifiers, then you have a topological-oriented data object. An area chain is a chain with left and right identifiers but without the node identifiers.

An area is a bounded, continuous, two-dimensional object which may or may not include its boundary. An interior area is an area not including its boundary.

A polygon is an area consisting of an interior area, one outer ring that has a single boundary around that and zero or more nonintersecting, nonnested inner rings. This is very important when we consider the topological data structures such as the TIGER files that the Census Bureau is going to be coming out with. The nature of this definition coincides for the most part with the terminology of zero, one, and two cells which the Census Bureau is going to be using for the TIGER system. We can have a complex polygon with nested lakes or islands that need a somewhat more rigorous definition. Why did we come up with this terminology? One thing we wanted to do was to try and harmonize the situation with respect to computer-assisted cartography to date, and go into the future with a somewhat more say cooperative effort. We wanted to avoid coming up with different terminology, such as having the same term for three different things, or three different terms for the same thing. These terms harmonize a previously confusing situation. They define objects for geometry and topology, and take into consideration the need for drafting only systems as well as topologically oriented systems. It is a building block that one could use for complex objects. The compound and complex objects could be built on the more primitive and simple objects.

For the Working Group 2, on data quality, their main focus was to come up with a statement of quality to describe data so that somebody else knows what it is. The convention we used here was something called truth in labelling. It seems to be working very well in the consumer industry. That is, tell the consumer what it is they are getting. We are not going to set any threshholds for what these things should be as of yet. There are other standards that do that. There is an ASPRS standard, and so forth, about line accuracy threshholds, for example. A second one is positional accuracy, or how accurate a map should be. What our main focus was to come with a set of specifications so that one could describe to someone else the quality of the data. Or at least one party receiving the data could ask, what is the nature of this data? Don't tell me what your standards are, just tell me what the data is like. The first case is the category for lineage. This is an historical record of the production of the data. That is, how did the data get into the system? Where did it come from? What was the original source? Was it photography? Was it a map? The second category is positional accuracy. There are several levels used to describe positional accuracy, and these are deductive estimates, internal evidence, comparison of the source, or independent source of higher accuracy. So that in a sense, these are layers where the highest level, an independence source of

higher accuracy, is something that you truly go to get the word on. An independent source of higher accuracy is the objective source. The deductive estimate on the other hand is simply a statistic which describes the nature of the positional accuracy. The internal evidence would tell you about the relationships with respect to those statistics. A comparison to source is if you happen to have the source information around you can compare the output back to that original source. That is not going to be the situation very often where we have digital data. Often we no longer have that original source around.

The third category is attribute accuracy. This is somewhat of an undeveloped area as it is right now. But with respective to all the attribute information that Frank Cooper was talking about in GIS systems, there are some very difficult situations one could get into if one is not going to describe the bridge with the right type of composition. For example, with the attribute value of steel composition for a bridge, if you happen to label it wood, that is going to give somebody else an impression that is going to have somewhat a different weight limit. The attribute accuracy is going to become a very important area in the GIS world. We are trying to get ready for that.

Logical consistency is a category that deals with the internal spatial consistency respect to relationships of the coordinates and the relationships in the topology. So that one can discover inconsistency in polygon closures by doing certain tests.

The completeness category is everything in the database that I expect to be in the database. Or what is the realm of the elements that should exist in this database? And each one of these things, of course, are described much more completely in the standards that will be published.

The advantages of this view point on data quality is that we don't have any fixed level of quality that we are specifying. We are not saying that every map, if it is going to be produced at a certain scale, should approach national map accuracy standards. It should be consistent with national map accuracy standards. What we want is a standard for data quality which speaks, "tell me what it is and I'll make the decision if national map accuracy standards are not sufficient for my organization." So we have no fixed level of quality that was specified. A producer should provide the information to a user so that if you go to buy data from a vendor

and they perhaps offer this information or quality that you can use it to assess the nature of the database. Or you might be worried about using it in certain applications where you might not really have the level of quality you really need in the data. The user makes the decision for the use of that data.

We come to my area of work, the spatial data exchange standard. I will say at this time as I said before that it is no longer called the data exchange standard. It is now called the spatial data transfer specification, which I think is consistent with a number of other documents that have been coming out in the standards world. Data transfer, regardless if anybody is going to exchange information, focuses on perhaps just the one-way transmission of data rather than cooperative give and take situation of exchange. That is why the terminology is now different.

There are four objectives that we have mainly. One is that we want to produce a standard whereby computer systems could communicate with one another without having any human input in the transmission of that data if at all possible. This is a lofty goal, but I think we are on our way to this situation. We wanted a standard whereby the meaning of the data could be carried with the data transmission. As I said before, we wanted to reduce the need for external documentation so that if somebody lost a page in external documentation or perhaps it wasn't available anymore, one could still read that particular data. What we wanted to do is to put all that into the data transmission itself so that it would be stored out there digitally and would be archived just as easily as the data itself was being archived.

The second objective is to be consistent with the other work in cartographic features and the work that was being done as a committee as a whole on the cartographic objects. The data transfer specification is consistent with the objects and entities that I talked about previously. We wanted to be able to specify other types of information that were necessary for the transfer of information. This included not only the coordinate data and attribute information, but other very important data which describe the actual data that was being transferred. Something that I call metadata. You will probably be hearing a little more about that in the future in the context of data management.

The third objective, is that we wanted a model that we could follow that was user oriented in terms of the objects that we've described. When I say interchange

model, I am referring to an implementation mechanism that actually transfers data or allows you to describe the objects and the relationships for the transfer. We wanted that part to be as user oriented as possible. In the second part of the objective, we wanted to preserve a meaning such that the recipient could discern whether or not that data he received conforms to the standard. In addition to this, it would also allow for nonstandard transfer. We are not trying to be autocratic individuals and don't believe that we have the answer or had the answer to everything. We realize that there are some private agreements that might be made between organizations out there, because there are special circumstances. So we wanted to allow for that.

Our fourth objective, is sort of the all encompassing one. We wanted to be able to represent all the types of data that currently exist for spatial data. The reason why "spatial data" is used rather than cartographic data is that we foresee the GIS force as being perhaps an even larger growth area than the strictly computer assisted mapping world. We see maps being a very important component in geographic information system

We wanted an implementation methodology that is media independent, so it does not matter whether it is floppy disk, whether it is hard disk, whether it is tape, or whether it is electronic transmission. We want the transfer mechanism to be independent of that. We wanted the system to be able to be what we call "self-describing," so that the description of the data was contained in the actual transmission. And of course, we wanted to conform to the existing standards which are already out there so as not to duplicate those and possibly to interface where at all possible with those.

What we have is a three-level data transfer description. I can use this as describing the entire content of this subcommittee's efforts. This first level is the highest level, the conceptual, model of spatial data. In any database design process, when you sit down to define the nature of your database, what you first do is think about it. You think about what you have to put into the database. That is not any different than what you have to do in a data transfer. Somebody is going to call you up and say, will you send over so and so data? Or maybe one computer calls up another computer and there is no human involved that says, will you send over such and such data? So the conceptual model of spatial data is at the feature

level. It is those features about bridges, about composition, about all those terms that we know as they correspond to things out there in the world. This is our conceptual model of what the data is. The conceptual model of data then refers to a real world orientation. It so happens that we really can't stuff the real world into the computer, we have to make it digital at some time. And sometimes we have to bend over backwards to make things digital. When we produce maps we can't really represent everything in a one-to-one correspondence, we have to come up with some cartographic object which is the best geometric and perhaps topological representation about what that feature is in the world.

At the second level are the exchange forms. We have an object exchange form. We have a raster exchange form. We have a relational exchange form. In a sense, these are the data structures that are necessary to conveniently transfer our conceptual model of spatial data.

At the lowest level is the exchange mode. This is how we actually encode those data structures. That's all it means really. There isn't any more, there isn't any less. Each of the exchange forms has several modules. A module a grouping of similar data. Global information is a grouping of what pertains to that entire transmission. Then we have data quality modules as the data that pertains to the quality characteristics of the data. Then we have the exchange form modules. The exchange modules are each a collection of data fields grouped together because of the purpose and/or function of the information. It is a matter of convenience. That is what it is, no more no less.

With the global information modules, this global information is the metadata used to describe the contents of the spatial data exchange. One example is the spatial reference information. How do you reference the mapped information to the earth? Well, you can do that through several modules and these are the modules that you might use. This is a listing of all the global information modules. But actually, I'm sorry it is not a complete listing, because there is actually a new module that we devised actually just this summer in our last liberations. We came up with a data dictionary module. So now we have a data dictionary because we felt that was essential in order to get across all the meaning. I won't go into each one of these because each of themselves can take almost a 15- to 20-minute explanation. The first three simply describe what is in the transmission. How do I

know what is in it? Well I'd have to refer to these modules in order to determine that. Identification and security are more organizational specific in that you can describe the transmission however you want to. You can tell me whether it is some secure data, whether is high priority, low priority, or something like that. The spatial reference modules are there in order to reference information both to the earth and the source from which they were produced. The source is the coordinate systems in the digitizing process. The spatial domain and registration points describe the spatial domain as being the graphics area of the map. The registration points are the points that were used to tie that data to the individual map space.

The data quality modules are the five modules that I talked about before. We have a module for each one of those. This is about as detailed as we have gotten this far with these. We do not have specific data fields for each one of the modules. It was decided by the committee to see whether or not these actually got used. Normally, these aren't in any data interchange right now, so even this level is somewhat more detailed then currently exists in any data transfer.

The three exchange forms are the object form, the relational form, and the raster grid form. This slide is now almost nine months old. The object form has been relabeled to vector form. The committee decided that after the three or four years we called it object form that it was perhaps not so consistent with the other data structure forms we called relational and raster grid form. I'll show you why. The object form, or what is now called the vector form, consists of what we normally think of as the mapping objects that we use: points, nodes, lines, polygon rings, arcs, composites, and attribute descriptions. A composite is a very powerful one. And a composite is a module that can be used to combine together any of the others so that you can build more complex objects out of the more simple objects by just using the composite form. The attribute description is a special module where you can store attribute information. It did not have any geometry or topology to go along with it. Then we had a list of objects--we had about six of them. In the relational form, we have essentially taken all of the objects and broken them out into nonredundant categories of information so that now we have a schema, feature element, polygon chain. Each module stores the information pertinent to build nodes out of points, build chains out of nodes, build chains out of points, build rings out of points, build rings out of chains, build polygons out of points, build polygons out of chains, build polygons out of rings, and build features

out of elements. The schema provides the data description for the relational form. That was only the first half of it. So here we have the second half of the relational form that is needed. What you see on this slide is the same terms that I just used in the vector form. What we have here is a three-level description, and what is at the right is the data structure flow. So we have a different way of structuring data. Some organizations might find it more convenient to transfer the data with the relational form rather than using the vector form.

Finally, here are the raster grid form modules. We have four. We have grid definition, grid cells, raster definition, and raster cells. As I said before, the difference between the two is that the grid is for a little bit larger geographic partitioning of an area, and the raster is a finer partitioning of an area. It was very important that we included the space data community in our efforts in the committee so we did have a representative from the Jet Propulsion Laboratory from Pasadena who has been working with interchange formats for a good 12 to 15 years, and so that our efforts to try and include imagery data as being part of the transfer, I think, is now finally a consistent effort. Whereas before that has never been the case where you have actually gotten cartographic point minded people together with the space data people.

What I would like to do in review is to talk again about the entire effort by looking at a similar slide to one we saw before the data transfer description. I'd like to talk about how each one of these is different and how each one will help support the data interchange.

The conceptual model of spatial data is what you want to transfer as a cartographer. This information structure level focuses on features as bridges, features as road segments, or features in a number of different ways. At first, we do not want to be tied down to a particular data structure implementation. So it is data structure independent. As we talk about things in the world, we don't care how they are stored in the computer. But at this level we're implementation coding independent. That is, you may code up the structure in a slightly different way for a different media. Finally, of course, we are going to have to transfer on some medium, i.e., the floppy disk, the magnetic tape, or electronic transmission. And down at this lowest level is when we commit ourselves to do the actual transfer encoding.

We are trying to make a clear distinction between the content of a data transmission, the quality of the data, and the nature of the feature in terms of those descriptions. We are trying to make a clear distinction between the data content, the data structure, and the way that something is implemented on a computer. If we do that, then we make this particular standard have a longer life than what some other standards have had. Because we know computer technology is going to change, we know that there are going to be different data structures employed in these vendor systems. So we want to take that into consideration, but most of all, what we want to get on with the data interchange problem now. Unfortunately, it has taken us about four or five years to finally come up with this definition, but I think we have something here that would stand the test of time.

These are the three coding implementations which were proposed. The first one is the International Standards Organization 8211 Data Descriptive File and Coding Mechanism. That is already an existing international standard. It is already being used in some other application areas. It is very convenient to allow us to support this data structure and implementation independent stuff. And as I said, it is already established. That is the one right now that we have embraced. That decision was made at this last meeting or two meetings ago actually. The FICCDC Committee put a lot of effort in trying to investigate what they called was a delimiter coding mechanism, the second one. The problem with that one is that if one drops a byte, one could be in some very, very big trouble. So we tended to shy away from that now and go for something that is already an international standard. The last one is the NASA General Data Interchange Language Coding. The representatives from the space community said that, well you guys have done a good job, but we want to capture data in real time from satellites on the order of ten times which you guys are talking about. Thus, we need something that performs better. So the general data interchange language coding mechanism is somewhat of an extension of the ISO8211 data descriptive filing coding. This strategy permits one to define an implementation mechanism that performs better than those defined already. That's all I have for you. Thank you very much for being attentive.

3:PR&PT10

Session A Synopsis
1:30, 2:30 and 3:30 p.m., Tuesday, September 22, 1987

STANDARDIZATION IN TRANSPORTATION COMPUTERIZED CARTOGRAPHY

Mr. Frank Cooper, President, Cooper Technologies, Inc.

The discussion examined two aspects of computer assisted transportation cartography:

1. Cartographic drafting standards and
2. Cartographic data exchange standards.

Cartographic Drafting Standards

Standards for highway mapping symbology evolved during the decades when the Federal Highway Administration actively supported and monitored state government highway mapping. These standards reflect the manual map making methods of that time. Many DOTs simply retained this symbology when they installed computerized drafting systems. It was suggested in this workshop that graphic standards be examined for greater adaptability to computer assisted cartography.

Some of the benefits of revamping symbology for computer mapping might be reduced storage requirements, more efficient performance of output devices and improvement of vendor mapping products. It was also noted that the standardization of symbols

among states would foster interstate information exchange, and ease the use of products from various states.

Issues. Is the lack of symbol standardization among states truly detrimental? With the FHWA taking a less assertive role in state mapping, what is the motivation for individual states to adapt their mapping programs with respect to a nation-wide standard? A Census Bureau representation suggested that state highway maps could play an central role in their activities if some standards could be relied upon to guarantee the usefulness of data from the various states.

Would the American Association of State Highway Transportation Officials (AASHTO) or the FHWA be an appropriate coordinator of efforts by DOT cartographers to develop interstate graphic standards? There was some interest in the possibility of a working group to initiate such an effort.

Group Position. No strong general consensus emerged on this subject. There is a need to clarify whether or not the issue of graphic standards is really a problem, particularly with respect to the changing technology in the field.

Workshop attendees generally felt that a clearinghouse for sharing symbology among users would have some value, and that any standard symbology should be presented as guidelines rather than requirements.

Cartographic Data Exchange Standards

Standards to enable the exchange of digital cartographic data are becoming vital to the productive use of computer mapping systems. Such systems continue to increase in popularity among all levels of government and for all types of mapping. When different agencies' file formats do not allow the efficient and accurate transfer of data, the sharing of cartographic information is even more difficult than it was when agencies used predominantly manual drafting methods. Representatives of the FHWA and the Census Bureau expressed a strong interest in digital data exchange standards.

Issues. DOTs will eventually be involved in the exchange of digital cartographic data because road networks are so basic to many kinds of geographic analysis. As some interstate facilitator will be necessary to coordinate the effort, this issue might be addressed by the FHWA or AASHTO.

It was suggested that the efforts of the National Committee on Digital Cartographic Data Standards (NCDCDS) be recognized as a model of the methodology for developing data standards for transportation cartography. The logical starting point for such an effort would be to systematically define transportation features and convey these definitions to the NCDCDS.

Group Position. In contrast to the issue of graphic symbology standards, some feeling of general consensus, or at least common recognition of the problem, was apparent. It was widely felt that AASHTO should play a significant role in examining the problem, and that discussions must continue with the creators and users of digital data and the vendors who must eventually implement data exchange solutions.

Session A Synopsis
2:00 and 3:15 p.m., Tuesday, September 15, 1987
7:45 p.m., Wednesday, September 16, 1987

STANDARDIZATION

Frank Cooper & Benjamin Ramey

Issue:

The need for creation and implementation of data exchange and symbology standards in order to provide a uniform and timely exchange among various agencies in the development of automated mapping.

Discussion, group 1
GIS Data Exchange

Discussion began with a comment that there should be clarification of the feature code to user symbols. One suggestion made was that ASCM guidelines might be used as standards with the encoding and decoding process being streamlined.

A number of state representatives were unclear as to whom the primary parties are to be in exchanging data. The question was raised as to whether or not vendors have been contacted and involved. It was made clear that the transfer priorities are to be within various levels of government and agencies within the state; not among states.

Another problem which was pointed out was the incompatibility among various systems. This problem makes difficult the transfer and combination of information and that in turn influences the time frame necessary to accomplish the task.

An early stand should be taken on making exceptions to sharing data with others so that precedents are not set with one group that would open the door to granting continual exceptions from that point on. The question of how states might accomplish this task was raised.

One suggestion was that data exchange could be made cost effective by going to the "best" source for supplying the particular data, get agreement on this and take the agreement to AASHTO in the early stages to prevent time delay and any additional future expenses for agencies to redo work already completed. Tests might be done before any actual standard information transfer is attempted. It was suggested that these "paper tests" be done by several states and that their efforts could be jointly financed with the end result being presented to AASHTO.

Discussion, Group 2
Symbology

This group aimed its discussion toward the symbology issue facing standardization. The time lost in shading to recreate the standard symbols familiar to most in the preautomated map creation was discussed extensively. The idea of using colors to represent various highway types was discussed. Within this discussion the question was raised concerning whether to give up aesthetics for computerized symbology. A final thought was that the vender will undoubtedly be very instrumental in the final supply of standardized symbols.

The question of how and who should be involved in making a decision about symbol standardization was raised. Would the FHWA be involved in the final analysis? Bob Hall from the FHWA suggested that AASHTO or this Computer Assisted Cartography Conference may be good vehicles to approach FHWA, but he was uncertain if the FHWA would want to pursue a leadership role.

It was decided to put together recommendations and send them to AASHTO and the GIS Committee for consideration.

The group then moved the discussion to data exchange. Vendors present at the session stated that there are no generic symbols packages available yet. USGS is "high on standards" for data exchange because of the analytical as well as graphic output.

It was hoped that standardization could be accomplished as quickly as possible. The high cost of digitizing prohibits repetitious development of the data base. The desire for a standardized basic format, which the states could embellish when they produce their own graphics, was desired.

Due to time constraints, it was decided to continue the discussion at a 7:45 p.m. meeting the following evening.

Discussion, Continuation

This session began with the statement that the present process does not work and merging data and symbols cannot take place until a group of states is formed to resolve a standardization process. Considerable discussion among the states centered on symbology and it was suggested that it would be a good idea to come up with a forum on this for next year's meeting. It was thought that if a DOT consensus was presented through AASHTO, USGS decisions may be influenced to some extent. A Task Force on Standardization in a AASHTO sub-committee was proposed.

The following resolution was agreed on by those states present. "As we go into GIS we see problems in productivity and would like to see a resolution on symbology uniformity and at least look at ASCM standards."

It was stated that standards should be developed as soon as possible. Going to a consultant without standards, could and would drive his fees up, if he must develop a format.

Session B Synopsis
1:30, 2:30 and 3:30 p.m., Tuesday, September 22, 1987

DESIGN, ACQUISITION AND SUPPORT OF A COMPUTER-ASSISTED CARTOGRAPHY SYSTEM

Mr. Lee Eason, Support Services Manager, WSDOT
Mr. Art Wagner, PennDOT

Mr. Eason described the process Washington State Department of Transportation (WSDOT) went through in the acquisition of a Computer Aided Design and Drafting (CADD) system for the Department. A prime consideration was that WSDOT leadership felt the need for an integrated system for engineers, designers and cartographers so all could use and exchange information. The concept of a Geographic Information System (GIS) as a part of a CADD system was not recognized by most of those involved in the process at the time. Mr. Eason's viewpoint is that WSDOT should have:

1. Started ten years sooner,
2. Begun earlier to educate themselves on geographic database technology and
3. Moved more quickly to develop local area networks and distributed processing.

Mr. Eason recommended DOTs involved in this process should:

1. Develop an executive-level steering committee,
2. Use a multi-discipline approach,

3. Choose knowledgeable, enthusiastic people with positive attitudes,
4. Develop a user group among CADD users,
5. Write tight specifications for any vendor software,
6. Get information from other DOTs, etc. and
7. Allow CADD to change their way of doing business.

Mr. Eason contrasted the two approaches to developing GISs. He characterized the cartographic approach as relatively unstructured, inexpensive and present, while the Data Processing (DP) approach is very structured, expensive and future. Hopefully, both groups should be moving in the same direction. However, cartographic units will have to become more visible in their GIS efforts. Otherwise, DP or vendor solutions will be imposed upon DOTs without adequate consideration for the spatial relationships for which cartographers are the experts. He suggested that turf battles over GIS must be avoided between cartography and DP, and that a cooperative effort should be used to achieve the needed systems.

Art Wagner discussed the implementation of a CADD system, identifying the following steps:

1. Assessment of functional needs,
2. Assessment of hardware and software needs,
3. Initial considerations,

4. Management and personnel preparations,
5. Site preparations,
6. Training,
7. Operational and developmental support,
8. Organization and
9. Growth.

Due to presentation length and brevity of sessions, little time was available for questions or discussion. One session concluded with the thought-provoking question: "With the advent of CADD and GIS, is your role still really that of a cartographer?"

Session B Synopsis
2:00 and 3:15 p.m., Tuesday, September 15, 1987

DESIGN & ACQUISITION OF A SYSTEM

Art Wagner

Issue:

This session dealt with the issues involved in designing and acquiring a system to meet the needs of the department.

Discussion:

The attached presentation served as a basis for discussion in this design and acquisition session. What follows now are some comments and concerns raised concerning the position paper.

The paper did not consider database design.

There were no directions or guidelines for the selection of an appropriate database system.

Vendors are not likely to deliver a system that will totally meet a user's needs.

The turnkey alternative is the best approach.

Consultants can help plan an automated system, but the user must assume a leadership role defining needs ;and capabilities.

All prospective users should participate in the planning and development of a system. Assessing functional needs should not be arbitrarily limited to one area or organizational unit.

Incorporating data base capabilities into computer assisted cartography changes the way a cartographic unit does business.

Improvements in scanning equipment and services require a close look at digitizing costs before deciding how to proceed.

Session C Synopsis
1:30, 2:30 and 3:30 p.m., Tuesday, September 22, 1987

HUMAN RESOURCES AND COMPUTER TECHNOLOGY

Mr. Paul Moody, Supervisor, WSDOT Cartographic Unit

The primary discussion centered around dealing with the conversion from manual to automated work. However, the discussion should apply to any work environment where optimum production is expected from people.

The primary keys to increased production are the people who operate the tools of his trade, computers and software. Training is significant, and it is important to treat these co-workers and employees as partners, always with dignity and respect. It is important that each supervisor periodically check his management style. As work must be fulfilling to the employee, it is important to match a job to the individual's personal goals.

Age group differences may occur where older employees selected their jobs because of the need for income, and then followed those jobs through to their current positions. Younger workers see their jobs as means to realizing the purpose and value of their own lives. In either case, the job is a part of the individual's personality.

Mr. Moody indicated if you can not find a way to advance a particular employee within your own organization, it is important

to help that person move to another organization or location. The payoff in this action will be future contacts and benefits through the reputation your departments gains as an employer. It is necessary to keep a list of qualified candidates who can be brought in to fill positions as they become vacant. A person can easily be trained, but it is difficult to change their attitude, so in looking for new personnel look for capabilities and attitude. Many times attitudes can be found in little keywords between big phrases. He indicated you should hire people whom are more knowledgeable than yourself in key areas, and insist on excellence while giving the employee the limelight.

Concluding remarks indicated transition from manual to automated operations is a traumatic job experience, and there is a strong need to raise the individuals' self-esteem. Mr. Moody pointed out a continuous need for new talent sources in the cartography field. There is a need for additional emphasis at colleges and universities on developing a source of people.

Session C Synopsis
2:00 and 3:15 p.m., Tuesday, September 15, 1987

HUMAN RESOURCE CONSIDERATIONS

Paul Moody

Issues:

There are no 'experts' in the automated cartography field, making it difficult to find good recruits. Attendees are concerned with the large variance in employee classifications from state to state. Too many excellent employees are being lost to the private sector.

Discussion:

There are two classes of employees, no matter what the organization: the 'old breed' and the 'new breed. The 'old breed' has the following positive characteristics. They are more knowledgeable about the organization and they know all the communication channels. These positives are partially offset by the 'old breed's' resentment of change, resentment of new employees, resentment of change in status due to technology and the 'old breed's' desire for retirement. On the other hand, while the 'new breed' is enthusiastic, often has the latest training and sees the problems and procedures with new eyes, the 'new breed' sometimes lacks depth, is frustrated with protocol and has no past orientation with the organization.

By introducing automated graphic procedures into the organization, a rift is caused between the 'old breed' and the 'new breed'. The result is friction within the organization. It is the cartographic manager's job to minimize this rift and to insure the continuation of smooth work flow within the department.

The two major issues facing a manager when he or she is searching for a good employee are: the job candidate's capability and the job candidate's attitude. If the interviewing manager finds someone who meets his criteria in these two areas, hiring a good employee is practically insured.

The following resolution to the issues stated earlier was presented by the group. Look to local colleges and universities for interns, co-ops and temporaries. Look at personality, attitude and computer background of all applicants. Attempt to standardize job descriptions and pay scales. The problem of losing talented people to the private sector has always been with state government and no quick resolution is seen.

Session D Synopsis
9:45 and 10:55 a.m., Wednesday, September 16, 1987

MAP CREATION

Ron Cihon

Issues:

The issues under discussion at this session were the methods of creating the graphic representation for producing maps, manual digitizing and computerized digitizing, and the role of the digitizer in these efforts.

Discussion:

The attached presentation served as a basis for discussion in the map creation session. What now follows is some additional discussion generated by this topic.

A survey of the attendees indicated that of the states into computerized mapping, two are digitizing via the scanning method and the remainder are doing manual digitization. One attendee expressed concern as to whether or not he will 'go under' with these duties due to lack of computer technology. It was suggested that communication problems must first be resolved and then technical problems can be conquered by using specialization to develop a sense of teamwork.

Another point which was raised was that upper level management must be made aware that CADD is no 'magic solution' and that project management and decision making must be utilized to make CADD as productive as it can be. Also the digitizers must be allowed to obtain adequate training.

It was a consensus opinion that as automated map creation is undertaken, management should be given some sample output products periodically to show them some hard copy results.

Discussion followed on distribution of data with a decision that it should be made available on a cost basis rather than giving it away. This will prevent requests for information that really is not needed.

The importance of making intelligent decisions before committing to the systems to be used in computerized mapping and the importance of maintaining a link between the graphics and attributes was discussed next. It was stressed that some consideration should be given to the digitizers

before making the final decisions. Systems with which digitizers feel more comfortable should be used whenever possible.

Session D Synopsis
Ron Cihon
10:00 and 11:00 a.m., Wednesday, September 23, 1987

DATABASE SELECTION

Dr. Tim Nyerges, Assistant Professor,
Geography Department, University of Washington

The basic intent of the workshop conducted by Dr. Nyerges was to discuss issues concerning database design methodology and the selection of a database management system. These items of concern included the following:

1. The types of spatial information systems,
2. Data environments,
3. Data modeling and database design, and
4. Spatial data structuring.

The discussion included an in-depth analysis of these issues through the use of a detailed outline which was distributed at the beginning of the workshop.

Spatial Information Systems (SIS)

Dr. Nyerges described an SIS as an information system which encompasses any one or more of the following types of systems:

1. Computer Aided Design and Drafting System (CADD) - focus on plan drawings.
2. Map Information Management System (MIMS) - focus on quality map display.
3. Geographic Information System (GIS) - focus on analysis for planning functions.

4. Image Information System (IIS) - focus on imagery analysis.

5. Multipurpose Land Information System (MLIS) - focus on land record activities.

Each of the above systems is implemented to specific spatially related functions. The selection of a spatially related information management system is based on particular uses. Dr. Nyerges suggests a combination of systems may be necessary to solve the assortment of transportation problems.

Data Environments

Data can be collected and stored in a number of different ways, or environments. The most basic storage environment is separate data files oriented to a specific use. This technique causes data redundancy which leads to inconsistent data values. Storage environments have evolved through the single file storage technique to database technology.

According to the definition offered by Dr. Nyerges, a database is a "collection of interrelated data stored together with controlled redundancy to serve one or more applications." A database management system (DBMS) is a set of procedures for accessing, storing, and retrieving data in a consistent manner. Creating a database involves data modeling, or how to get the data into the computer that best represents the real world.

Data Modeling

Dr. Nyerges pointed out that much confusion exists surrounding the term "data model". He made a distinction between a data model and a conceptual data model. A conceptual data model holds the notion of the logical representation of the data structure that forms the database. It shows the data types and the relationships among these data types. The true meaning of a data model consists of three components:

1. A collection of object types,
2. A collection of operators on the object types, and
3. A set of constraints on a database.

The conceptual data model is the framework to develop the database, whereas the data model is the constructs and operators for manipulating the types in the database. Effective database design requires the utilization of multiple data models. The process of data design consists of requirements collection, conceptual view specification, logical modelling, and physical modeling.

Spatial Data Structuring

Traditional spatial data structuring techniques were explained by Dr. Nyerges. These basic types are Vector- and Grid-based approaches. The main issues concerning transportation application is topological or non-topological structures. Structures that have either implicit or explicit topology are useful

for analysis, whereas non-topological structures are primarily useful for fast graphic display. The choice depends on the applications.

Several additional spatial data structuring techniques were also discussed. These "hybrid" approaches included the hypergraph, quadtree, and georelational data structures.

Session E Synopsis
10:15 and 11:00 a.m., Wednesday, September 23, 1987

SCANNING

Mr. Charles Wells, Chicago Aerial Survey

The theme of this workshop was the use of raster scanned data in digital cartography. As an example, a slide presentation was given of a Chicago Aerial Survey project for the Wisconsin Department of Transportation. This project involved creating a digital base map of that state for future use in a Geographic Information System.

The source materials used were special five-color proofs of the U.S. Geological Survey 1:100,000 series. Raster scanning, as well as later vectorizing, was done on a Scitex system which included a color scanner. The items captured included roads, hydrology, county boundaries and landmark buildings. After scanning, raster editing isolated each feature in its own color. Finally, the raster file was vectorized, improving line quality, and then converted to an Intergraph design file.

Discussion also included comments on Laser-scan's technology of vector scanning of negatives. This process uses a line follower, which is an automatic/manual digitizer that tracks center lines.

Workshop observations included:

1. The quality of the source material is very important, both for raster scanning and vector line following.

2. Certain types of information are more suitable for scanning than others; contours and polygons are easier to scan, while features containing intersections, such as roads, may require considerable interactive editing.

3. Scanning of color composites requires careful calibration of the equipment, and a fair amount of editing; the use of source material separates reduces the amount of work involved.

Scanning may be suitable for bulk digitizing of certain types of information, and is a technology whose future developments should be monitored.

Scanning Workshop

Suggested Discussion Topics

General comments concerning applicability of scanning to cartography and DOT cartography in particular

- bulk entry of cartographic data is undoubtedly desirable, but is not without problems
- scanning technology is becoming more affordable
- more sophisticated software is being developed to reduce interactive editing of scanned data

Raster data vs. vector data

- advantages of scanned raster data
  - scan digitizing is faster than manual digitizing in many situations
  - scanned data will normally be more precise than manually digitized data
  - easy retrieval
  - maintainability, although not always superior to vector data
  - data can be converted to vector if necessary
  - high-quality output is possible on some raster plotters
- disadvantages of scanned raster data
  - large storage requirements, although compression techniques may assist here, as will the use of optical disk storage
  - difficulty of storing attributes (adding intelligence) as compared to vector data
  - individual data elements are not as easily distinguishable from each other, hence the need for sophisticated recognition software
- advantages of vector data
  - more common; more systems are available which work with vector data
  - data elements are distinguishable from each other
  - attribute data can be easily linked to graphic elements
  - moderate storage requirements

- disadvantages of vector data
    - may be difficult or costly to digitize certain source maps manually
    - the accuracy of manually digitized data may be of inconsistent or poor quality

Source document quality and type

- type of data on source document
    - intersecting lines, symbols, text
    - multiple feature layers on one source which need to be separated
    - presence of extraneous data or other noise
- general quality of source document
    - is document scannable at all?
    - is edit time cost effective? (engineering drawings for example)
    - size limitations of scanner
- color vs. black and white scanner
    - scanner capabilitites (color / black-white)
    - storage requirements; 1 bit per pixel vs. 1 byte per pixel
- separability of data
    - can various types of features be distinguished
    - can various data types (points, lines, areas) be distinguished
    - thresholding techniques

Scanning resolution

- high speed scanners may have limitations such as 200 or 400 lines per inch and may not permit accuracy needed for some applications
- higher resolution is available but the cost may be more storage space and perhaps more scanning time

Text

- text as raster data may be difficult to handle
    - may not be separable from other data
    - how to convert text from groups of contiguous pixels to usable text strings
- text as a graphic feature vs. text as attribute data

- character and symbol recognition

    - a problem of aritificial intelligence
    - most character recognition systems attempt to recognize possible textual information (sometimes with a probability tolerance) and allow the user to either accept the software's interpretation or to reenter the text as it should be
    - these work best under ideal conditions of high-quality source documents, uniform fonts fonts, and uncluttered source documents
    - text is still not meaningful beyond its graphic sence in raster form

Basic features of raster editing

- character and/or symbol recognition
- 'noise' reduction or elimination
- line thinning or skeletalization
- edge detection and enhancement
- feature separation by line width and/or color
- raster-to-vector conversion

Session E Synopsis
9:45 and 10:55 a.m., Wednesday, September 16, 1987

MAP MAINTENANCE

Charles Groves

Issue:

Ohio's STAIRS, Statewide Accident Identification and Reporting System

Discussion:

These two sessions were approximately 55 minutes lectures on Ohio's STAIRS procedures with the remaining five minutes for questions and answers. Overall, the sessions were presented in a very simplified format so that all could understand the technical aspects of developing an automated cartographic system with ease.

All follow up questions were directed at the specifics of the Ohio system. There were questions concerning the financing of STAIRS as well as questions about whether or not municipal roads were digitized along with state roads. Ohio's system really does not need a lot of maintenance now, since it is running smoothly. A main reason for Ohio's successful system is the excellent data base with which they began.

Session F Synopsis
9:45 and 10:55 a.m., Wednesday, September 16, 1987

SCANNING

Thomas Slayton & Stuart Layne

Issue:

The use of scanning as an alternative to digitizing

Discussion:

The following points were set forth in the two presentations:

-There are problems with coordinating the system.

-There are high start up costs.

-Has there been a study between scanning and digitizing?

-What is the time frame to a finished product?

-There are two scanning techniques, raster and vector.

-It is better to use map separates.

-There are no lettering plate problems.

-You can control size (close to original size).

-Control points must be set.

-You can go in and change things after scanning.

-You can do different features on different levels.

-What can be done with the expensive equipment after scanning all maps.

Session F Synopsis
10:15 and 11:00 a.m., Wednesday, September 23, 1987

MAINTENANCE OF GRAPHIC DATABASES

Mr. Dan Wyly, Manager, Engineering and Development and Mr. Tony Pulliam, Mapping Manager, Texas State Department of Highways and Public Transportation

The Texas State Department of Highways and Public Transportation mapping program consists of a series of General Highway maps in County format, a series of Federal and State Highway System maps in District format and a State Departmental map which shows the complete Federal and State Highway System.

In order to continue an established mapping program, a manual revision process is maintained on existing hardcopy maps. Future major digital updating of existing files will be done only in high-growth, urbanized counties. Digital U.S.G.S. quad files will be used as they become available, and will be edited into existing databases. Aerial photography will be used to digitize observed changes. District offices will furnish digital alignments for new and realigned highways.

Presently, Texas has limited automatic procedures for map maintenance. Automated procedures now in use are adaptations of procedures used for base map creation.

Reasons for automated map maintenance are:

1. The completion of significant portions of the mapping databases.
2. The growing demand for special map production.
3. The creation and maintenance of parts of the databases.
4. The requirement to distribute the databases to other computers in the network.
5. The requirement to have different data on each computer in the network.

Maintenance is the most overlooked element in an automated system. A system like the "Map Maintenance Subsystem", presented by Cooper, appears to be a logical solution to the problem of maintaining the integrity of a database.

An automated map maintenance system should be able to:

1. Extract a maintenance work file from the cartographic master file,
2. Create an audit trail,
3. Create plots or displays that allow the viewing of the updated map,
4. Protect against unauthorized write access,
5. Protect against multiple updating,
6. Provide status information relative to ongoing maintenance,
7. Merge maintenance work with the master file,
8. Archive, backup and recover,

9. Maintain access to the master file from multiple computers within the organization's network and

10. Allow a cartographer at a remote site to perform creation and update activities on a portion of the master file.

Session G Synopsis
Ron Cihon
1:30 and 2:30 p.m., Wednesday, September 23, 1987

GEOGRAPHIC INFORMATION SYSTEMS

Dr. Kenneth J. Duecker, Director,
Center for Urban Studies, Portland State University

Dr. Duecker accomplished the following in this workshop:

1. He offered suggestions on issues which warrant further development in the Conference's position paper.

2. He reviewed a recently published article (Duecker, 1987) which distinguished between Computer Aided Mapping (CAM) Systems and Geographic Information Systems (GIS).

3. He presented a proposal for a Georelational Structure for transportation GIS.

4. Finally, Dr. Duecker suggested approaches to examining the problems of geographic information systems for transportation.

Dr. Duecker described several issues which needed further discussion in the Conference's position paper. He maintained GIS has not been fully supported in state transportation agencies because these agencies have used system acquisition specifications designed primarily for CAD (drafting) functions. Greater emphasis is needed for developing enhanced systems capable of GIS applications, particularly with respect to lineal geographic features. Standards need to be developed concerning what are GIS

transportation features. Present systems lack "spatial operators", or algorithms to do normal GIS applications such as print in polygon or shortest path functions. He also felt a GIS for transportation should be part of a multipurpose, interagency activity which must also have a local government component.

Dr. Duecker reviewed the differences between CAM and GIS, terms which are often used interchangeably, creating much confusion. Computer Aided Mapping (CAM) consists of points and lines stored in one or more data layers which are displayed layer by layer or simultaneously. The relationships among the features are made solely by the observer. This is limited to a visual interpretation while viewing the display. Geographic Information Systems (GIS) contain a database which consists of features systematically described in terms of point, line or areas. A GIS has procedures to collect, store, retrieve, analyze, and display geographic data. The emphasis in a GIS is to utilize stored algorithms to do the spatial analysis across data layers.

A common concern when implementing a GIS in transportation is to relate feature location, stored in one database, to corresponding records of attribute information often stored in a separate database. Duecker describes the linkage of the feature's locational data to its attribute data as a georelational structure. It is a one-to-one, attribute-to- graphic relationship which enables both the graphic and the attribute databases to be

selected or analyzed. Maintaining this one-to-one correspondence for lineal data may be difficult and would require "run time" segmentation of the lineal features in order to produce homogeneous chains which can be mapped.

The implementation of a GIS for transportation agencies will not be easy and many problems must be overcome. Dr. Duecker has offered the following suggestions:

1. There must be a clear articulation of the problems and issues involved.

2. State transportation agencies should work collectively to identify and solve the problems.

3. Once problems have been identified, vendors should be made aware of these and encouraged to come up with solutions.

Reference: Duecker, K. "Geographic Information Systems and Computer Aided Mapping", American Planning Association Journal, Summer, 1987.

Session G Synopsis
2:15 and 3:45 p.m., Wednesday, September 16, 1987

DATA LINKAGE

Ike Leistikow

Issue:

This session was a demonstration by PennDOT of Pennsylvania's current production status of computerized mapping, highlighting on their digitizing and data linkage efforts.

Discussion:

This demonstration, done on INTERGRAPH equipment, the same as that used by PennDOT, was made doubly effective through the speaker's narration of the events being viewed on a projection screen of the CRT image.

Graphic display of IBM based attribute data was linked to map graphics. By querying the data base, various scenarios were demonstrated such as road surface types, pavement roughness ratings by surface type and network maps.

Also displayed were samples of various products being created and maintained on the computer system.

Standards are available defining digital data characteristics.

Some states are entering into cooperative agreements with USGS so a duplication of effort does not occur.

Guidelines will be mailed to all conference attendees. A newsletter, FEDERAL DIGITAL CARTOGRAPHER, is available from USGS. This newsletter announces available software and who to contact for this software.

Session H Synopsis
2:15 and 3:45 p.m., Wednesday, September 16, 1987

EXISTING DIGITAL DATA

Richard Kleckner, Sheldon Peipenburg,
Kathryn Neff and Gary Fairgrieve

Issues:

This workshop consisted of how USGS and the U.S. Census Bureau are prioritizing their program for both federal and state agencies. Duplication of effort and how to avoid it were two other issues also discussed. Finally, guidelines were discussed and it was decided that USGS would mail out guidelines to all conference attendees.

Discussion:

How is USGS prioritizing its program? On the federal level the AIG process is used and on the state level SMAC is used.

Where did USGS' road classification system come from? It is the result of old military requirements.

Are any guidelines published on digital data submissions? Standards are available defining digital data characteristics.

Some states are entering into cooperative agreements with USGS so a duplication of effort does not occur.

Guidelines will be mailed to all conference attendees. A newsletter, FEDERAL DIGITAL CARTOGRAPHER, is available from USGS. This newsletter announces available software and who to contact for this software.

Session I Synopsis
1:30 and 2:30 p.m., Wednesday, September 23, 1987

U. S. CENSUS BUREAU

Mr. Timothy Trainor, Mapping Operations, Geography Division

Mr. Trainor made a presentation of the new Topologically Integrated Geographic Encoding and Reference (TIGER) System of the U. S. Census Bureau, which is being used as a database source in creating the cartographic products in support of the 1990 Decennial Census.

The applications computer programs, written by cartographers at the Census Bureau, provide a completely automated map production environment in a batch mode without any human intervention including interactive editing. Computer programs automatically determine map image area, sheet layout, inset areas, map scale, map identification, map control and map sheet indexes. Automated names placement, a current technological development, is also accomplished in a reasonably acceptable manner to meet the needs of maps to take the census.

The TIGER System is comprised of selected cartographic features from the U.S. Geological Survey's 1:100,000-scale database, the Census Bureau's GBF/DIME files for 345 metropolitan areas, nationwide feature updates collected from the Census Bureau's 12 regional offices, feature names, 1980 political and statistical

areas and their identifiers and 1990 census collection geography. The TIGER files are partitioned by county.

The Census Bureau historically has been a user of the map products from state departments of transportation. Maps provided from the states have served as primary update sources for transportation networks, road names and other cultural features portrayed on census maps.

Mr. Trainor invited the Departments of Transportation (DOTs) to investigate using TIGER files as their base file upon which to build their automated mapping systems. TIGER files contain many of the feature categories states are planning to digitize or are currently in the process of digitizing. Having an already existing base file such as a TIGER file will allow state DOTs to allocate valuable resources toward enhancing the file to meet specific transportation, planning and other department needs.

A test file of Boone County, Missouri, will be available in December, 1987. The cost of the file is $175. All TIGER files will be available by the end of 1989. State DOTs with modem-equipped PCs can access current on-line information about the TIGER System by calling 1-301-763-1568.

Session J Synopsis
8:00 and 9:00 a.m., Thursday, September 24, 1987

JOINT DEVELOPMENTS OF TRANSPORTATION COMPUTER ASSISTED CARTOGRAPHY EFFORTS

Mr. Lee Eason, Support Services Manager, WSDOT
Mr. Frank Cooper, President, Cooper Technologies, Inc.

Mr. Lee Eason explained that the AASHTO (American Association of State Highway Transportation Officials) Geographic Information System (GIS) Symposium was held to look at the development of joint projects among Departments of Transportation (DOTs). As no single definition of a GIS exists among DOTs, joint development of a GIS project is premature, though the concept is desirable. Such joint development would allow pooling of resources to contract problem solving among DOTs who share a common need.

The AASHTO sub-committee has looked at the concept of GIS strictly as a computer function, to be defined and developed by Data Processing (DP) staff. The more informed view is that both cartographers and users must necessarily be included as major players in this process. This AASHTO misconception is being assimilated by upper management in the nation's DOTs, and needs to be replaced by a more enlightened view which includes planners, cartographers and DP staff. Hopefully, a more rounded

concept of GIS could be developed by having DOT cartographers form an organization similar to the Highway Engineering Exchange Program (HEEP), or by operating through an existing organization.

Mr. Frank Cooper explained that HEEP is a technical working group made of engineers and DP personnel. It has developed considerable influence as an organization, but must work through AASHTO, as they are not a corporate entity. Mr. Cooper encouraged the group to address a consensus of our GIS concerns to the existing organizations of HEEP and AASHTO, as well as to considering organizing as DOT cartographers into a professional group.

There was agreement that DOT cartographers should not rely entirely on organizations like HEEP for representation of their views, as HEEP's focus is engineering and DP. The cartographic needs are likely to receive less emphasis than desirable within those organizations. Even getting approval to attend such meetings is unlikely, as travel approval is perceived as being more readily available for engineers and DP personnel than for cartographers. However, making our concerns known to existing organizations in the very near future seems desirable as a way to start. Mr. Cooper will take these concerns to the upcoming HEEP meeting.

Discussion centered around how to get the transportation GIS concept centered back on geography, where it started. Tapping into various committees was discussed, as well as the possibility of exploring a subcommittee on transportation cartography and GIS under AASHTO's planning task force.

A major consensus was that transportation computer cartographers need to have an annual meeting, preferably on a national level.

COMPUTER ASSISTED CARTOGRAPHY CONFERENCE

OLYMPIA, WASHINGTON

SEPTEMBER 24, 1987

WORKSHOP J

JOINT DEVELOPMENT FOR G.I.S.

- NATIONAL EFFORTS BY STATE TRANSPORTATION AGENCIES -

Lee W. Eason, II, P.E.
Chairman, Graphics Task Force
AASHTO Subcommittee on Computer Technology
Washington State Department of Transportation

In March of this year, a GIS Symposium in Tempe, Arizona was jointly sponsored by the AASHTO Subcommittee on Computer Technology, the Standing Committee on Planning, and the Highway Engineering Exchange Program (HEEP). It was attended by 134 persons representing 25 states, 6 Federal Agencies, 1 Canadian provence, and others.

The purpose was to explore the possibility of an AASHTO Joint Development project that would benefit interested State DOTs in a meaningful way. The specific objective of some was to move forward deciding on a Vendor/Software combination that would solve DOTs geographic information requirements--requirements that have yet to be determined and that are definitely not uniform between most states.

The program consisted primarily of presentations by a University, the Census Bureau, several vendors and consultants. In summary, the conference indicated that GIS is a computer function--"a strategic computer system for the 1990's". A good acedemic definition of GIS became better understood, although very scary; also the offerings of the vendor community are better known. It was obvious to most, I believe, that most vendors don't understand the needs of transportation agencies--and possibly neither do most of us!

Most DOT attendees had problems with the "it's a computer function" idea. There was general agreement that:

- Joint Development of a project was premature.
- Further education is necessary.
- Involvement of others, particularly cartographers and users is essential. Planning a GIS is a long term, evolutionary, agency-oriented process.

The attached diagram illustrates the benefits of merging three or more separate pyramids into one.

There are also some non-graphic pyramids coming into the integration picture, as DOTs move towards Geographic Information Systems (GIS)--conventional information management systems, for example, will be integrated with the cartographic data base to produce more CADD end products. There are at least two schools of thought on the GIS of the future. Information scientists and many vendors view GIS as the analysis and display of analysed information in a computerized base (node-to-node), or coversely, the retrieval of information by pointing to a computerized map. In this context, the highly structured GIS data base is the source for both the graphics and the data. Symbolic maps are produced by connecting or linking the identified coordinates. (Link-Node)

Transportation map makers are defining the GIs of the future somwhat similarly, but with one big difference in philisophical design--specialized maps of superior quality and utility are produced from the geographic data base created by automated cartography, thereby adding the dimension of customizing the map upon which information is displayed. Although the battle lines are being drawn, I believe we will have need for both concepts; and perhaps we can ultimately have the best of both worlds. Engineering data bases, AM&FM, and multi-purpose cadasters will no doubt require the former, while the bulk of information collected and used by DOTs for planning and public information will dictate the reasonable compromise of linking non-graphic information to our cartographic data base.

Also attached are notes and one-liners from the round table discussion following the presentations at the Tempe meeting. They provide further insight and observations from a wide cross section of attendees.

18:SS-5

Attachment 1

NOTES FROM GIS SYMPOSIUM
Tempe, Arizona

March 31, 1987

Dr. Marble New York: These demonstrations have shown that just having the hardware and software won't solve your problems. Scale generalization is not going to be effective--we will no doubt have different data bases for different uses.

Data base size will be a problem. Tiling or breaking up into sections is a probability.

Most of what we heard in these two days was toward automated mapping. GIS will focus on the analysis of geographically related data and its use in decision making.

Our discussions are not influenced enough by cartographers. We need cartographic involvement, for it's not soley a D.P. function.

Didn't hear enough about hardware and sofware independence. Device independence is most desirable.

Be cautious about networking GIS. Encourage pilot projects, take some first steps, then build modularly toward ultimate GIS.

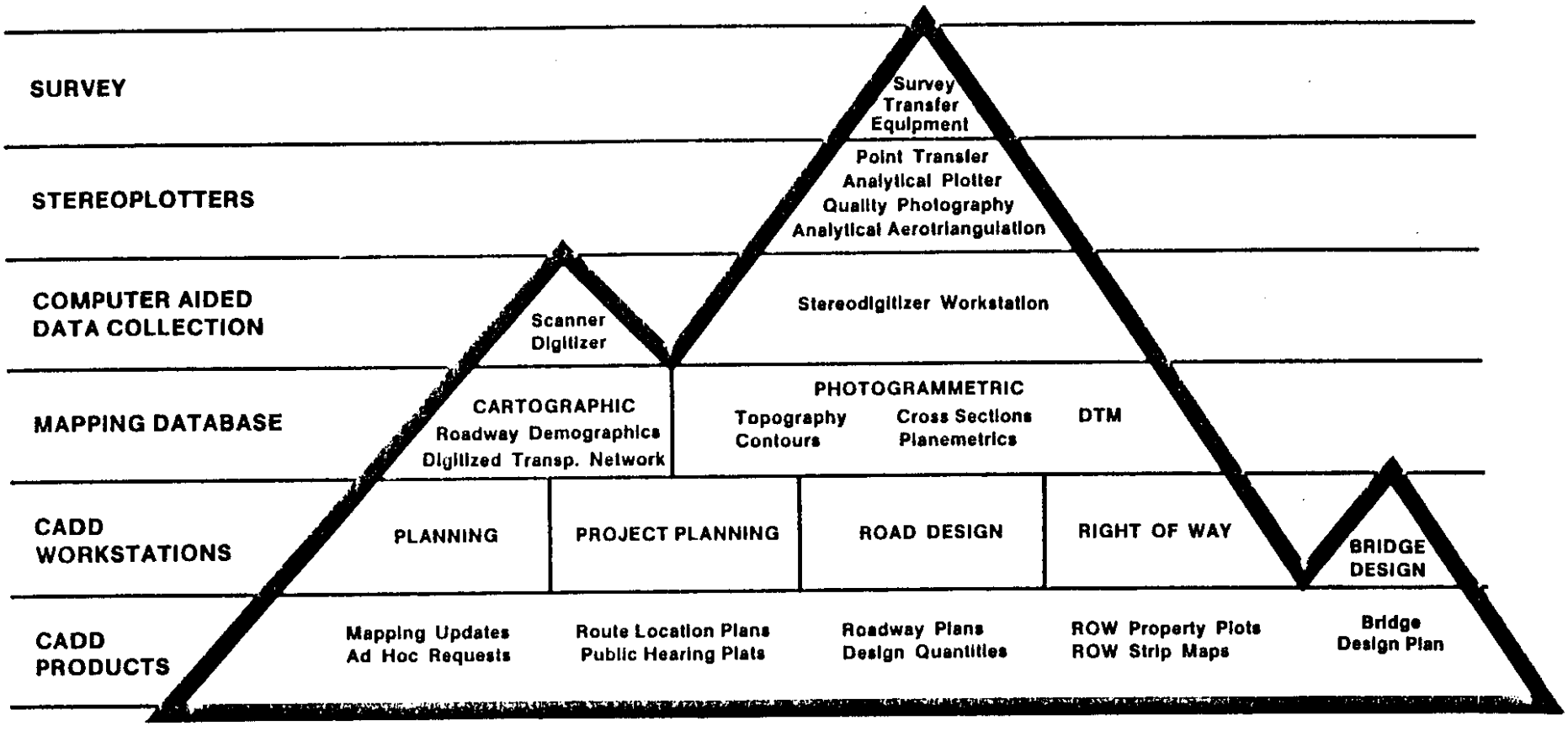
Wisconsin: Until now, we haven't understood what GIS is, or what the vendor community has to offer. It's now obvious that most vendors don't understand our needs.

Michigan: Really, GIS is not a system-it's a concept for the future. Joint development of a project is premature. Our options are: (1) Further education, and (2) the development of a specification for DOT oriented GIS--using a Task Force or a consultant. It's obvious this is a very expensive process, in both commitment and money.

Minnesota: Information modeling techniques are needed. Most agencies don't realize how much data they have. Also, there are unresolved problems with high-resolution vs. low resolution data. Multiple data bases is a possibility. Long-range, we will need high degree of detail and high resolution.

Arizona An operating (maintenance) manager--"You folks aren't realizing this goes beyond a data processing function. Involve your cartographers and the people who collect data!"

Iowa:	Agreed that, in the end, GIS is not a technical problem, but a management or institutional problem.
Dept. of Defense:	planning GIS is a long-term evolutionary process. Get other involved. Need to employ information modeling techniques.
Pat Gaines:	Recommends a 3-level approach towards evolving into GIS: (1) graphic manipulation, (2) display existing data thereon, (3) analytical work with combinations of data. We need something quickly initially. Add other features later.
Washington:	We are taking a cautious approach, first producing a geographic map base, with proper hooks to link attribute data using mile post, then displaying existing data on a customized map. Top-down guidance is hard to come by because not enough is known about GIS potential.
Penn. DOT:	Don't expect to get it all done at once. Penn. DOT is planning on five years or more.
S. Dakota:	Much need for information and also some short term progress.
Frank Cooper:	Much of the data already exists. Surely we'll find a way to use it in GIS.
FHWA:	Two Conferences on Computer Assisted Cartography are scheduled in Harrisburg, Pa. and Olympia, Wa. this fall. These should provide further education on Automated Mapping and GIS and valuable input from mapping and planning practitioners.


SURVEY
STEREOPLOTTERS
COMPUTER AIDED DATA COLLECTION
MAPPING DATABASE
CADD WORKSTATIONS
CADD PRODUCTS
Survey Transfer Equipment
Point Transfer
Analytical Plotter
Quality Photography
Analytical Aerotriangulation
Stereodigitizer Workstation
Scanner Digitizer
CARTOGRAPHIC
Roadway Demographics
Digitized Transp. Network
PHOTOGRAMMETRIC
Topography
Contours
Cross Sections
Planemetrics
DTM
PLANNING
PROJECT PLANNING
ROAD DESIGN
RIGHT OF WAY
BRIDGE DESIGN
Mapping Updates
Ad Hoc Requests
Route Location Plans
Public Hearing Plats
Roadway Plans
Design Quantities
ROW Property Plots
ROW Strip Maps
Bridge Design Plan

Session J Synopsis
8:00 and 9:05 a.m., Thursday, September 17, 1987

JOINT DEVELOPMENT

Norman Baker

Issues:

Should there be an annual forum for this type of meeting? How should this group be organized? Some suggestions were: as an AASHTO subcommittee, aligned with HEEP or as an independent organization. Where will the next meeting be held?

Discussion:

The future of automation belongs with the users. Cartographers and engineers need to understand one another. There is also a need for cartographers to establish relationships with AASHTO. HEEP may be too engineering oriented for the cartographer's purpose. Future conferences must be organized so as to meet the needs of the cartographers not their managers. The next meeting should be a completely national meeting with both eastern and western states meeting together.

Resolutions:

There should be an annual meeting.
The cartographers should align with AASHTO or HEEP and move from there.
Ohio was suggested as a possible site for the next meeting.
Whatever type of organization arises, the cartographer's identity must not be lost.

Session K Synopsis
8:00 and 9:00 a.m., Thursday, September 24, 1987

THE ROLE OF FHWA IN RELATIONSHIP TO STATE COMPUTER ASSISTED CARTOGRAPHY PRACTICES

Mr. Charles Chappell, Washington Division, FHWA

The participants were invited to express their impressions of the role of the Federal Highway Administration (FHWA) in the past and present, and to comment on the role they would like the agency to assume in the future. Ensuing discussion reflected a wide range of ideas about present requirements and seemed to indicate varied interpretation of federal guidelines between FHWA regions.

Suggestions for future FHWA involvement included:

1. Facilitator role; support interaction by sponsoring conferences, newsletters and user groups.

2. Promote a process to develop mapping standards and definitions.

3. Represent states' transportation interests on national (federal) committees on GIS and cartography.

4. Participate on American Association of State Highway Transportation Officials (AASHTO) committees dealing with GIS and cartography.

5. Encourage state DOT representation on national committees.

6. Define the cartographic needs of HPMS and provide funding.

Three general points emerged from this workshop:

1. As FHWA mapping requirements were scaled back, Region and Division offices have assumed greater independence in defining the FHWA role,

2. FHWA has become more of a user and funder than a standards-setter and

3. DOTs are now more responsible for defending their own mapping programs for the allocation of HPR funds than in the past.

Session K Synopsis
8:00 and 9:05 a.m., Thursday, September 17, 1987

AGENCY ROLES

Woody McGee

Issues:

The discussion in these two sessions centered on the roles the cartographer and the FHWA should play in the Computer Assisted Cartography field.

Discussion:

Roles the cartographer should play:

-provider of service products to customers
    *distribution of maps
    *meet the needs of customers

-provider of information system

-salesperson - sell what you can do for a customer

-expeditor of a quality product

-maintainer of a community base

-except the challenge of change and an expanding role in the transportation field

-designer - tell the vendors what is needed

-liaison with management to develop work programs and budget

-builder of trust level

-make people aware that quality is our product

-leader and an educator

-encourage ideas - let people be an active part of the process

Roles the FHWA should play:

-decision making of system design, inter-agency activities, and transfer of information

-interacting roles between FHWA and the DOTS

-help with funding

-encourage voluntary standards and guidelines

-coordinate internally

-use committees as a way of communication

-encourage active participation of all interested parties

-provide conferences and other forums for dialogue, idea exchange and recognition

-be facilitators of information from other countries

Session L Synopsis
Ron Cihon
8:00 and 9:00 a.m., Thursday, September 24, 1987

THE ROLE OF TRANSPORTATION COMPUTERIZED CARTOGRAPHY IN STATE AND LOCAL GOVERNMENT

Mr. Ron Cihon, Production Supervisor, Mapping Section, Washington State Department of Transportation

The workshop was changed slightly from what was originally planned. The subject matter was broadened to include the following:

1. The role of transportation computerized cartography in state and local governments.
2. The role of the Cartographer.
3. The role of this conference in the future.

Workshop participants were initially asked to reflect on these three issues and write their responses on paper to be collected at the end of the session. Mr. Cihon had an informal discussion of these three issues.

It was generally agreed that the role of transportation cartography, manual or automated, was to provide a current inventory, in graphic form, of the state highway network. Participants were asked what role should a state transportation agency play in the development of a statewide, multipurpose cadastre or GIS. Most attending this conference felt state DOTs should

participate, but not take the lead role, in the development of a statewide shared geographic information system.

When asked to discuss the role of the cartographer, particularly when changing from a manual to an automated production mode, the responses included the following:

1. To market the unit's products, and capabilities within and outside the department.

2. To provide complete and accurate products in the form of a base map series, thematic maps, and an official state highway map.

3. To maintain a relationship with other state and local agencies, and exchange information when desirable.

4. To cooperate with agency data processing personnel in the development of automated tools to create a geographic information system.

The final topic of discussion centered around the role of the conference in the future. The respondents unanimously agreed these meetings were worthwhile, and the conference should be continued in the future. However, several suggestions were made by participants. The conference was conceived with the idea of including mapping supervisors and cartographers, but the attendees were predominantly supervisors and managers. It was felt these different levels of expertise were desirable but more "hands on" level of participants and workshops should be included in the future. It was also suggested that preliminary questionnaires be distributed to participants prior to the workshops in order to align the conference more directly with agency consensus.

Western Region*

Computer Assisted Cartography Conference

PROGRAM

Dates: September 22 - 24, 1987
Location: Department of Transportation
Olympia, Washington

TUESDAY, SEPTEMBER 22, 1987

7:30 **Registration**
State Office Building 2

8:00 **Welcome**
Duane Berentson, Secretary, Washington State Department of Transportation (WSDOT)

8:30 **Conference Overview and Introductions**
Paul Moody, Supervisor, WSDOT Cartographic Unit

9:15 **Role of Computerized Mapping in the Planning Process**
Christopher Fleet, Chief, Planning Support Branch, Office of Planning, Federal Highway Administration (FHWA)
The role of computerized mapping in the overall planning process will be presented. FHWA guidance and support to state transportation agencies will also be addressed.

9:45 **Break**

10:00 **Keynote Session**
Frank Cooper, President, Cooper Technologies, Inc.
Mr. Cooper will give an overview and historical perspective of the computerization of mapping in the transportation field. A position paper on state-of-the-art technology and issues relating to computer assisted cartography in transportation will also be introduced.

11:00 **Panel Discussion - Standardization in Transportation Cartography**
Moderator: *Tim Nyerges*, Assistant Professor, Geography Department, University of Washington
Various issues and positions will be discussed by federal, state and private industry representatives.

12:00 **Lunch** – Westwater Inn. Shuttle provided.

Afternoon Workshops. Conference rooms will be announced. The following afternoon workshops will be repeated three times. Choose one to attend during each afternoon session.

Workshop A – Standardization in Transportation Computerized Cartography
Frank Cooper, Cooper Technologies, Inc.
This workshop will present a forum in which participants can discuss and provide input into the issue of standardization for the purpose of developing a state-of-the-art position.

Workshop B – Design, Acquisition and Support of a Computer Assisted Cartography System
Lee Eason, Support Services Manager, WSDOT, and *Art Wagner*, Pennsylvania Department of Highways
This workshop will provide participants information on criteria for designing a system, how to justify a system, aspects of selecting hardware and software and other organizational issues involved in developing support for a system.

Workshop C – Human Resources and Computer Technology
Paul Moody, Mapping Supervisor, WSDOT
This workshop will explore human resource issues relating to the use of computerization in cartography. Training, employee selection, adaptation to new technology and other related topics will be discussed.

1:30 **Workshop Session 1**

2:30 **Workshop Session 2**

3:15 **Break**

3:30 **Workshop Session 3**

4:15 **Exhibits and Wine Reception**

WEDNESDAY, SEPTEMBER 23, 1987

8:00 **Panel Discussion -- Creating a Graphic Database**
Moderator: *R. Bradford Harvey*, V.P., Weston Consultants
Panel Members: *Jim Russell*, Chicago Aerial Survey, *Gale LaBlanc*, Louisiana Department of Transportation, *Tom Perry*, Pennsylvania Department of Transportation, and *Mike Sety*, U.S. Geological Survey
Experts will discuss methods of creating a graphic database, including manual, scanning, van, contract, using existing databases.

9:45 **Break**

Morning Workshops will be held in TWO sessions. Each workshop will be held twice. Choose one to attend during each morning session.

Workshop D – Database Selection
Tim Nyerges, Associate Professor, Geography Department, University of Washington
This workshop will explore in depth the various sources of databases, how to select a database, formatting, composition of files, etc.

Workshop E – Scanning
Jim Russell, Chicago Aerial Surveys
This workshop will focus on using scanning techniques on resource maps and other source documents to create a land base map for GIS application.

Workshop F – Maintenance of Graphic Databases
Dan Wyly, Manager, Engineering and Development, and *Tony Pulliam*, Mapping Manager, Texas State Department of Highways and Public Transportation
Maintenance activities that are required to update and maintain an existing database will be discussed. Updating sources and map management will also be addressed.

10:00 **Workshop Session 1**
11:00 **Workship Session 2**
12:00 **Lunch** (on your own)

Afternoon Workshops. The following afternoon workshops will be repeated three times. Choose one to attend during each afternoon session.

Workshop G – Geographic Information Systems
Dr. Kenneth J. Dueker, Director, Center for Urban Studies, Portland State University
This workshop will provide detailed information on the whats, whys, hows, benefits, costs and attributes of GISs.

Workshop H – U.W. Geological Survey
Barry Napier, Cartographer, Western Mapping Center, USGS
What is a DLG? Why is this data needed by transportation cartographers? Programs and services provided by the USGS digital mapping program will be discussed.

Workshop I – U.S. Census Bureau
Timothy Tainor, Mapping Operations, Geography Division, U.S. Census Bureau
This workshop will deal with mapping from the Census Bureau's TIGER file: a large, national, non-cartographic database.

1:30 **Workshop Session 1**
2:30 **Workshop Session 2**
3:15 **Break**
3:30 **Workshop Session 3**
4:15 **Product demonstrations by other state** DOTs
5:30 **Departure for Northwest Salmon Barbeque** at Tumwater Historical Park

THURSDAY, SEPTEMBER 24, 1987

Morning Workshops will be held in TWO sessions. Each workshop will be held twice. Choose one to attend during each morning session.

Workshop J – Joint Developments of Transportation Computer Assisted Cartography
Lee Eason, Support Services Manager, WSDOT, and *Frank Cooper*, Cooper Technologies, Inc.
This workshop will present national efforts regarding joint development by state transportation agencies of computer assisted cartography projects.

Workshop K – The Role of FHWA in Relationship to State Computer Assisted Cartography Practices
Charles W. Chappell, Washington Division, FHWA
This workshop will be a discussion by cartographers on FHWA's role in computer assisted cartography practices.

Workshop L – The Role of Transportation Computerized Cartography in State and Local Government
Ron Cihon, WSDOT
The relationship of computer cartographic practices to local government, state agencies and other organizations will be discussed.

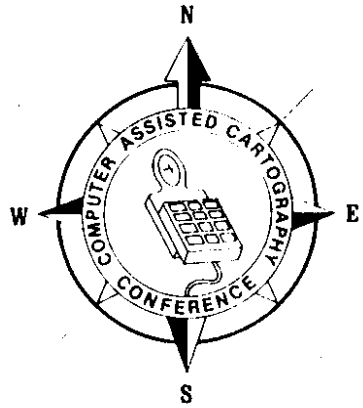
8:00 **Workshop Session 1**
9:00 **Workshop Session 2**
9:45 **Break**
10:00 **Reports from Workshop Leaders**
Moderator: *Paul Moody*, Supervisor, WSDOT Cartographic Unit
Each workshop leader will deliver a summary of the workshop and recommendations. Participants will be given an opportunity to express their opinions and suggestions on each topic in order to consider a consensus opinion on relevant issues.

11:45 **Conclusion**
James P. Toohey, Assistant Secretary, WSDOT, Planning, Research and Public Transportation

This program may be subject to change

SEPTEMBER 17, 1987

7:30	COMPLIMENTARY CONTINENTAL BREAKFAST	- Medici Foyer
8:00 - 9:00	WORKSHOPS J-K	
9:05 - 10:05	WORKSHOPS J-K	
	J - JOINT DEVELOPMENT - Norm Baker, Iowa DOT	- Tivoli
	K - AGENCY ROLES - Woody McGee, PA DOT	- Medici
10:05 - 10:20	BREAK	- Medici Foyer
10:20 - 11:35	POSITION PAPER REVISIONS-Frank Cooper	- Medici
11:35 - 12:00	CLOSING REMARKS - FHWA, PA DOT	- Medici
12:00	MOTEL CHECK OUT	- Lobby
12:00	LUNCH - PROVIDED	- Concetta Gardens



SEPTEMBER 15, 16, 17, 1987

VILLA LEO RESORT AND CONFERENCE CENTER

NEW CUMBERLAND, PENNSYLVANIA

PROGRAM

SEPTEMBER 14, 1987

2:00 - 7:00	CONFERENCE REGISTRATION	- Piazza Foyer
2:00	MOTEL REGISTRATION	- Lobby
6:00 - 9:00	VENDOR EXHIBITS	- Piazza

SEE DINNER MENU SELECTION AT THE CONFERENCE REGISTRATION DESK

SEPTEMBER 15, 1987

7:30	CONFERENCE REGISTRATION	- Piazza Foyer
8:00	COMPLIMENTARY CONTINENTAL BREAKFAST	- Medici Foyer
8:30	INTRODUCTIONS- T. M. Perry, PA DOT	- Medici
8:45	WELCOMING ADDRESS- Lois Dostalik	- Medici
9:15	OPENING REMARKS - Mr. Barna Juhasz, Chief Planning Analysis Division Federal Highway Administration	- Medici
9:45	BREAK	- Medici Foyer
10:00	POSITION PAPER -Frank Cooper,Cooper Technology	- Medici
11:00	STANDARDIZATION - Mr. Benjamin S. Ramey, USGS	- Medici
11:30	DESIGN & ACQUISITION OF A SYSTEM - Art Wagner PA DOT	- Medici
12 - 1:30	LUNCH - PROVIDED	- Concetta Gardens
1:30	HUMAN RESOURCE CONSIDERATIONS - Paul Moody, Washington DOT	- Medici
2:00 - 3:00	WORKSHOPS A-B-C	
3:00	BREAK	- Medici Foyer
3:15 - 4:15	WORKSHOPS A-B-C	
	A - STANDARDIZATION - Messrs Ramey/Cooper	- Medici North
	B - DESIGN & ACQUISITION - Art Wagner	- Tivoli
	C - HUMAN RESOURCES - Paul Moody	- Medici South
4:15	DOT PRODUCT DISPLAYS - All DOT's and Marty Popola-PA DOT	- Piazza
5:00 - 6:30	VENDOR EXHIBITS AND DEMONSTRATIONS	- Piazza
6:30	ATTITUDE ADJUSTMENT PERIOD (Cash Bar)	- Concetta Gardens
7:30	DINNER - PROVIDED 8:30 - ENTERTAINMENT	- Concetta Gardens

SEPTEMBER 16, 1987

7:30	COMPLIMENTARY CONTINENTAL BREAKFAST	- Medici Foyer
8:00	DATA COLLECTION PANEL Panel Leader- Frank McGough, NJ DOT	- Medici
	MANUAL DIGITIZING - Ron Cihon, Washington DOT VAN DIGITIZING - Gaylord Cumberledge, IA DOT SCANNING - Thomas Slayton, Virgina DOT CONTRACTS - Gerald Gingras, Vermont DOT EXISTING DIGITAL DATA - Richard Kleckner, USGS National Mapping Center	
9:30	BREAK	- Medici Foyer
9:45 - 10:50	WORKSHOPS D-E-F	
10:55 - 12:00	WORKSHOPS D-E-F	
	D - MAP CREATION-Ron Cihon, Washington DOT	- Medici North
	E - MAP MAINTENANCE-Charles Groves,Ohio DOT	- Medici South
	F - SCANNING - Stuart Layne, Virginia DOT	- Tivoli
12:00 - 1:30	LUNCH - PROVIDED	- Concetta Gardens
1:30	INTRODUCTION TO GIS - Dr. Reza Wajih	- Medici
2:15 - 3:30	WORKSHOPS G-H	
3:30	BREAK	- Medici Foyer
3:45 - 5:00	WORKSHOPS G-H	
	G - DATA LINKAGE DEMONSTRATION - Ike Leistikow, Marty Popola, PaDOT	- Piazza
	H - EXISTING DIGITAL DATA US Census Bureau - Sheldon Pietenburg USGS, Kathy Neff & Gary Fairgrieve	- Medici South
5:00 - 9:00	VENDOR EXHIBITS AND DEMONSTRATIONS	- Piazza
5:00 - 10:00 PM	ITALIAN BUFFET-PROVIDED Dine at your leisure	- The Cafe

ROSTER

WESTERN REGION 1987
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RESPONSES TO COMPUTER-AIDED CARTOGRAPHY QUESTIONNAIRE

RESPONSES TO COMPUTER-AIDED
CARTOGRAPHY QUESTIONNAIRE

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RESPONSES TO COMPUTER-AIDED
CARTOGRAPHY QUESTIONNAIRE

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ARKANSAS HIGHWAY & TRANSPORTATION DEPARTMENT	P.O. BOX 2261	LITTLE ROCK	AR	72203	(501)569-2205
CALTRANS	P.O. BOX 1499		CA		(916)445-8928
COLORADO DEPARTMENT OF HIGHWAYS	4201 E. ARKANSAS AVE. ROOM 220	DENVER	CO	80222	(303)757-9811
IOWA DEPARTMENT OF TRANSPORTATION	800 LINCOLN WAY	AMES	IA	50010	(515)239-1007
KANSAS DEPARTMENT OF TRANSPORTATION	8TH FLOOR, STATE OFFICE BLDG.	TOPEKA	KS	66612	(913)296-4899
LOUISIANA DEPT. OF TRANSPORTATION AND DEVELOPMENT	P.O. BOX 94245	BATON ROUGE	LA	70804	(504)358-9113
MONTANA DEPARTMENT OF HIGHWAYS	2701 PROSPECT AVE.	HELENA	MT	59620	(406)444-6103
NEBRASKA DEPARTMENT OF ROADS	P.O. BOX 94759	LINCOLN	NE	68509	(402)479-4550
MISSOURI HIGHWAY AND TRANSPORTATION COMMISSION	P.O. BOX 270	JEFFERSON CITY	MO	65102	(314)751-2551
NEVADA			NV		
NEW MEXICO STATE HIGHWAY DEPARTMENT	P.O. BOX 1149	SANTA FE	NM	87504	(505)827-5412
NORTH DAKOTA			ND		
OKLAHOMA DEPARTMENT OF TRANSPORTATION	200 NE 21 STREET	OKLAHOMA CITY	OK	73105	(405)521-2728
OREGON DEPARTMENT OF TRANSPORTATION	ROOM 22, TRANSPORTATION BLDG.	SALEM	OR	97310	(503)378-6256
SOUTH DAKOTA DEPARTMENT OF TRANSPORTATION	700 BROADWAY AVE. E.	PIERRE	SD	57501	(605)773-3278
TEXAS DEPT. OF HIGHWAYS AND PUBLIC TRANSPORTATION	P.O. BOX 5051, W.A.S.	AUSTIN	TX	78763	(512)465-7437
UTAH DEPARTMENT OF TRANSPORTATION	4501 S. 2700 W.	SALT LAKE CITY	UT	84119	(801)965-4347
WASHINGTON STATE DEPARTMENT OF TRANSPORTATION	TRANSPORTATION BUILDING KF-01	OLYMPIA	WA	98504	(206)753-6084
WYOMING STATE HIGHWAY DEPARTMENT	P.O. BOX 1708	CHEYENNE	WY	82002	(307)777-4184
ALABAMA HIGHWAY DEPARTMENT	1409 COLISEUM BLVD.	MONTGOMERY	AL	36130	(205)261-6408
NORTH CAROLINA DEPARTMENT OF TRANSPORTATION	P.O.BOX 25201	RALEIGH	NC	27611	(919)733-7600
GEORGIA DEPARTMENT OF TRANSPORTATION	5025 NEW PEACHTREE ROAD	CHAMBLEE	GA	30341	(404)986-1361
INDIANA DEPARTMENT OF HIGHWAYS	100 N. SENATE ROOM 1205	INDIANAPOLIS	IN	46256	(317)232-5477
NEW HAMPSHIRE DEPARTMENT OF TRANSPORTATION	P.O. BOX 483	CONCORD	NH	03301	(603)271-2348
KENTUCKY TRANSPORTATION CABINET	419 ANN STREET	FRANKFORT	KY	40622	(502)564-7183
MAINE DEPARTMENT OF TRANSPORTATION	CHILD ST., STATE HOUSE STATION #16	AUGUSTA	ME	04333	(207)289-2672
FLORIDA DEPARTMENT OF TRANSPORTATION	605 SUWANNEE ST., MS 5-L	TALLAHASSEE	FL	32399	(904)488-2059
MINNESOTA DEPARTMENT OF TRANSPORTATION	ROOM 809, TRANSPORTATION BUILDING	ST. PAUL	MN	55155	(612)296-1680
MARYLAND STATE HIGHWAY ADMINISTRATION	2323 W. JOPPA ROAD	BROOKLANDVILLE	MD	21022	(301)321-3518
ILLINOIS DEPARTMENT OF TRANSPORTATION	2300 S. DIRKSEN PARKWAY	SPRINGFIELD	IL	62764	(217)785-2757
VERMONT AGENCY OF TRANSPORTATION	133 STATE STREET	MONTPELIER	VT	05602	(802)828-2675
NEW JERSEY DEPARTMENT OF TRANSPORTATION	CN 600, ROOM 3200	TRENTON	NJ	08625	(609)530-2841
MISSISSIPPI STATE HIGHWAY DEPARTMENT	P.O. BOX 1850	JACKSON	MS	39215	(601)354-7172
SOUTH CAROLINA DEPT. OF HIGHWAYS & PUB. TRANSPORT.	P.O. BOX 191	COLUMBIA	SC	29202	(803)737-1444
MICHIGAN DEPARTMENT OF TRANSPORTATION	425 W. OTTOWA ST.	LANSING	MI	48909	(517)335-1889
VIRGINIA DEPARTMENT OF TRANSPORTATION	1401 E. BROAD ST.	RICHMOND	VA	23219	(804)786-5163
OHIO DEPARTMENT OF TRANSPORTATION	25 S. FRONT ST.	COLUMBUS	OH	43214	(614)466-4224
PENNSYLVANIA DEPARTMENT OF TRANSPORTATION	912 TRANSPORTATION AND SAFETY BLDG.	HARRISBURG	PA	17120	(717)787-4247

RESPONSES TO COMPUTER-AIDED CARTOGRAPHY QUESTIONNAIRE

NUMBER OF MAPS LOCAL	LIFE OF MAPS LOCAL	NUMBER OF MAPS COUNTY	LIFE OF MAPS COUNTY	NUMBER OF MAPS STATE TOURIST	LIFE OF MAPS STATE TOURIST	NUMBER OF MAPS TRAFFIC FLOW	LIFE OF MAPS TRAFFIC FLOW	NUMBER OF MAPS OTHER	LIFE OF MAPS OTHER	NO. OF EMP.	PERCENT MAPPING USING CAM/CADD	DO YOU SUBCON. WORK?	IF YES, NAME OF AGENCY	ST.
130						30		200		5		NO		AK
		531	INDEF	1	INDEF			1	INDEF	5	0			AZ
500+	3-5	75	3-5	1	1	1	1	1500+	3-10	10	5	NO		AR
900	INDEF	900	INDEF	1	INDEF			50	INDEF	14	5	NO		CA
630	20	460	15	1	1	30	3			3		NO		CO
956	15	99	10	1	10	99+956	1	MANY	VARIES	11	25	NO		IA
627	VARIES	105	7	1	4	1	2			11	0			KS
615	10-15	83	10-15	1	5	64+1	5	9	10-15	8	25	NO		LA
277	20	285	50			1	1	11	20	2	0			MT
532	10	93	10	1	10	94	10	10	10	7	100	NO		NE
800	10	114	25	1	20	1	10			11	0			MD
169	12		12	1	2	6	1	31	12	3	0			NV
100+	20+	33	20+	1	20+	20	20+	10	20+	5	15	NO		NM
390	?	87	?	1	?	88	?	??	?	3	0			ND
650	10	102	30	1	20	1	2			5	0			OK
300	2	72	2-5	1	1	SOME	1-3	300	1-4	8	95	NO		OR
311	15-20	66	15-20	1	2	30	2		3-5	2	65	NO		SD
357	15	254	15	1	10	3	10	48	10	11	60	NO		TX
212	20	39	20	19	20	5	3			4	0			UT
				1	2	500	1	1000	1	7	100	NO		WA
3	1	93	10	1	2			89	10	5	80	NO		WY
		67	6	1	2	1	2			14	80			AL
64	10	209	25	7	12	3	1	226	1	13	0			NC
600		159		1		160		63		12	0			GA
568	3	92	3	1	1	92	3			11	0			IN
86+	10-20	78	26+	1		1	10-15	20+	5-20	4	10	NO		NH
534	7	120	7	1	10	1	10	447	8	10	0			KY
118	6	214	6-8			1	5	6	5-8	4	0			ME
		67	10	1	2			7	5	6	90	YES	MARTEL, BRILEY/WILD, CRAVEN/THOMPSON	FL
855	5-7	129	5-7	1	2		2-5			19	25	NO		MN
158	VARIES	23	10-12	1	10	1	1			12	0			MO
1300		102		1		402				15	0			IL
335	10	58	20	1	20	1	20	20	25	7	90	YES	MARKHURD CORPORATION	VT
20+	4	21	10	1	18	64	75	64	15	16	50	NO		NJ
290	7	82	7	1	1	229	1	420	5	5	10	NO		MS
430		46		1		152				7	20	NO		SC
531		96		1	2	1	2			8	95	NO		MI
172	2	165	2	1	2					10	0	YES	CADD SYSTEM UNIT OF VA. DOT	VA
941	10	88	INDEF	1	INDEF				5-10	10	35	NO		OH
1500	50	66	40	2	15	1	15	80	20	21		NO		PA

RESPONSES TO COMPUTER-AIDED CARTOGRAPHY QUESTIONNAIRE

IF NOT USING CAM/CADD, PLAN TO?	DID YOU CONSIDER & REJECT CAM/CADD?	IS CARTOG. UNIT RESPON. FOR OTHER GRAPHICS?	IF YES, ARE THE TASKS NOW AUTOMATED?	ARE OTHER DIVISIONS AUTOMATING MAPS/PLANS?	WERE THESE NEEDS CONSID. WHEN EVAL. CAM/CADD?	ST.
		YES	YES	YES		AK
YES	YES	NO		YES		AZ
		YES	YES	YES	YES	AR
		YES	YES	YES	YES	CA
		YES	YES	YES	YES	CO
YES	NO	NO		YES	YES	IA
YES	NO	YES	NO	YES	YES	KS
		YES	YES	YES	YES	LA
YES	NO	YES	NO	YES	YES	MT
		YES	YES	YES		NE
YES	NO	YES	NO	YES	YES	NO
YES	NO	YES	NO	YES	YES	NV
		YES	YES	YES		NM
YES	YES	NO		YES	NO	ND
YES	NO	YES	NO	YES		OK
		YES	YES	YES	YES	OR
		YES	YES	YES	YES	SD
		YES	YES	YES	YES	TX
YES	NO	YES	NO	YES	YES	UT
		NO		YES	YES	WA
		YES	NO	YES	YES	WY
YES	NO	YES	YES	YES	YES	AL
YES	NO	YES	NO	YES	YES	NC
YES		YES	NO	YES		GA
YES	NO	YES	NO	NO	YES	IN
YES	NO	YES	YES	YES	YES	NH
YES	NO	YES	NO	YES	YES	KY
YES		YES	YES	NO	YES	ME
		NO		YES	NO	FL
		YES	NO	YES		MN
YES		YES	NO	YES	YES	MD
YES		YES	NO	YES		IL
		YES	YES	YES	YES	VT
		YES	NO	YES	YES	NJ
YES		YES	NO	YES	YES	MS
		YES	NO	NO	YES	SC
		YES	YES	YES	YES	MI
YES	NO	NO		YES	YES	VA
		YES	YES	YES	YES	OH
		YES	YES	YES	YES	PA

RESPONSES TO COMPUTER-AIDED
CARTOGRAPHY QUESTIONNAIRE

HARDWARE: BRAND & MODEL CPU	HARDWARE BRAND & MODEL MONITOR	SCREENSIZE	RESOLUTION	ST.
PC/AT	IBM (3) VECTRIX (3)	12" 19"	1024 x 1024	AK
				AZ
VAX 11/785 32-BIT CPU 1300 MB STORAGE, 16 MB MEMORY	DUAL SCREEN 1 MONO, 1 COLOR	19"	12080 x 10024	AR
VAX 780 VAX 785	TEKTRONIX	19"		CA
MICROVAX II	TEKTRONIX	19"		CO
INTERGRAPH	INTERVIEW COLOR WORKSTATION	19"		IA
VAX 11/785	INTERVIEW COLOR WORKSTATION		1280 x 1024	KS
VAX 11/785	INTERGRAPH	19"		LA
				MT
VAX 11/785	INTERGRAPH MONO/COLOR	19"	1280 x 1024	NE
				MO
				NV
DEC VAX 8550	TEKTRONIX 4115, DIGITAL VT220	11", 18"		NM
				ND
				OK
				OR
VAX 11/785	1-INTERVIEW, 5-INTERACT	19"		SD
2-VAX 11/780 1 VAX 11/785 (CENTRAL)		11"		TX
				UT
2-VAX 11/785	2 DUAL SCREENS 1 MONO, 1 BOTH			WA
INTERGRAPH 250 & 11/785 (CENTRAL)	INTERGRAPH INTERVIEW	19"	1280 x 1024	WY
VAX 785	INTERGRAPH INTERVIEW	2-19"		AL
				NC
				GA
				IN
VAX 8300	TECHTRONIX 4125	19"	1280 x 1040	NH
DIGITAL 8650 DIGITAL 750	TEKTRONIX	19" DUAL		KY
				ME
INTERGRAPH 11/751/32 BIT PLUS 250 VAX 200	68000K COLOR	18"	1280 x 1024	FL
				MN
				MD
				IL
INTERGRAPH VAX 11/730	INTERVIEW	19" DUAL	1280 x 1024	VT
VAX 780	INTERGRAPH	19" DUAL	1280 x 1024	NJ
				MS
INTERPRO 32 (UNIX)	INTERPRO 32, INTERACT 32C	19"	884 x 1184	SC
VAX	INTERGRAPH	19" DUAL		MI
VAX 11/785	INTERACT	19" DUAL		VA
DEC PDP 1170 DEC VAX 785	INTERACT	19"	1024 x 1024	OH
INTERGRAPH VAX 780 INTERGRAPH 200	INTERGRAPH	19" DUAL	1280 x 1024	PA

RESPONSES TO COMPUTER-AIDED CARTOGRAPHY QUESTIONNAIRE

HARDWARE BRAND & MODEL DIGITIZER	APPROXIMATE SIZE OF DIGITIZING TABLE	HARDWARE BRAND & MODEL PLOTTER	FLAT BED?	ROLL TYPE?	MAX. PAPER SIZE	NO. OF PENS	ST.
CALCOMP 9100 (2)	36"x48" 44"x60"	GERBER MODEL 88		YES	40"x48"	0	AK
							AZ
BACKLIT	42" x 60"	2 ELECTOSTATIC 400DPI 11 x 17 ELECTROSTATIC 200DPI		YES	36" x 160"		AR
	40" x 60"	CALCOMP-XNETICS VERSATEC	YES	YES	40" x 72"	2	CA
CALCOMP	44" x 60"	CALCOMP ALSO CALCOMP 5744 ELECTROSTATIC		YES	36"	8	CO
TISO15 BACKLIT	42" x 60"	VERSATEC 44" V80 11"		YES	11" & 44"		IA
	36" x 48" BACKLIT	CALCOMP 1077		YES	36"	4	KS
INTERGRAPH	60" x 42"	CALCOMP 42" VERSATEC V80 PRINTER PLOTTER	YES	YES		4	LA
							MT
INTERVIEW & INTERACT	42" x 60", 24" x 36"	CALCOMP & VERSATEC		YES	33" & 22"	4	NE
							MO
							NV
CALCOMP 9100	54" x 72"	CALCOMP 5835 (COLOR ELECTROSTATIC)			36"		NM
							ND
							OK
							OR
VERSATEC 7236	36" x 48"	CALCOMP 1077		YES	34"	4	SD
IGDS	48" x 72"	CALCOMP also KONGSBERG PHOTO HEAD 48 x 56		YES	34"	4	TX
							UT
INTERGRAPH	48" x 60" 52" x 72"	HP		YES	36" x 42"	6	WA
INTERGRAPH	36" x 48"	VERSATEC 7434 CALCOMP 1077 (ELECTROSTATIC)		YES	34"	4	WY
INTERGRAPH	42" x 60" 36" x 48"	VERSATEC ELECTROSTATIC		YES	44"		AL
							NC
							GA
							IN
CALCOMP	60" x 44"	CALCOMP ELECTROSTATIC			36"		NH
	48" x 60" 36" x 48"	CALCOMP 1051 VERSATEC 7436		YES	36"	4	KY
							ME
INTERGRAPH	22" x 34"	VERSATEC 400 ELECTROSTATIC CALCOMP 1077	YES	YES	44" 44"	4	FL
INTERVUE		KONGSBERG 1216 CALCOMP 1055 CALCOMP ELECTROSTATIC					MN
							MO
							IL
INTERGRAPH	36" x 48"	HP 7595B			E SIZE	8	VT
INTERGRAPH	42" x 72"	CALCOMP VERSATEC	YES	YES	55"	4	NJ
							MS

INTERGRAPH	42" x 60"	HP		YES	36"	8	SC
INTERGRAPH	42" x 60"	CALCOMP 748, 960, 1051	YES	YES	42"	4	MI
	42" x 60"	BENSON ELECTROSTATIC			36"		VA
INTERACT	24" x 48"	HP 7585B		YES	44"	8	OH
INTERVUE	48" x 60"	VERSATEC 7441					
		CALCOMP FLATBED					
		CALCOMP 960					
68K	40" x 50"						PA

RESPONSES TO COMPUTER-AIDED CARTOGRAPHY QUESTIONNAIRE

HARDWARE BRAND & MODEL SCANNER	IF YOU USE A PC, DOES IT PERFORM ADEQUATELY?	IS YOUR PC ON-LINE WITH AGENCY MAINFRAME?	SOFTWARE: COUNTY MAP SERIES	SOFTWARE: CITY MAP SERIES	SOFTWARE: TRAFFIC FLOW MAP SERIES	ST
						AK
						AZ
			WMS/MFC/IGDS/DMRS	WMS/MFC/IGDS/DMRS	IGDS	AR
OPTRONICS	YES	NO	SYNERCOM INFOMAP	SYNERCOM INFOMAP		CA
			ARC/INFO (ESRI)	ARC/INFO (ESRI)	ARC/INFO (ESRI)	CO
	YES	YES				IA
	YES	YES				KS
			WORLD MAPPING	WORLD MAPPING	WORLD MAPPING	LA
						MT
			INTERGRAPH WMS & MFC	INTERGRAPH WMS & MFC	INTERGRAPH WMS & MFC	NE
						MD
						NV
						NM
						ND
						OK
	YES	YES	STANDARD INTERGRAPH	STANDARD INTERGRAPH	STANDARD INTERGRAPH	OR
	YES		WMS	WMS	WMS	SD
			INTERGRAPH	INTERGRAPH	INTERGRAPH	TX
						UT
	YES	YES	WMS,GPPU,IGDS,DMRS	WMS,GPPU,IGDS,DMRS	WMS,GPPU,IGDS,DMRS	WA
		YES	INTERGRAPH IGDS	INTERGRAPH IGDS		WY
			VAX SYSTEM SOFTWARE			AL
						NC
						GA
						IN
	YES	YES	MCDONNEL DOUGLAS GIS	MCDONNEL DOUGLAS GIS	MCDONNEL DOUGLAS GIS	NH
	YES	YES				KY
						ME
			INTERGRAPH			FL
			DEVELOPED IN-HOUSE	DEVELOPED IN-HOUSE	DEVELOPED IN-HOUSE	MN
						MO
						IL
			IGDS, DMRA, FORTRAN	IGDS, DMRS, FORTRAN	IGDS, DMRS, FORTRAN	VT
	YES	YES	IGDS	IGDS	EVALUATING	NJ
						MS
			MICROSTATION & MICRO-IGDS	MICROSTATION & MICRO-IGDS	MICROSTATION & MICRO-IGDS	SC
						MI
OPTRONICS 4040			SCANNED DATA CAPTURE	SCANNED DATA CAPTURE	SCANNED DATA CAPTURE	VA
			INTERGRAPH GENERIC	INTERGRAPH GENERIC	INTERGRAPH GENERIC	OH
	YES	NO	WORLD MAPPING	ELASTIC BODY	DISTRIBUTIVE GRAPHICS	PA

RESPONSES TO COMPUTER-AIDED CARTOGRAPHY QUESTIONNAIRE

WAS YOUR SOFTWARE CUSTOMIZED?	WHAT DID THE CUSTOMIZING CONSIST OF?	WHO DID YOUR CUSTOMIZING?	DO FORMER DRAFTSMEN NOW DO DIGITIZING?	HOW MUCH TIME TO TRAIN EMPLOYEES?	WHO TRAINED YOUR EMPLOYEES?	ST.
			YES	THREE WEEK	SYSTEM VENDOR	AK
						AZ
YES	SPECIAL SYMBOL NEEDS FOR EACH SERIES OF MAPS	SECTION PERSONNEL	YES	3 WEEKS	INTERGRAPH & INHOUSE	AR
NO			YES	4 WEEKS	SYNERCOM	CA
NO			YES	4 WEEKS	SOFTWARE VENDOR ESRI	CO
YES		DEPARTMENT PERSONNEL	YES	3 WEEKS	VENDOR (INTERGRAPH)	IA
YES	CHANGES TO FONT, TUTORIALS, SYMBOLS	DEPARTMENT PERSONNEL	YES		VENDOR/IN-HOUSE	KS
YES	CUSTOMIZED USER COMMANDS AND MENUS	DEPARTMENT PERSONNEL	YES	1 WEEK	VENDOR/ IN-HOUSE	LA
						MT
YES	CUSTOMIZED COMMANDS	DEPARTMENT PERSONNEL	YES	8 WEEKS	VENDOR & IN-HOUSE	NE
						MD
						NV
YES	ALL SYMBOLS HAD TO BE SPECIALLY PROGRAMMED	DEPARTMENT PERSONNEL	YES	2 WEEKS	DIGITAL CO. TRAINERS	NM
						ND
						OK
YES	SYMBOLS AND USER COMMANDS	DEPARTMENT PERSONNEL	YES	30 WEEKS	COMM.COLL., IN-HOUSE	OR
NO			YES	2-3 WEEKS	INTERGRAPH	SD
YES	SYMBOLS, COMMANDS, TABLE DRIVEN PLOTTING & DIGITZING	DEPARTMENT PERSONNEL	YES	6 WEEKS	IN-HOUSE	TX
						UT
YES	PROGRAMS, TUTORIALS AND COMMANDS	DEPARTMENT PERSONNEL	YES	12 WEEKS	3DAY VENDOR	WA
					IN-HOUSE	
YES	LIBRARY FONT/MENU	DEPARTMENT PERSONNEL	YES	1 WEEK	VENDOR/IN-HOUSE	WY
YES	SPECIAL SYMBOLS, PATTERNS AND TYPE STYLES	DEPARTMENT PERSONNEL	YES	1 WEEK	VENDOR/IN-HOUSE	AL
						NC
						GA
						IN
YES	MACROS, MENUS, LINESTYLES	DEPARTMENT PERSONNEL	YES	4 WEEKS	VENDOR/IN-HOUSE	NH
						KY
						ME
YES	MENU COMMANDS, SYMBOLS	VENDOR/DEPT. PERSNL.	YES	4 WEEKS	INTERGRAPH	FL
YES	CUSTOM COMMANDS	DEPARTMENT PERSONNEL	YES	4-6 WEEKS	IN-HOUSE	MN
						MO
						IL
YES		VENDOR	YES	24 WEEKS	IN-HOUSE	VT
NO	MENU, SYMBOLS	DEPARTMENT PERSONNEL	YES	26 WEEKS	VENDOR/IN-HOUSE	NJ
						MS
NO			YES	1 WEEK	WILBUR SMITH & ASSOC	SC
			YES	2 WEEKS	IN-HOUSE	MI
						VA
NO			YES	6 WEEKS	IN-HOUSE	OH
YES	USER COMMANDS	IN-HOUSE/OTHERS	YES	12 WEEKS	PITT. TECHNIC. INST.	PA

RESPONSES TO COMPUTER-AIDED CARTOGRAPHY QUESTIONNAIRE

SOFTWARE: OTHER MAPS	ARE ALL MAPS OF A SERIES DIGITIZED?	DID YOU RE-EVAL MAPPING CONTENT?	MUST YOU CHANGE SYMBOLS FOR CAM?	ARE YOU USING USGS DATA?	HOW DO CAM MAPS COMPARE TO MANUALLY DRAWN MAPS?	SATISFIED WITH THE FINISHED PRODUCT?	HOW LONG HAS YOUR UNIT BEEN DIGITZING?	ST.
		YES		YES				AK
								AZ
ICS,EBSAL,EGM	NO	YES	NO	NO	SAME	YES	1 YEAR	AR
SYNERCOM INFOMAP	YES	YES	NO	NO	SAME	YES	3 YEARS	CA
ARC/INFO (ESRI)	NO	YES	YES	YES	SAME	YES	9 MONTHS	CO
	NO	YES	YES	YES	BETTER	YES	2 MONTHS	IA
	NO	YES	YES	YES	SAME	YES	1 YEAR	KS
WORLD MAPPING	YES	YES	YES	NO	WORSE	NO	4 YEARS	LA
								MT
INTERGRAPH WMS & MFC	NO	YES	NO	NO	BETTER	YES	2 YEARS	NE
								MO
								NV
	YES	YES	NO	NO	SAME	YES	1 YEAR	NM
								ND
								OK
STANDARD INTERGRAPH	NO	YES	YES	NO	MUCH BETTER	YES	3 YEARS	OR
WMS	NO	YES	YES	YES	BETTER	T	1.5 YEAR	SD
INTERGRAPH	NO	YES	YES	NO	MUCH BETTER	YES	2 YEARS	TX
								UT
WMS,GPPU,IGDS,DMRS	NO	YES	YES	NO	MUCH BETTER	YES	3.5 YEAR	WA
	YES	YES	YES	NO	ALMOST SAME	YES	1 YEAR	WY
EDGE MATCHING SYSTEM	YES	YES	YES	NO	SAME	YES	2 YEARS	AL
								NC
								GA
								IN
MCDONNEL DOUGLAS GIS	NO	YES	NO	YES	MUCH BETTER	YES	3 MONTHS	NH
								KY
								ME
	NO	YES	YES	NO	WORSE	F	9 YEARS	FL
DEVELOPED IN-HOUSE	YES	YES	YES	NO	SAME	YES	5 YEARS	MN
								MD
								IL
IGDS, DMRS, FORTRAN	NO	YES	YES	YES	BETTER	YES		VT
IGDS	NO	YES	YES	NO	SAME	YES	2 YEARS	NJ
								MS
	YES	YES	YES	YES	SAME	YES	6 MONTHS	SC
	YES	YES	NO	YES	BETTER	YES	10 YEARS	MI
SCANNED DATA CAPTURE								VA
INTERGRAPH GENERIC	YES	YES	YES	YES	BETTER	YES	7 YEARS	OH
MAP FEATURE CODING	YES	YES	YES	NO	SAME	YES	2 YEARS	PA

RESPONSES TO COMPUTER-AIDED CARTOGRAPHY QUESTIONNAIRE

EMPLOYEES HAVE A POS. ATT. RE: CADD?	HOW DOES CADD TIME COMPARE TO DRAFTING?	HAS CADD INCREASED PRODUC-TIVITY?	COMMENTS	CONSIDERATIONS FOR MULTI-STATE CONFORMITY OF DIGITAL DATA	HOW DO YOU SHARE DIGITAL INFORMATION WITH OTHER STATE ORGANIZATIONS?	ST.
YES			WE ACQUIRED OUR SYSTEM VERY RECENTLY	WE HAVE NOT INVESTIGATED THIS ISSUE.	AN EARLY STEP IN OUR DIGITAL MAPPING SYSTEM ACQUISITION PROCESS INVOLVED INTERVIEWING FEDERAL, STATE, AND LOCAL AGENCY REPRESENTATIVES HAVING MAPPING RESPONSIBILITIES IN ORDER TO DETERMINE INTERFACE FEASIBILITY.	AK
YES	LESS	YES	TRAINING FOR SUPERVISORY PERSONNEL TOOK SIX TO NINE MONTHS, WITH TRAINING AND UPGRADING ONGOING.		WE ARE NOT AT THIS TIME, BUT WE DO HAVE ISIF, INTERGRAPH STANDARD INTERCHANGE FORMAT TO TRANSMIT GRAPHIC DATA BETWEEN SYSTEMS.	AZ AR
YES	LESS	YES	WE ARE IN THE PROCESS OF UPGRADING OUR SYNERCOM SYSTEM. OUR INTERGRAPH SYSTEM HAS JUST BEEN INSTALLED AND WILL BE USED FOR ROAD AND STRUCTURE DESIGN.	WE HAVE NOT GIVEN ANY CONSIDERATION TO THIS AREA AT THIS TIME.	NOT APPLICABLE AT PRESENT, THOUGH OTHER AGENCIES ARE INTERESTED IN ACCESSING OUR DATABASE.	CA
YES	LESS	YES		WE ARE NOW IN THE PROCESS OF ACQUIRING A PRE-DIGITIZED DATABASE WHICH USED THE USGS 1:24,000 SCALE AS ITS SOURCE FOR DIGITIZING. THIS SCALED SERIES IS RECOGNIZED AS A NATIONAL STANDARD FOR MAPPING PURPOSES. IN ADDITION, THE SOFTWARE UTILIZED BY US, ARC/INFO FROM ESRI, ALLOWS US TO IMPORT AND EXPORT DATA IN A DLG FORMAT, A COMMON EXCHANGE FORMAT FOR DATA.	THE DEPARTMENT OF HIGHWAYS IS THE LEAD AGENCY WITHIN THE STATE GOVERNMENT FOR COORDINATING GEOGRAPHIC INFORMATION. A RESULT OF OUR EFFORTS SHOULD BE THE ESTABLISHMENT OF DATA STANDARDS, AN INVENTORY OF AVAILABLE DIGITAL DATA, AGREEMENTS RELATING TO THE EXCHANGE AND TRANSFER OF DATA, AND STRATEGIES FOR DEVELOPING THE DIGITAL DATA NECESSARY FOR SUPPORTING THE ACTIVITIES CONDUCTED BY VARIOUS STATE AGENCIES.	CO
YES	MUCH LESS	YES		THE PLANNING AND RESEARCH DIVISION HAS BEEN WORKING WITH FHWA IN DEVELOPING NEW STANDARDS AND SYMBOLS FOR THE PRODUCTION OF STATE, COUNTY, AND CITY MAPS.	AT THIS TIME WE ARE NOT INTERFACING, HOWEVER, DISCUSSIONS WITH OTHER STATE AGENCIES HAVE EMPHASIZED THE NEED FOR COMPATIBLE SYSTEMS SO THAT DIGITAL INFORMATION CAN BE EXCHANGED. AT THIS TIME, NO OTHER STATE AGENCIES HAVE CADD. WE ARE ALSO WORKING WITH COUNTY ENGINEERS AS THEY GET CADD SYSTEMS.	IA
YES	LESS	NO	WE ARE STILL IN THE INITIAL STAGES OF OUR CAM OPERATION, AND HOLD GREAT HOPES FOR ITS FUTURE APPLICATIONS.	NONE AT PRESENT.	NONE	KS
YES	LESS	NO	THE COMPUTER-AIDED PROCESS HAS INCREASED THE WORK LOAD BECAUSE WE STILL HAVE THE MANUAL PROCESS TO UPDATE AND WE HAVE NOT BEEN GIVEN ADDITIONAL PERSONNEL.	AS CLOSELY AS POSSIBLE, WE HAVE TRIED TO FOLLOW MANUAL MAPPING STANDARDS SET UP BY AASHTO, AND FEDERAL HIGHWAY ADMINISTRATION GUIDELINES.	AS OF YET, WE HAVE NOT.	LA
YES	MUCH LESS	YES		NONE	WE ARE NOT AT THE PRESENT	MT NE

YES	SAME	NO	WITHIN TWO OR THREE YEARS, PRODUCTIVITY WILL INCREASE DUE TO FAMILIARITY WITH CADD SYSTEM.	AS YET, IT HAS NOT BEEN GIVEN SERIOUS CONSIDERATION, BUT WOULD BE OF BENEFIT TO ALL STATES INVOLVED.	WE ARE THE ONLY STATE AGENCY IN NEW MEXICO USING THESE PROCEDURES.	MD NV NM
YES	MUCH LESS	YES	OUR GOAL WAS TO PRODUCE ON A COMPUTER AS GOOD IF NOT BETTER PRODUCTS THAN WE DID BY HAND. WE HAVE SUCCEEDED. REMEMBER, YOU WILL BE JUDGED BY HOW THE OUTPUT LOOKS, NOT ON HOW WELL YOUR FILES ARE ORGANIZED. ALSO, TRAINING PRIOR TO PRODUCTION IS EXTREMELY IMPORTANT. WE WERE ABLE TO PRODUCE TWO CITY MAPS IN THE FIRST WEEK OF PRODUCTION. WE HAVE JUST COMPLETED OUR FIRST COUNTY MAP, BUILT IN COOPERATION WITH OTHER STATE AGENCIES SO THAT WE CAN ALL USE COMMON DATA. WE HAVE STARTED ON FOUR MORE COUNTIES. UMATILLA COUNTY WILL HAVE ALL COUNTY ABD STATE TRANSPORTATION DIGITAL DATA AVAILABLE TO BE ATTACHED TO THE ROADS ON THE MAPS. UMATILLA COUNTY HAS ORDERED A CCAD SYSTEM SO THAT WE CAN EXCHANGE DATA WITH THEM. TWO OF THE LARGER CITIES IN THE COUNTY ARE TALKING ABOUT BUYING CCAD SO THEY CAN USE OUR MAP DATA. ONE IMPORTANT NOTE: IF YOU GET AN AUTOMATED SYSTEM, DO NOT SET STANDARDS OF YOUR PRODUCTS IN CONCRETE BEFORE YOU FIND OUT WHAT THE SYSTEM WILL DO WELL, NOT WHAT IT MIGHT DO POORLY.	WE HAVE SEVERAL COMMITTEES WORKING ON THIS ISSUE.	NOT VERY WELL AT PRESENT DUE TO DIFFICULT EQUIPMENT, BOTH HARDWARE & SOFTWARE IN MOST AGENCIES. WE ARE WORKING ON TRANSLATORS AT PRESENT.	ND OK OR
YES	MUCH LESS	YES	EVEN THOUGH WE ARE NEW TO A MAPPING PROGRAM OF THIS TYPE, IT IS MOVING ALONG VERY WELL, AND WE EXPECT PRODUCTION TO BE WELL AT HAND SOONER THAN ANTICIPATED. WE ARE PLANNING ON USING THE DIGITIZED USGS 1:100,000 QUADS THAT ARE BEING PRODUCED FOR THE BUREAU OF THE CENSUS AS A BASE FOR COUNTY MAPS; WE MAY ALSO BE ABLE TO TAKE CITY STREET PLATS FROM THESE QUADS FOR CITY PRODUCTIONS ALSO.	NONE AT THIS TIME.	NONE AT THIS TIME.	SD

YES	MUCH LESS	YES		NONE	EACH STATE AGENCY HAS A DIFFERENT COMPUTER-DRIVEN GRAPHICS SYSTEM. WE DO HAVE AN AGENCY (TEXAS NATURAL RESOURCES INFORMATION SYSTEM AGENCY) THAT IS STORING VARIOUS DATABASES. THEY CAN DISTIBUTE THIS DATA TO THE OTHER STATE AGENCIES IN VARIOUS FORMATS, BUT THEY CANNOT HANDLE THE INTERGRAPH FORMAT AS YET.	TX
YES	MUCH LESS	YES	ORIGINAL INPUT OF INFORMATION IS TIME CONSUMING. UPDATING IS INSTANTANEOUS. THIS IS WHERE THE SAVINGS OCCUR. YOU MUST ALLOW MUCH TIME FOR CUSTOMIZING SOFTWARE IN THE BEGINNING BEFORE YOU CAN NOTICE PRODUCTIVITY GAINS.	WE ACTIVELY PARTICIPATE IN STATEWIDE ORGANIZATIONS (NWCAMA, SMAC, GIS WORKING GROUPS) IN AN ATTEMPT TO KEEP ABREAST OF CURRENT AND FUTURE EXCHANGE FORMATS AND CONSIDERATIONS FOR SHARING DATA AMONG OTHER AGENCIES.	TAPE ONLY - LOAD TAPE AND REFORMATTING FILES.	UT WA
YES	LESS	YES	COMPUTER-AIDED DRAFTING HAS BEEN OPERATIONAL IN OUR UNIT LESS THAN 9 MONTHS. OVERALL EVALUATION IS NOT READILY AVAILABLE AT THIS EARLY DATE, AS, IN MY OPINION, WE ARE STILL IN THE LEARNING PROCESS. WE ARE VERY PLEASED WITH THE PROGRESS AND PRODUCTS PRODUCED THUS FAR.	WE ARE STRIVING TO CONFORM TO THOSE STANDARDS AS SET FORTH BY THE FEDERAL HIGHWAY ADMINISTRATION AS FAR AS MAP SYMBOLOGY. WE HAVE HAD GOOD SUCCESS IN MOST AREAS BUT CAN SEE THE NEED TO CHANGE IN SOME AREAS SUCH AS PATTERNING AND ROADWAY SURFACE TYPES. I ASSUME THAT AS MORE AND MORE STATES BECOME COMPUTERIZED, NEW STANDARDS WILL BE FORTHCOMING FROM THE FHWA.	CONTACTS HAVE BEEN MADE WITH OTHER AGENCIES BUT NO INTERFACING HAS BEEN DETERMINED AT THIS TIME.	WY
YES	MUCH LESS	NO	WE ACQUIRED TWO WORKSTATIONS IN MARCH, 1985. ONE OF THE STATIONS HAS BEEN USED FOR STATE MAPPING AND ONE FOR COUNTY MAPPING. TWO ADDITIONAL WORKSTATIONS WERE ACQUIRED IN FEBRUARY, 1986. WE ARE NOW OPERATING TWO 8-HOUR SHIFTS USING FOUR WORKSTATIONS.	WE ARE AWARE OF THE POSSIBLE NEED FOR THE CONFORMITY OF DIGITAL INFORMATION HAVE CONSULTED OTHER STATES ON ALL MATTERS HOPING TO CONFORM TO SOME OF THEIR METHODS AND PROCEDURES FOR OUR DIGITIZING AND DATA INFORMATION. WE ARE AWARE THAT EACH PHASE OF DIGITAL INFORMATION IS USED IN DIFFERENT FORMS.	WE ARE NOT INTERFACING WITH OTHER STATE AGENCIES AT THIS TIME, BUT ARE INTERFACING IN SOME AREAS WITHIN OUR DEPARTMENT.	AL
			A PROPOSAL IS NOW BEFORE THE MANAGEMENT OF THE DEPARTMENT THAT WE BE ALLOWED TO GO INTO COMPUTER-AIDED MAPPING.	NONE	WE ARE NOT AWARE OF ANY OTHER STATE AGENCY USING DIGITAL CARTOGRAPHIC PROCEDURES.	NC GA
YES	MUCH LESS	YES	WE ARE IN THE VERY EARLY STAGES OF IMPLEMENTING OUR NEW GIS SYSTEM, AND ARE CONTINUOUSLY CUSTOMIZING AND STREAMLINING PROCEDURES AND PROCESSES AS EXPERIENCE AND KNOWLEDGE OF THE SYSTEM ARE ADVANCED.	TO DATE, HAVE NOT CONSIDERED IT.	MEMBER OF STATEWIDE GIS ADVISORY COMMITTEE DESIGNED TO ESTABLISH STANDARDS, CONSIDER A SHARING OF DATABASES, AND ASSIGN RESPONSIBILITIES FOR VARIOUS DATABASE DEVELOPMENT TO APPROPRIATE AGENCIES.	IN NH
YES	MORE	NO	SINCE OUR WORK IS REPETITIVE,	FLORIDA HAS NOT AS YET	WE ARE NOT AT PRESENT.	KY ME FL

			WE EXPECT TO INCREASE OUR PRODUCTIVITY WHEN WE UPDATE THE MAPS AT A LATER DATE.	ADDRESSED THIS ISSUE.		
YES	SAME	YES	TIME SPENT ON REVISION AND UPDATES IS GREATLY REDUCED. MAPS DIGITIZED FOR A SPECIFIC SERIES CAN EASILY BE ADAPTED FOR USE IN ANOTHER SERIES, THEREBY ELIMINATING DUPLICATION.	AT THE PRESENT TIME, SEVERAL AGENCIES ARE INVOLVED IN DIGITIZING INFORMATION. THIS IS BEING DONE FOR VARIOUS PURPOSES AND IS AT DIFFERENT LEVELS OF ACCURACY AND CONCENTRATION. MEETINGS ARE BEING HELD TO INVESTIGATE THE READY TRANSFER OF INFORMATION BETWEEN AGENCIES. THERE IS, HOWEVER, SOME DIFFICULTY IN GOING BETWEEN SYSTEMS DUE TO ACCURACY LEVEL.	THE ONLY INTERFACING THE CARTOGRAPHIC UNIT CURRENTLY DOES IS WITH OTHER UNITS OF THE TRANSPORTATION DEPARTMENT (OTHER OFFICES, DISTRICTS, ETC.) THROUGH THE HOOKUPS TO COMMON MAINFRAME COMPUTERS. SOME USE IS BEING MADE, PARTICULARLY BY OUTSIDE CONSULTANTS, OF DIGITAL TAPES OF OUR DATA.	MN
			THE CARTOGRAPHIC SECTION IS TO RECEIVE THE FIRST OF SEVERAL INTERGRAPH "INTERVIEW 32 C" WORKSTATIONS IN FY88.			MD
NO	MUCH LESS	NO				IL VT
YES	LESS	YES	WE HAVE HAD OUR INTERGRAPH WORKSTATION FOR 11 MONTHS. IT TAKES 3-6 MONTHS FOR A WORKER TO REACH PRODUCTION MODE. WE EXPECT TO INCREASE PRODUCTIVITY AND QUALITY OVER TIME. A SHORT- AND LONG-RANGE PLAN HAVE BEEN DEVELOPED, ALONG WITH EVALUATING RESULTS AND CONTINUAL RESEARCH ON HARDWARE AND SOFTWARE.	WOULD BE EXTREMELY BENEFICIAL, PARTICULARLY WITH STATES IMMEDIATELY ADJACENT.	ALL ADJACENT STATES (N.Y., DEL., PA., MD.) ALSO USE INTERGRAPH. WE HAVE VISITED BOTH NEW YORK AND DELAWARE CONCERNING DIGITAL MAPPING.	NJ
YES			WE HAVE NOT DONE ENOUGH DIGITIZING TO DETERMINE IF THE COMPUTER-AIDED PROCESS WILL INCREASE PRODUCTIVITY, OR IF IT WILL BE QUICKER THAN MANUAL DRAFTING.	WE HAVE CONTACTED SEVERAL OTHER STATE DOTs (ALL WITH INTERGRAPH SYSTEMS) AND HAVE RECEIVED THEIR SPECIFICATIONS FOR FEATURES AND FEATURE LEVELING. WE ARE CURRENTLY IN THE PROCESS OF EVALUATING THESE AND FORMULATING OUR OWN STANDARDS.	CURRENTLY WE ARE NOT INTERFACING WITH OTHER STATE AGENCIES WITHIN OUR STATE. WE ARE WORKING ON THIS, BUT IT IS GOING TO BE DIFFICULT BECAUSE OF THE DIVERSITY AND INCOMPATIBILITY OF SYSTEMS IN OUR STATE.	MS SC
YES	LESS	YES	AT HIS POINT, QUALITY IS AS GOOD AS A PEN & INK MANUALLY PRODUCED MAP. NOT AS GOOD AS A SCRIBED MAP, WHICH IS WHAT OUR COUNTY MAPS ARE. WE PLAN TO OBTAIN PLOTTING EQUIPMENT TO RIVAL THE SCRIBED MAP.	VERY LITTLE. THE STRUGGLE HAS BEEN TOUGH JUST GETTING UNDERWAY. WE HAVE TRIED TO DUPLICATE OUR SCRIBED MAPS.	OUR DEPARTMENT OF NATURAL RESOURCES IS USING THE SAME SYSTEM WE ARE, AND WE ARE ABLE TO SHARE SOME INFORMATION, BUT OUR END PRODUCTS VARY CONSIDERABLY.	MI
YES	LESS	YES		NONE AT THIS TIME.	PRODUCTS ARE AVAILABLE TO OTHER STATE AGENCIES ON REQUEST.	VA OH
YES	LESS	YES	WE ARE TOO NEW TO DETERMINE AN ACCURATE PRODUCTIVITY GAIN, BUT IT IS OBVIOUS THERE IS ONE.	WE HAVE KEPT ABREAST WITH NATIONAL STANDARDIZATION CONSIDERATIONS, BUT HAVE TAKEN NO INITIATIVES.	WE HAVE HELD MEETINGS TO COMMUNICATE DIGITAL PROGRESS, BUT AT PRESENT HAVE NO DIGITAL INTERFACE.	PA

RESPONSES TO COMPUTER-AIDED
CARTOGRAPHY QUESTIONNAIRE

WHAT ARE YOUR PLANS FOR CREATING A STATEWIDE GIS?	HOW DO YOU READ MAINFRAME INFO INTO YOUR DIGITAL SYSTEM?	ST.
AT THIS TIME, NONE, OTHER THAN HIGHWAY SYSTEM DATA.	WE ARE CURRENTLY WORKING TO LINK OUR MAPPING SYSTEM TO OUR ADABAS HIGHWAY SYSTEM ATTRIBUTE FILE.	AK
NONE	1 DATABASE,FILE = ADT 3 VSAM FILES = PAVEMENT MANAGEMENT, BRIDGE, ROADWAY 1 SEQUENTIAL FILE = ACCIDENT WE HAVE WRITTEN A SERIES OF COBOL PROGRAMS TO TAKE SELECTED INFORMATION FROM EACH OF THE ABOVE FILES AND COMBINE THEM INTO ONE SEQUENTIAL FILE. WE THEN MOVE THE FILE TO THE VAX AND FORMAT IT INTO DMRS INSERT STATEMENTS AND BULK LOAD TO THE DMRS DATABASE. THE INDIVIDUAL RECORDS ARE THEN MANUALLY ATTACHED TO THE GRAPHICS ELEMENT. THER GRAPHIC DATABASE WILL BE USED TO PRODUCE BRIDGE NUMBER, ADT, AND ADT LOCATOR MAPS. AS WELL AS GRAPHIC REPORTS FROM THE PAVEMENT MANAGEMENT AND ACCIDENT FILES.	AZ AR
AT PRESENT WE ARE REVISING OUR PROCEDURES TO ADD ATTRIBUTES, AND ARE INVESTIGATING OTHER DATABASES THAT MAY BE USEFUL.	WE HAVE NOT ATTEMPTED TO INCORPORATE ANY OTHER DATABASES INTO OUR SYSTEM.	CA
THE SOFTWARE PACKAGE ACQUIRED BY US FOR OUR GIS IS THE SAME AS THAT UTILIZED BY OUR DEPARTMENT OF LOCAL AFFAIRS, AND INDICATIONS ARE THAT OTHER AGENCIES, AS THEY MOVE TO A GIS, WILL CONCEIVABLY ACQUIRE THIS SAME SOFTWARE PACKAGE. EFFORTS ARE NOW MADE TO SHARE DATA, AND A PRE-DIGITIZED DATABASE SOON TO BE ACQUIRED BY THE DEPARTMENT OF HIGHWAYS WILL BE PROVIDED TO OTHER AGENCIES FOR THEIR USE. BY WORKING WITH THE SAME BASE DATA, WE MAY INSURE A CERTAIN LEVEL OF COMPATIBILITY WITH OTHER STATE AGENCIES. IN ADDITION, ACTIONS ARE BEING TAKEN TO PROVIDE A FORUM FOR THE EXCHANGE AND STANDARDIZATION OF DIGITAL AND OTHER GEOGRAPHIC INFORMATION AT THE STATE LEVEL.	WE PRESENTLY POSSESS THE CAPABILITY TO IMPORT STATISTICAL DATA FROM DEPARTMENTAL DATABASES THROUGH VARIOUS MEDIUMS. INFORMATION HAS SUCCESSFULLY BEEN TRANSFERRED VIA 9-TRACK MAGNETIC TAPE, FLOPPY DISC, AND VIA MODEM. STANDARDS HAVE BEEN ESTABLISHED FOR FILE TRANSFER OF DATA INTO THE GIS.	CO
WE ARE IN THE PROCESS OF TYING CARTOGRAPHIC GRAPHICS TO THE ROAD BASE RECORDS ON THE STATE PRIMARY ROAD SYSTEM. USING THIS TIE, GRAPHICS HAVE BEEN PRODUCED WHICH SHOW SPECIFIC INFORMATION. THIS IS OUR FIRST IN CREATING A STATEWIDE GIS ON TRANSPORTATION.	ALL GRAPHIC INFORMATION IS BEING HAND DIGITIZED IN.	IA
WE ARE CURRENTLY IN THE PROCESS OF FORMING A GEOGRAPHIC INFORMATION SYSTEMS COMMITTEE.		KS
A STATEWIDE GIS IS IN PLACE WITH DATABASE ATTACHED.	PROGRAMS ARE WRITTEN TO INTERFACE FROM IBM FILES TO VAX.	LA
		MT
WE ARE JUST REALLY STARTING TO CONSIDER THIS CAPABILITY	WE HAVEN'T TRIED	NE
		MD
		NV
THE NEW MEXICO GEOGRAPHIC INFORMATION ADVISORY COMMITTEE (NMGIAC) WAS FORMED IN 1984 FOR THE PURPOSE OF ESTABLISHING COOPERATION AND INFORMATION EXCHANGE BETWEEN FEDERAL, STATE, AND LOCAL AGENCIES. THE NMGIAC MEETS TWICE A YEAR.	NOT YET IN USE. CONSULTANTS ARE NOW IN THE PROCESS OF BUILDING DATABASES FOR THE STATE HIGHWAY DEPARTMENT.	NM
		ND
		OK
WE WOULD, AS A TRANSPORTATION DEPARTMENT, CONTRIBUTE THE MAJOR TRANSPORTATION NETWORK. WE ARE WORKING ON A COMBINED STATEWIDE GIS FOR ALL AGENCIES.	WE HAVE DEVELOPED PROCEDURES AND SOFTWARE TO TAKE IBM MAINFRAME ROAD & HIGHWAY MILEPOST DATA AND PRODUCE STRAIGHT LINE CHARTS AND MAP GRAPHICS FROM THESE DIGITAL DATABASES. IT WORKS EXTREMELY	OR

	WELL.	
MINOR ACTIVITY TO INCLUDE SOME TESTING OF RELATING A PRESENT ROADWAY ENVIRONMENT SYSTEM FEATURES FILE (TRAFFIC, PHYSICAL FEATURES, DYNAFLECT, SKID, ETC.) INTO A BASIC GRID SYSTEM.	NO TREND YET - WORKING WITH THE BASICS OF TRYING TO SET A SYSTEM OR METHOD WITH OUR REFERENCED SYSTEM OF ALL DATABASE TIED TO AN MILEAGE REFERENCE MARKER (MRM) SYSTEM.	SD
NONE AS YET.	HAVE NOT AS YET.	TX
		UT
WE WILL PARTICIPATE IN A STATEWIDE GIS IF ASKED. A MANPOWER SHORTAGE PREVENTS US FROM INITIATING ONE. OUR INFORMATION IS AVAILABLE TO ANYONE WANTING TO USE IT IN A GIS.	INTERGRAPH SIF (STANDARD INTERCHANGE FORMAT) CAN BE USED TO CONVERT FILES FROM OTHER AGENCIES IF NECESSARY.	WA
NOTHING DEFINITE	NOTHING HAS BEEN DONE IN THIS AREA AS YET.	WY
NO PLANS AT THIS TIME.	WE ARE USING THE INFORMATION WHICH WE HAVE ON THE SYSTEM WE HAVE WITHIN OUR DEPARTMENT.	AL
		NC
WE ARE CURRENTLY TRYING TO CONVINCE MANAGEMENT TO INSTALL COMPUTER-AIDED MAPPING WITH CAPABILITIES FOR FUTURE EXPANSION TO A GIS SYSTEM.	WE HOPE TO USE LASER SCANNING.	GA
		IN
THE OFFICE OF STATE PLANNING IS DEVELOPING PROCEDURES FOR IMPLEMENTING A SHARED DATABASE SYSTEM WITH OTHER STATE AGENCIES.	PRESENTLY TRYING TO CONVERT SOME EXISTING DATABASES INTO A FORMAT THAT CAN BE TRANSLATED INTO OUR SYSTEM. WE ARE ALSO REQUIRING PHOTOGRAMMETRY CONTRACTORS TO PROVIDE DIGITAL DATA READABLE BY OUR SYSTEM. WE ARE HOPING SHORTLY TO HAVE A TRANSLATOR FOR ARC-INFO/GIS GRAPHIC DATA. THE DOT IS THE FIRST STATE AGENCY TO USE A CADD SYSTEM FOR MAPPING.	NH
		KY
		ME
FDOT NOW HAS ONE REMOTE STATION IN EACH DISTRICT OFFICE. DISCUSSIONS ARE BEING HELD TO PROMOTE THIS. A HIGH LEVEL DEPARTMENT POSITION HAS BEEN PROPOSED TO COORDINATE THIS TYPE OF ACTIVITY. SEVERAL COUNTIES HAVE ESTABLISHED EXTENSIVE FILES OF DATA WITHIN THEIR OWN COUNTIES.	NON-EXISTANT	FL
	AT THE PRESENT TIME WE HAVE NOT MADE ANY CONCERTED ATTEMPT TO ABSORB DATABASES INTO OUR CARTOGRAPHIC FILES. WE FEEL THAT WE DO NOT HAVE ENOUGH OF OUR CARTOGRAPHY DIGITIZED TO MAKE THE ATTEMPT. SOME PLANIMETRIC MAPPING IS BEING DONE ON P.C.S USING ROAD DATA. THESE MAPS ARE EXTREMELY LOW RESOLUTION, AND ARE USED MOSTLY TO SHOW TRENDS.	MN
		MD
		IL
		VT
A PILOT PROJECT FOR ONE COUNTY IS IN PRODUCTION. THE STATEWIDE GIS WILL COMMENCE UPON COMPLETION AND EVALUATION OF THE PILOT.	BOTH MANUAL AND COMPUTER-AIDED TECHNIQUES. EXISTING ASCII FILES ARE BULK-LOADED USING INTERGRAPH DATA FORMS LANGUAGE (DFL).	NJ
		MS
WE WOULD LIKE TO CREATE A STATEWIDE GIS, BUT WE HAVE NOT MADE ANY SPECIFIC PLANS AT THIS TIME.	WE HAVE NOT BEEN ABLE TO DO THIS AS YET.	SC
THERE ARE STUDIES UNDERWAY AT PRESENT.	OTHER THAN DIGITIZING, THERE ARE SEVERAL PROGRAMS THAT HAVE BEEN WRITTEN FOR THIS PURPOSE.	MI
		VA
OHIO IS IN THE PROCESS OF TESTING A GIS SYSTEM WHICH WILL GENERATE EITHER POINT OR SEGMENT INFORMATION GRAPHICALLY, AND WILL RELATE THE GRAPHICAL INFORMATION TO A DATABASE. THE RESULTING INFORMATION CAN BE FOUND IN THE DATABASE AND CAN BE HIGHLIGHTED GRAPHICALLY.	DATABASE INFORMATION RESIDING IN OUR MAINFRAME IBM SYSTEM IS CONVERTED FROM EBCDIC TO ASCII FORMAT. AS LONG AS THE INFORMATION CONTAINS THE KEY IDENTIFICATION FIELDS, IT CAN BE DISPLYED GRAPHICALLY AND ALSO BE STORED IN AN INTERGRAPH DATABASE FOR LATER PROCESSING OR HIGHLIGHTING IN GRAPHICAL FORM.	OH
PENNSYLVANIA DOT WILL CAPTURE ALL TRANSPORTATION FEATURES; WE ARE AT A PLANNING STAGE WITH OTHER STATE AGENCIES.	BY USING AN IBM/INTERGRAPH INTERFACE, CONVERTING IBM DATA INTO INTERGRAPH READABLE FORMAT.	PA

GEOGRAPHIC INFORMATION SYSTEMS IN TRANSPORTATION

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EXECUTIVE SUMMARY

Geographic Information System (GIS) concepts and technology can form the framework for an integrated highway information system. More effective integration of geometric, accident, traffic, roadway features, and other data are needed to enhance the planning, design, construction, maintenance, management, and operations of transportation systems. Increasingly, demands arise to relate data collected by different divisions of an organization about themes at the same location, e.g. accident data and roadway geometry. GIS concepts and technology provide an opportunity to relate and display separately collected data about spatially distributed transportation-related events and facilities. Spatial objects, called points, lines and areas, and the geographic locations of these spatial objects are a key means of integrating separately collected transportation data for enhanced analysis and map displays.

Technically, a GIS is defined as an integrated database containing information about georeferenced spatial objects -- points, lines and areas -- plus the software and hardware used by personnel to manipulate these objects.

Some of the benefits of geographically structured data and GIS technology include:

- retrieving transportation operations information on a geographical basis,
- linking data geographically for new applications,
- visualizing relationships through thematic mapping,
- computing spatial relationships using coordinates and transportation feature characteristics,
- building more complete network models for use in analysis, and
- editing data on a geographical basis using both graphical and non-graphical displays for better database maintenance.

Realizing potential benefits from the application of GIS concepts and technology requires organizational change, which has concomitant impacts. These impacts must be anticipated and accomodated, the positive ones fostered and the negative ones ameliorated. The impacts of organizational change must be managed to achieve the full advantage of the application of the GIS technology. It is not a mere add on to existing organizations, it both requires and causes organizational change.

Incorporating GIS Concepts and Technology into Existing Transportation Organizations

Existing state departments of transportation (DOTs) and metropolitan planning organizations (MPOs) are midstream with respect to adopting GIS concepts and technology. State DOTs are generally advanced in applications of computer-aided drafting and design (CADD) systems and computer-assisted cartography (CAC) systems and are in a transitional phase attempting to add the functionality of GIS to their repertoire. Similarly, MPOs have existing resources and skills for urban transportation planning. They may employ urban transportation planning models that have embedded in them limited GIS functionality. The GIS functionality needed by transportation organizations consists of:

- geographically structured data, with point, line, and area relations, i.e. topology
- linkage of locational and attribute data about transportation facilities,
- analytical map overlay of separate map data.

The requirements for geographic information management differ from the traditional management of information in Management Information Systems (MIS). The main reason is the importance of spatial proximity in storing and retrieving the data. What is located together in geographic space should be stored and retrieved together by the system. This enhances analysis and display performance.

Spatial Database Design

During conceptual design, a decision is made as to whether an entity is to be stored as a point, line or area. Some of these decisions are obvious, but with different types of point forms and area forms, the decision may require more thought. Decisions about locational data are critical to spatial database design. Locational information for spatial objects includes metrical, topological and graphical information.

Metrical data describe the location in terms of a coordinate space, e.g. using state plane coordinates.

Topological data describe the connectedness of the spatial objects in terms of nodes, lines and areas. When dealing with transportation related information, nodes represent intersections and physical ends of the highway; lines represent the highway connections between nodes; and areas are those physical spaces bounded by lines that are connected and closed. Without topology, strings of locational information about roads cannot be connected easily into roadway networks for analysis. Strings (as a sequence of points) can be graphically displayed, but routes cannot be traced. It is much better to represent the network connectivity explicitly rather than implicitly by coordinates.

Graphical data are those that enable the visual portrayal of the objects on a display device. Point, line and area symbolization have several variations which make some symbolizations better than others, depending on the requirements of the visual display.

Some applications require comparison or analysis of data layers on the basis of location. This requires a reference framework that is based on location, called a spatial reference framework or georeference system. The number of applications that require a comparison of data from one layer to another influences the sophistication of the reference framework needed.

Labeling point, line and area objects for easy reference by location is called geocoding. Many styles of geocoding can be used; some are coordinate based but most rely on names or locational codes other than coordinates. When many layers are geocoded to the same spatial reference framework, they can be more easily cross-referenced to support different types of displays and analysis.

In addition to a control framework, an organization needs a base data layer, which is used like a base map. The definition of a base map is by no means universal, but an operational definition is: a base map is any set of information that provides spatial orientation (background information) for another set of information of primary focus. The same set of information can at one time be considered base map information and at another time be considered the primary information, depending on context.

The most common base map information for DOTs and MPOs in mapping has been USGS topographic quadrangles where available. The map scale depends on the nature of the study. The USGS 7.5' or 15' quadrangle maps often provide the base for highway inventory systems or county highway maps. For a GIS application, the base map information may be the

highway network itself, plus georeference control, administrative boundaries, and hydrographic features. In some instances, the highway information can provide sufficient locational orientation such that the network is all that is needed.

Transportation Data Environments

Organizations that have responsiblilty for managing land or infrastructure operate simultaneously in three data environments:

- **applications databases** that are shallow in detail, but spatially extensive, such as maps of the organization's jurisdiction or service area,
- **project databases** that are deep in detail, but spatially constrained, such as project area analyses or construction plans, and
- **subject databases** that are both deep in detail and spatially extensive, but not tied to any one specific application or project.

The databases grow and evolve as the subject needs of the organization grows.

Transportation agencies have tended to function in a project mode, and data are sometimes maintained in that manner. A GIS is more applications and subject oriented. Transportation organizations will naturally evolve from applications and project data to a subject-oriented geographic database. The key question is: "What degree of subject integration of data is needed?" For instance, should highway inventory data be integrated into a single file containing geometric, sign, pavement, etc. data; or should these kinds of data be maintained separately, but with similar spatial referencing, by the units responsible for them? Although the latter approach is preferable in a relational database management environment, some degree of integration may be desired to reduce the amount of overlay analysis that would otherwise be needed.

Spatial Analysis

Spatial analysis is concerned with spatial patterns and processes. A spatial pattern is the locational relationship of geographically distributed entities represented by points, lines, areas, and surfaces (volumes). A spatial process is the dynamic behavior of those entities. The nature of change in terms of distance, direction and/or connectedness among the entities can be used to characterize the spatial process.

The present emphasis in GIS maps and displays is on depicting spatial patterns and modeling spatial processes with both vector and raster data. Being able to display vector and raster data on a single graphics display facilitates visual synthesis of the spatial patterns and enhances a feedback process for modeling. Displays can be produced for interactive feedback on a CRT monitor, as well as for plotter output. A raster-oriented color graphic output device can support both the vector and raster data. The higher the resolution of the device, the sharper the image produced.

GIS and an Organization's Mission

GIS concepts and technology must fit the mission and organizational structure of DOTs and MPOs. Because GIS technology necessitates or results in organizational change, the impacts

should be anticipated through strategic planning. For example, organizational structure might dictate separate files of attribute data versus one integrated file.

A GIS approach should be compatible with current computing environments in DOTs and MPOs. Many DOTs and MPOs have existing commitments to mainframe computing and the production of mapping products either on microcomputers, minicomputers or a mainframe. Regardless of the current type of environment, a GIS approach can help integrate the data across an organization.

A GIS approach can incorporate a mainframe with a bridge or gateway to a mapping system to support various tasks of the overall mission and existing mapping effort.

Alternatively, a distributed processing approach combines a number of computer workstations into an integrated computer network that mirrors the organizational structure. Each workstation would have separate files according to mission responsibility. This might mean a workstation for traffic data, one for highway inventory and a third for design construction. In this case there is a need for a fast, transparent data interface among the workstations.

For most large organizations, attributes are kept in mainframe databases, and are managed in a separate DBMS. This is not likely to change. Getting access to attributes is a systems integration problem which requires a thorough evaluation of a particular data environment. The major consideration involves how the data stored in one environment can be linked to data in another environment, although the data might not be stored in compatible structures and/or formats.

Future Trends of GIS in Transportation

A well-designed GIS can enhance the communication among user groups within a DOT or MPO. To do this transportation organizations will need to emphasize compatible spatial referencing systems and GIS concepts and technology as part of a trend toward better information integration.

A georeference approach makes it easier to integrate spatial data. Research in database management systems is leading toward continued data integration across different databases having different database structures. This stems from the inherent spatial character of data. Currently, data are represented and stored in terms of an organization task-oriented view, i.e. what an organization is doing with the data. A subject-oriented view of the world could enhance the consistency of data by identifying and reducing (if not elminating) data redundancy.

Trends will continue to focus on systems integration - getting one spatial system linked with another. For example, the spatial database management aspects of an engineering survey data collection system could be linked to the roadway design system, as well as the mapping system, so that all are linked to the same georeference system. This is starting to happen now using the Global Positioning System (GPS) of satellites to collect more accurate survey coordinate data in less time.

Conclusion

The challenge of the future is to examine more problems, or the same problems in more detail, in less time at lower cost. One way to do this is the through a GIS approach to data

processing. This approach will foster the integration of information across a transportation organization.

Collective developments in several sciences are responsible for bringing about a GIS approach, most notably those in the mapping sciences that focus on spatial processes and patterns. A GIS approach has been developed to integrate large amounts of spatial data in a map based form, using computer based models to analyze this data.

GIS concepts and technology are beginning to be used for many applications. Using them for transportation systems analysis, whether this be inventory or modeling, is fully possible now. A few transportation organizations have embarked on this path. It is up to each organization to learn more about these concepts and tools to realize the promise that GIS offers.

1. INTRODUCTION

Geographic Information System (GIS) concepts and technology can form the framework for an integrated highway information system. More effective integration of geometric, accident, traffic, roadway features and other data are needed to enhance the planning, design, construction, maintenance, management, and operations of transportation systems. Increasingly, demands arise to relate data collected by different divisions of an organization about themes at the same location, e.g. accident data and roadway geometry. GIS concepts and technology provide an opportunity to relate and display separately collected data about geographically distributed transportation-realted events and facilities on the basis of location as well as in the more traditional way.

Transportation organizations are taking advantage of GIS concepts and technology as a means of applying information technology to better describe, analyze and display spatially distributed transportation facilities. Spatial objects, called points, lines and areas, and the geographic locations of these spatial objects are a key means of integrating separately collected transportation data for enhanced analysis and map displays.

A GIS is defined as an integrated database containing information about georeferenced spatial objects -- points, lines and areas -- plus the software and hardware used by personnel to manipulate these objects.

This paper is organized as a general overview of GIS in Transportation. As such it outlines the importance of GIS to transportation organizations. The remainder of Section 1 identifies the nature of this importance. Section 2 describes the components of a GIS and contrasts these systems with computer-aided mapping systems. Section 3 describes transportation applications. Section 4 describes GIS functionality and how this is different from other information systems requirements. Section 5 considers administrative organizational issues for a GIS approach. Section 6 discusses future trends pertinent to transportation organizations. Section 7 is a series of case studies. Section 8 provides concluding remarks.

1.1 GIS as a Perspective

GIS concepts and technology provide a perspective on managing data about geographically distributed transportation facilities and transportation related phenomena. This perspective consists of viewing the world of transportation facilities as observations, or data, about geographic objects, and their manipulation and display with specialized graphics-based software. A critical component is spatial registration of separate data layers that will enable the sharing of compatible data resources. Figure 1 shows maintenance district and highway data layers both registered to the same georeference control. This provides coordinate compatibilty between the data layers. (See Section 4.2.4 for more detail.)

1.2 GIS as an Organizational Strategy

To take advantage of GIS concepts and technology, its application to transportation organizations must be accompanied by an organizational strategy to integrate information resources. The integration of geographic information may require changes to the parts of the organization that handle data and information flows. Existing computing environments may not be well suited to a transportation GIS environment. Consequently, it is not only a problem of introducing GIS to the existing organization, but one also of changing the organization to operate in a new information environment.

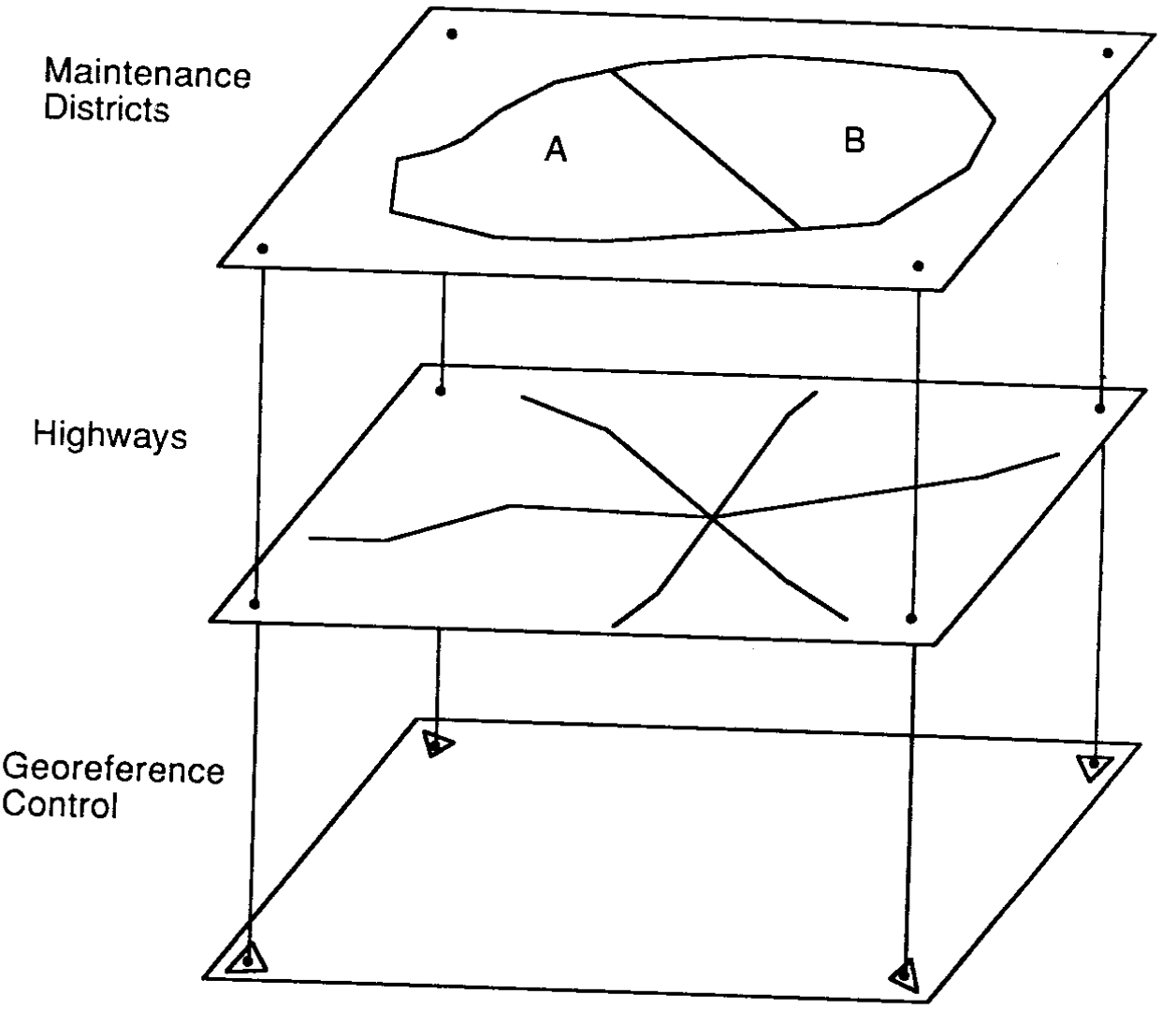


Figure 1. Spatial registration of three data layers.

1.3 Cost and Benefit Issues of GIS Technology

The technological and organizational changes to implement a GIS are costly, particularly, the cost of capturing geographic data. Clearly, there must be demonstrable benefits that exceed this cost, which tend to be large and immediate while the benefits tend to be diffuse and downstream. Consequently, it is important to plan carefully for new functions and partial products with quick payoffs, while avoiding shortsighted decisions that result in inflexible systems and wasted data.

The majority of dollars invested in GIS projects are spent on collecting/automating data (digitizing map data) and maintaining the database. This cost is largely for personnel. A portion of the GIS dollars spent are for specialized graphics software/hardware for manipulation and display, but these costs are fractional in comparison to the automation and maintenance of data as a valuable asset for the long term. However, if some data are already in digital form and referenced by location, which is the case with many organizations, a portion of the cost is in the restructuring of the data so that it can be used in GIS processing.

Some of the benefits of geographically structured data and GIS technology include:

- retrieving transportation operations information on a geographical basis,
- linking data geographically for new applications,
- visualizing relationships through thematic mapping,
- computing spatial relationships using coordinates and transportation feature characteristics,
- building more complete network models for use in analysis, and
- editing data on a geographical basis using both graphical and non-graphical displays for better database maintenance.

Many of these benefits are due to time and labor savings from automation of processes on a geographical basis; these are called efficiency benefits. Others are a result of enhanced decision making from more timely and better information derived from increased analysis capabilities; these are called effectiveness benefits. Still other benefits can be realized that are intangible in nature, due to unforseen applications. However, these latter impacts could also be negative if they affect an organization adversely (Prisley and Mead 1987). Estimating the true magnitude of GIS costs and benefits can be done if an organization has a clear strategy and a well-documented plan for incorporating the technology.

1.4 Organizational Implications of GIS Technology

Application of GIS concepts and technology requires a transportation organization to reassess information flows, as this approach has significant impacts on an organization and could change the way in which an organization functions. Realization of the potential benefits of the application of GIS concepts and technology requires organizational change, which has concomitant impacts. These impacts must be anticipated and accomodated, the positive ones fostered and the negative ones ameliorated. The impacts of organizational change must be managed to achieve the full advantage of the application of the GIS technology. It is not a mere add on to existing organizations; it both requires and causes organizational change.

1.4.1 Incorporating GIS Concepts and Technology into Existing Transportation Organizations

Existing state departments of transportation (DOTs) and metropolitan planning organizations (MPOs) are midstream with respect to adopting GIS concepts and technology.

State DOTs are generally advanced in applications of computer-aided drafting and design (CADD) systems and computer-assisted cartography (CAC) systems and are in a transitional phase attempting to add the functionality of GIS to their repertoire. Similarly, MPOs have existing resources and skills for urban transportation planning. They may employ urban transportation planning models that have embedded in them limited GIS functionality. The GIS functionality needed by transportation organizations consists of:

- geographically structured data,
- linkage of locational and attribute data, and
- analytical map overlay.

Geographically structured data consists mainly of point, line, and area spatial objects plus the relationships between them, i.e. topology. Figure 2a provides definitions for spatial data objects most commonly used in a transportation-oriented GIS. Figure 2b shows their use in a data layer and in a data structure form. The data structure contains explicit reference to topological spatial relationships. (See Section 4.2.1 for more detail.)

Linkage of locational and attribute data about transportation facilities is shown in Figure 3 using a chain identifier.

Analytical map overlay of separate map data can be used to identify spatial relationships between data layers. Figure 4 is a graphic depiction of an analytical map overlay process that is performed using the coordinate compatibilty referred to previously. New nodes are established, hence new chains are created during the process. The new chains are linked end to end to create the boundaries (rings) of new subareas.

1.4.2 Strategic Planning for GIS

Adding GIS concepts and technology to transportation organizations is an incremental process. New procedures and techniques must be incorporated into existing ones. There are two fundamental approaches:

- add new functionality to existing CADD, CAC, or modeling systems, or
- interface a new GIS to an existing computing environment.

There are advantages and disadvantages to either option. They will be discussed in Section 5.2

2. GIS CONCEPT AND PROCESSING

2.1 System Concept

Two different types of systems currently useful for processing transportation related geographical information are typically called a computer-aided mapping system and a geographic information system. Dueker (1987) provides a comparison of the two types. Computer-aided mapping systems have been in use for several more years than the latter. The focus in a computer-aided mapping system has been map design and map information management (hence it is sometimes referred to as a map information management system - MIMS). A MIMS is the principal type of system used for automated mapping and infrastructure facilities management (AM/FM) tasks. This focus satisfies the basic requirement for locational inventory as well as the production of maps. Such a system is very

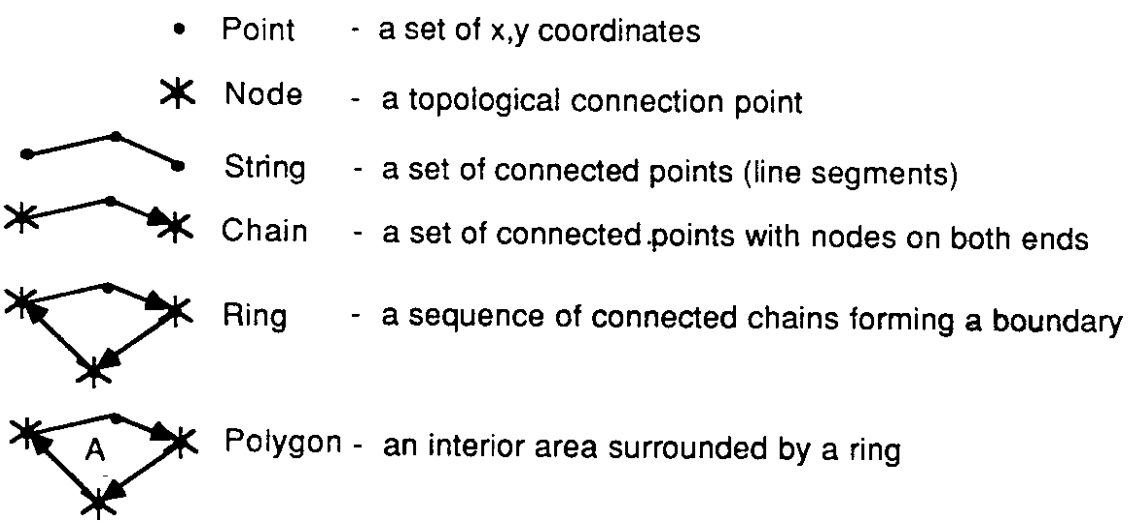
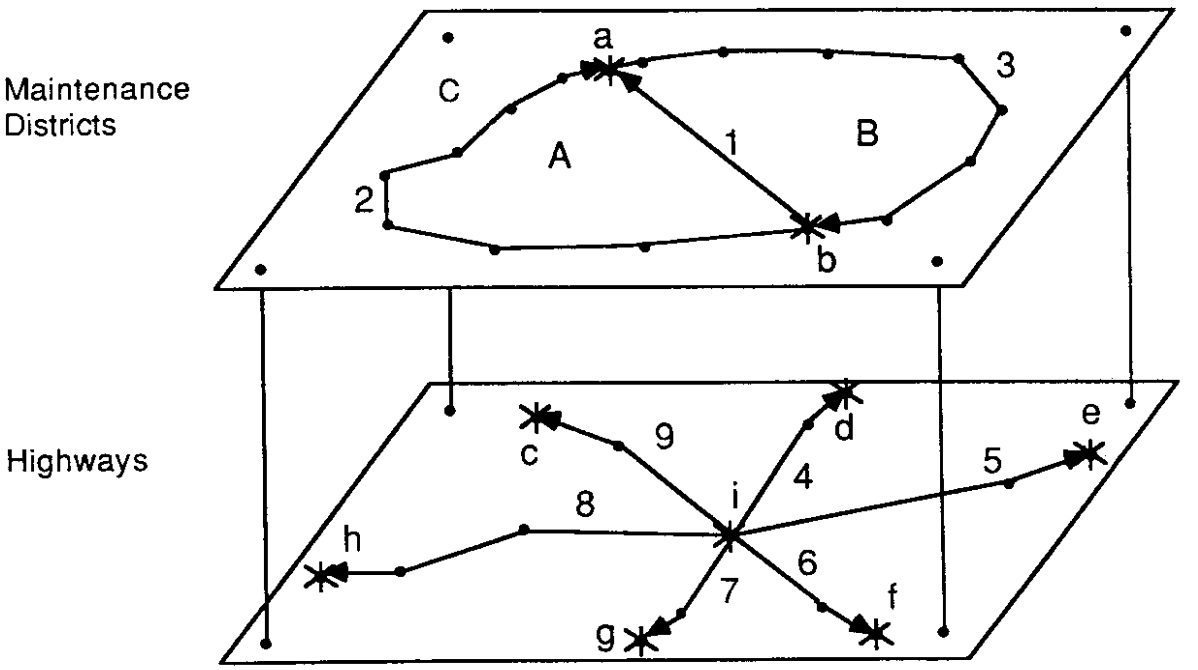


Figure 2a. Spatial data objects for GIS in transportation.

(Source: Digital Cartographic Data Standards Task Force, 1988)



Maintenance District - Polygons

Area ID	Ring (Chain list)
A	-1, -2
B	3, 1

(negative indicates reverse order)

Maintenance District - Boundary chains

Boundary chain ID	From node	To node	Left area ID	Right area ID	X, Y coordinates
1	b	a	A	B	x1,y1 ..... xn,yn
2	b	a	C	A	x1,y1 ..... xn,yn
3	a	b	C	A	x1,y1 ..... xn,yn

Highway - Network chains

Network chain ID	From node	To node	X, Y coordinates
4	i	d	x1,y1 ..... xn,yn
5	i	e	x1,y1 ..... xn,yn
6	i	f	x1,y1 ..... xn,yn
7	i	g	x1,y1 ..... xn,yn
8	i	h	x1,y1 ..... xn,yn
9	i	c	.x1,y1 ..... xn,yn

Figure 2b. Chain and polygon data records for GIS.

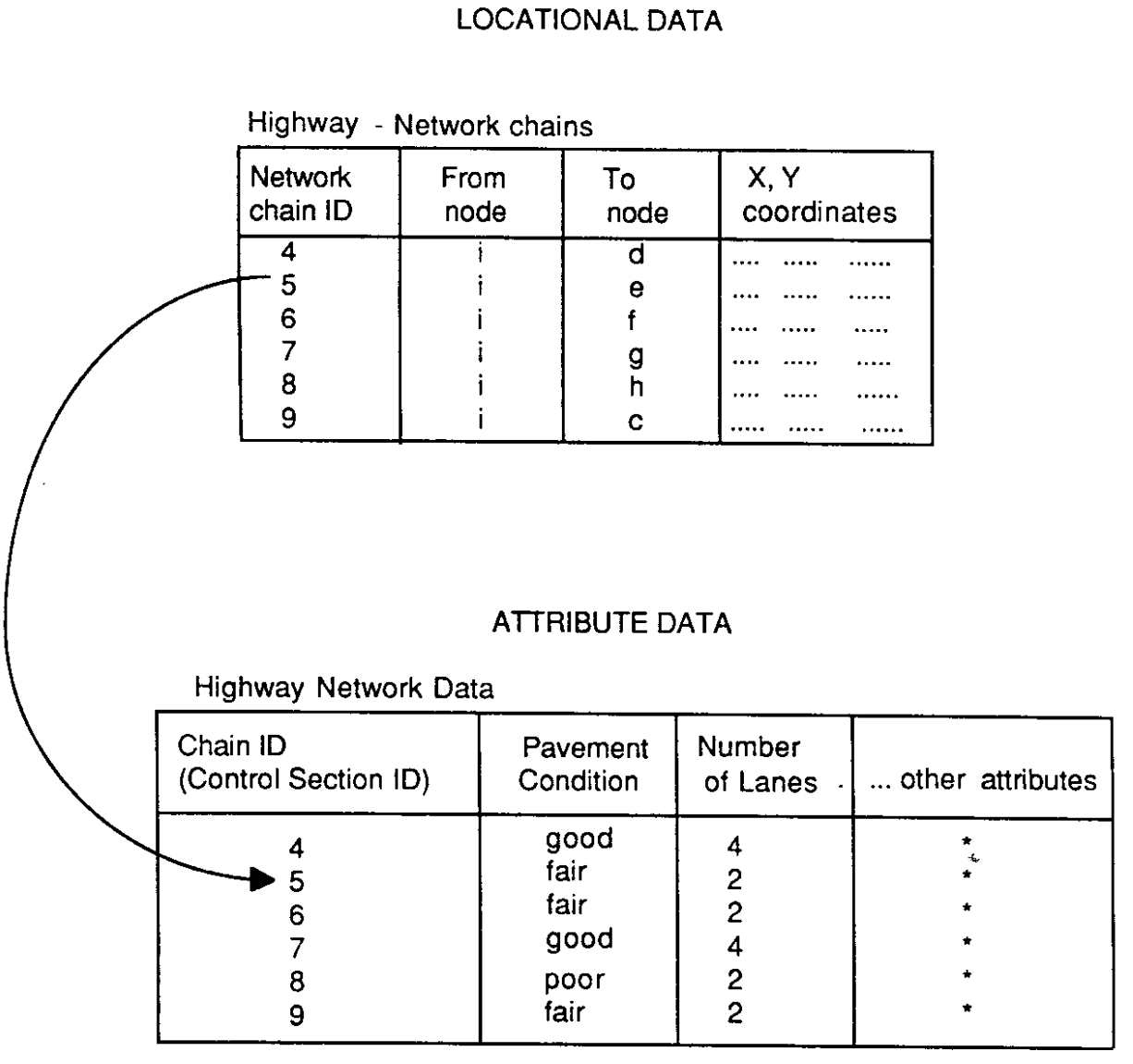


Figure 3. Locational data linked to attribute data.

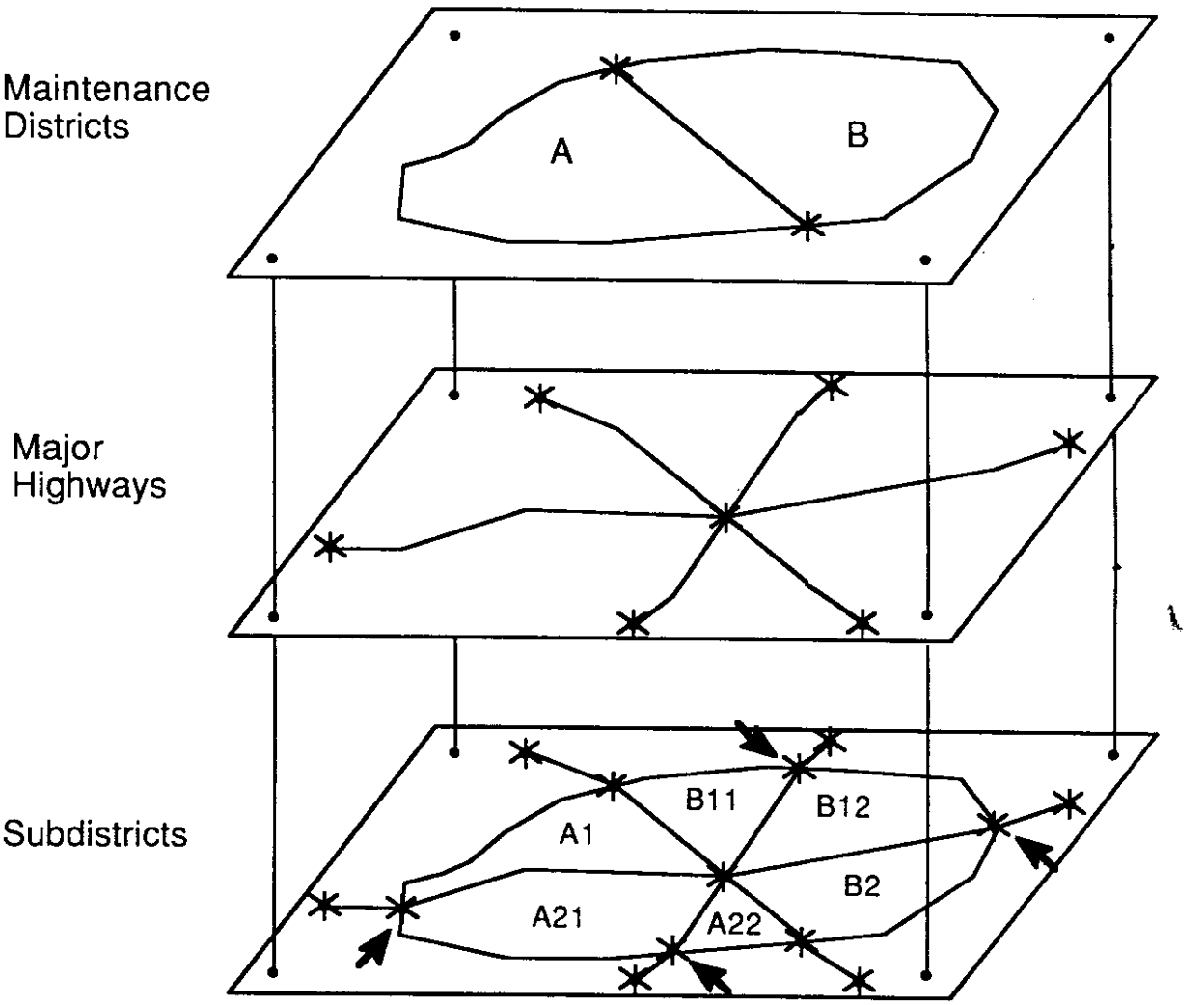


Figure 4. Maintenance districts (A , B) are overlayed with highways. Subareas A1, A21 and A22 are created from District A ; plus subareas B1, B11 and B12 from District B. Four new nodes are established in the process and are identified by: ↖ . Two nodes are used from the district data layer and seven from the highway layer.

useful in fulfilling a need for information in an operational setting where detailed map documents are required as tools to support daily decision making. In addition, such systems can support the production of high-quality images that are needed for map publishing. Evolving over the past several years, **the GIS-type goes beyond the visual analysis of spatial relations** to computer-aided analysis of geographical data. The focus in a GIS is not map-making per se, but geographical data analysis supported by map documents. Maintaining a locational inventory for facilities management can be accomplished with a GIS, but this is not the main use of such systems. The need for GIS is growing as pointed out in the first section due to data analysis, and will continue to expand as related to transportation applications discussed in Section 3.

The essential components of a GIS are its personnel, georeferenced database, graphics-based software and hardware. Without any one of these components a system cannot function. A GIS is often thought of as concepts and technology, or a tool box of software and hardware to manipulate geographic data objects. However, without the personnel to build, maintain and use the database in a particular organization, the GIS concepts and technology are incomplete. The application of GIS concepts and technology to particular issues or problems results in land information systems, stream information systems, or transportation information systems. A GIS is generic, referring to an entire system, the technology, and to specific functions. Consequently, a highway inventory system is not a GIS unless the system includes a set of observations about spatial objects that describe the location of the inventory data using coordinates, and the software, hardware, and personnel are used to manipulate these objects in a spatial manner.

2.2 GIS Stages of Processing

A GIS provides support for a staged process of data acquisition, management, analysis, and display of the geographical-based information. However, those four stages follow one after the other in only the simplest of situations. Hence they tend to be somewhat iterative in nature. That is, the process of analysis may result in the need to capture new data. Each of the stages can be subdivided into more detailed substages. Marble et al. (1984) observe that the iterative process occurs more often within the substages than between the major stages.

The **data acquisition** process can be subdivided into document and/or data research and collection, document and/or data preparation, digitizing and/or data integration, and data editing.

The **data management** process includes storage and retrieval of appropriate data for certain projects. There must be an awareness of a long term commitment to data maintenance and data organization for efficient access and/or analysis; including the continual update of data as an extension of the data acquisition process referrred to above. Spatial indexing becomes a major issue when dealing with a large volume of spatial objects to be accessed efficiently.

The **data analysis** process includes the use of special application programs to derive information needed in the operational or strategic decision making process of the transportation organization. Some examples include traffic flow analysis, routing of hazardous materials, and transportation facilities planning. Applications are discussed in more detail in Section 3.

The **data display** process includes the generation of reports, graphs, charts and maps for evaluation by decision makers. The major emphasis has tended to be on reports and maps. Section 4.5 discusses this further.

3. TRANSPORTATION APPLICATIONS OF GIS

Applications in transportation vary considerably in terms of the kinds of analysis and data. Particularly, the spatial resolution or detail of data differs, depending on the type of application. Also, urban applications differ from state DOT applications.

3.1 Urban Applications

MPOs interact with local governments with respect to urban data. Therefore MPO data requirements are similar to those of local governments. Local government GIS applications cluster with respect to map scale, accuracy and data detail. In turn, this scale, accuracy and detail are the major determinants of system requirements and thereby the cost of the GIS. Table 1 illustrates the clustering of urban GIS applications into three levels of geographic detail for application to **planning, management, and engineering** problems. The applications are distinguishable by orders of magnitude differences in map scale, accuracy, data volume, and cost of GIS and data acquisition. Data volume is the primary determinant of system complexity and cost. Consequently, the level III systems with two orders of magnitude more data than level II systems are two orders of magnitude more expensive. This is due to an order of magnitude increase in both the number of observations and the number of points per observation when going from street segment and city block observations to land ownership parcel observations, along with associated detail for infrastructure networks.

Currently, MPOs are focusing most of their attention on level I systems built around traffic zone and census tract levels of geographic detail, or granularity. These data support urban transportation planning models. Some MPOs are active at level II, because they have taken responsibilty for maintaining the U.S. Bureau of the Census GBF/DIME files for purpose of address matching of building permit, vital statistics, and employment data to update traffic zone data. A few MPOs are active at level III in cooperation with cities, counties and utilities. The MPO can benefit from fostering compatible data throughout the whole urban area. That data should be linked to administrative record keeping systems to reduce the need for separate and duplicative data collection.

3.2 State DOT Applications

Applications of GIS concepts and technology by state DOTs shows a similar clustering of **planning, management, and engineering** functions. Table 2 illustrates the order of magnitude differences in map scale, accuracy and data volume. As before, data volume is the determinant of system complexity and cost.

Level I applications, such as displaying routes and locations impacted by construction, generally relate to the state as a whole. The data to support these analyses are coarse, and spatial accuracy is not an important issue. Often aggregated data are preferred to illustrate major trends or differences.

Level II applications, require finer grain data; this additional detail often requires focusing on small study areas, such as a county or a substate region. Highway inventory, traffic safety, or pavement management systems are developed at this scale of analysis.

Level III applications, such as converting design plans to as-builts and adding them to a larger database, are geared to better integrating design, construction, and maintenance

TABLE 1. GIS APPLICATION AND LEVEL OF DETAIL: URBAN MPOs

SYSTEM LEVEL	I	II	III
APPLICATIONS	Transportation Planning Urban Planning Marketing Siting Service Facilities	Routing & Dispatching Address matching/geocoding Neighborhood Planning Resource Sensitive Facility Siting Local Service Facility Siting	Facility Managment Tax Mapping Engineering Design
SCALE	1 : 100,000	1 : 10,000	1 : 1,000
UNITS OF OBSERVATION	Census Tracts Traffic Zones Neighborhoods	City Blocks Street Segments & Nodes Approx Parcel Centers Boundaries	Parcels Utility Equipment Road Geometry Background Layers (land base)
POINTS PER OBSERVATION	10	1	10
ACCURACY POSITIONAL RELATIVE	 100' 10'	 10' 1'	 1' 0.1'
DATA LAYER REGISTRATION	Geocode	Geocode	Coordinate
DATA VOLUME (1 Million Pop)	1000	10,000	100,000
LAYERS	10	100	100
TIME	0.1 yr	1 yr	10 yr
COST	$10,000	$100,000	$10,000,000

Note: The values in this table are approximate, indicating an order of magnitude rather than specific values. A range of -50% to +150% could be applied to all values.

(Dueker 1988)

functions. More detailed data are needed, and consequently, corridor or project areas, rather than the whole counties, form the focus of these systems.

Examination of the rows for scale, accuracy and cost of Table 2 across the columns illustrates the importance of scale and spatial accuracy. Larger scale mapping and greater accuracy is needed when handling more detailed spatial data and this leads to more costly GIS. The cost of a GIS is directly proportional to the data volume. Data volume increases in the same manner as scale and accuracy, by an order of magnitude, when going from a level I system to a level II system and another order of magnitude when going from a level II system to a level III system.

Sharing data and GIS technology among applications is essential for the cost effective provision of transportation facilities and services. Each MPO and state DOT must assess application requirements to make wise GIS procurement and implementation choices. This section only provides a framework for such an assessment.

4. GIS FUNCTIONALITY

4.1 Spatial Database Design Issues

Describing what and how transportation entities are to be stored in a database is determined during a process of database design (Martin 1983, Nyerges 1987). There are several steps that can help insure that the design follows the goals of an organization. Organizational goals manifest themselves in the data processing applications undertaken by an organization, GIS processing being among these. Transportation applications in a GIS should follow in line with the goals of the organization, thereby insuring that the database being designed supports these goals.

Database design is performed usually in three stages: conceptual, logical and physical. A conceptual design is software and hardware system independent, i.e. it could be a description of what should exist in the database in terms of entities - such as highways, rivers, maintenance stations and the characteristics that describe these that are used for analytical manipulation. A logical design is software system specific, but hardware independent, i.e. the database design conforms to a specific software system design, but not to any particular computer. A physical design is both software and hardware system dependent, i.e. it conforms to a specific software package as well as a particular computer.

In the conceptual stage, entities are identified and described in terms of all applications that will process those entities for all of the reports or models that are to be used. Figure 5 shows an example of a set of transportation-related entities depicted as an entity-relationship diagram (Chen 1976, Lodwick and Feuchtwanger 1987, Nyerges 1980). An entity is any topic about which information is to be stored. A relationship is any association between entities about which information is to be stored or derived. The entities are indicated by boxes and the relationships between entities are indicated by arrows. In this example, physical road segments, route-milepoints and control sections are topics for which data are to be stored. Route-milepoints and control sections are locational references for the physical road segments.

The database design process is constrained by how transportation entities are measured and how the data are to be used. Thus, the data collected to describe a highway may be measured at milepoints and assigned continuously along the highway, or measured according to fixed control sections. The entity is still the highway, but the resulting computer representation could be different. (This is treated in Sections 4.2.1 and 4.2.2 in more detail.)

TABLE 2. GIS APPLICATION AND LEVEL OF DETAIL: STATE DOTs

SYSTEM LEVEL	I	II	III
APPLICATIONS	State-level network analysis State-level cartography products HPMS	Regional Planning County-level cartogr products Traffic Safety Highway Inventory	Project Planning Preliminary Engineering Engineering Design As-Built Plans
TOOLS	Transportation Planning Models Thematic Mapping CAC	GIS DBMS CAC	Coordinate Geometry CAD
SCALE	1 : 1,000,000 planning 1 : 500,000 wall map	1 : 100,000 planning & inventory 1 : 62,500 county highway atlas 1 : 24,000 data source maps 1 : 10,000 city inset maps	1 : 10,000 project planning 1 : 5,000 preliminary engineering 1 : 1,000 engineering design
ACCURACY			
POSITIONAL	1000'	100'	10'
RELATIVE	100'	10'	1'
COST	$100,000-1,000,000	$1,000,000-10,000,000	$10,000,000-100,000,000

(Dueker 1988)

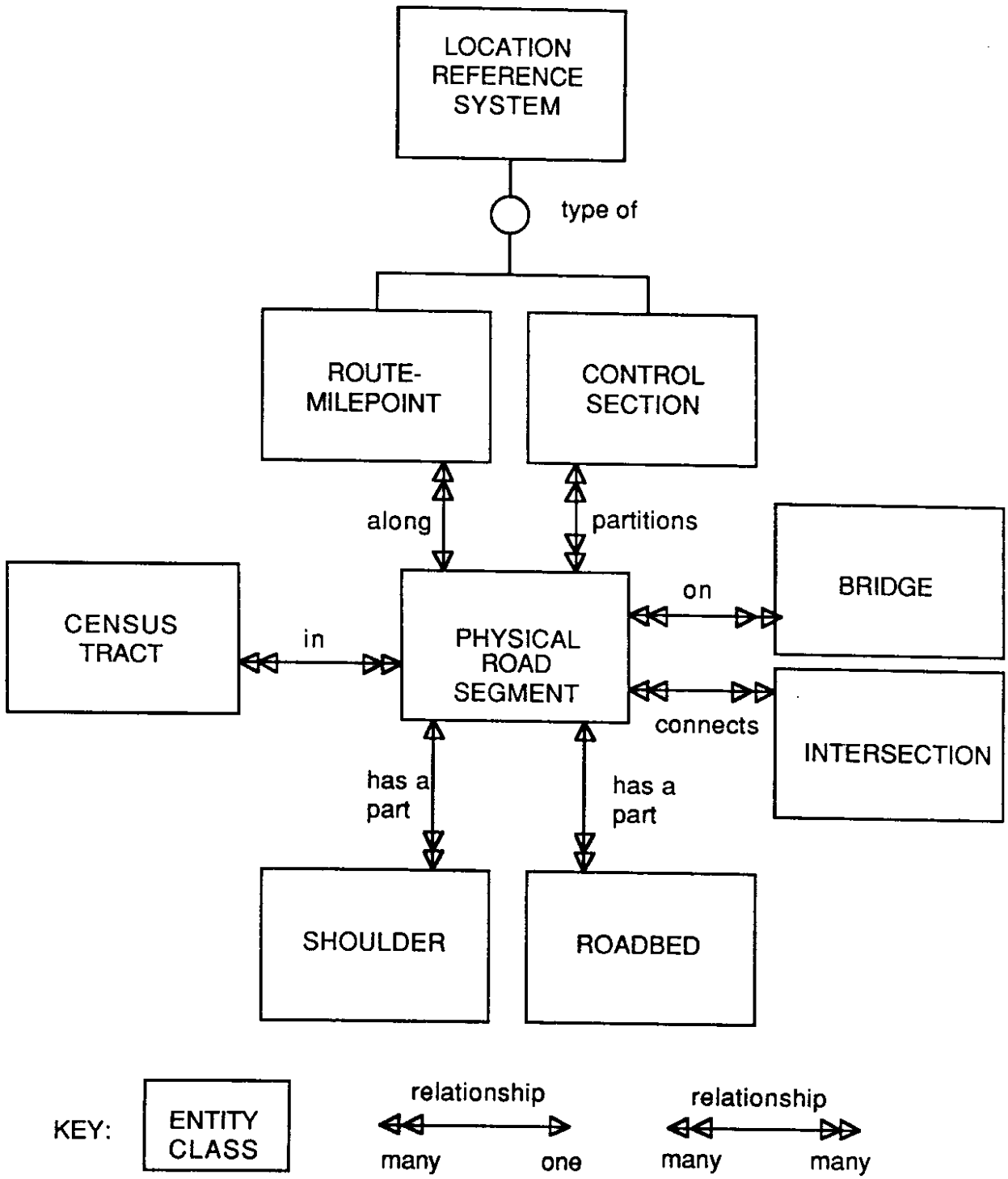


Figure 5. A conceptual model of transportation entities. Used as the first step in database design to clarify the characteristics of data to be represented. An entity class is a category of information. Each entity class contains several observations of the particular type indicated.

After entities are identified, then a decision is made as to how the entities will be stored in terms of spatial objects -- as points, lines and areas -- that best meet the needs of the applications. The Digital Cartographic Data Standards Task Force (1988) has identified several ways that points, lines and areas can be stored as "spatial objects". Figure 2b depicted several specific spatial objects such as point, node, chain and polygon. Spatial objects can be described by a set of locational information and attribute information, as are discussed in the following subsection. These objects are stored in a system using a spatial data structure suitable to the types of spatial objects.

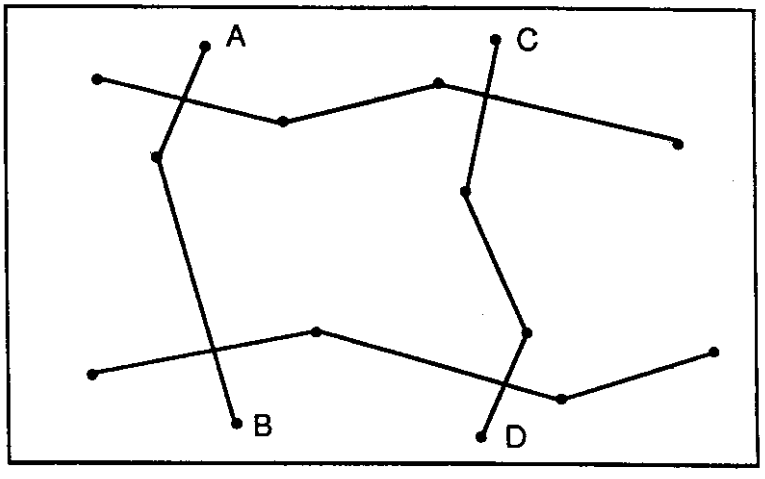
The entity description together with the spatial object representation description is termed the "Conceptual Model of Spatial Data" of the database. Database design decisions about the information content for entities in a conceptual model are based on whether the real-world dimensionality and connectedness of an entity are to be retained, as well as the detail of each entity being represented in terms of descriptive characteristics called attributes. In most instances, the decision about dimensionality is a matter of scale, i.e. should a maintenance station be represented as a point location, or as an areal boundary. In terms of connectedness, should the highway sections be explicitly linked end to end or does graphic visualization suffice. The answers lie in how the data are to be processed by the applications.

Many spatial data structures exist, but for GIS the one which has been shown to provide the best foundation for locational information is called the topological data structure (Peucker and Chrisman 1975, Burrough 1986). A topological data structure stores information about connectedness between spatial objects. A link/node network can be stored using a topological data structure. Such a data structure stores the connection of one highway link to the next highway link. Figure 6 depicts the differences in the string and chain spatial object types (hence data structures) that could be used in a routing application. Strings (having no explicit topological information stored) would have to be intersected before the routing process could take place. A chain-based data structure is ready to use because the topology of the network is stored. It is quite evident that a topologically-based spatial object is needed to represent the information in the database for GIS applications.

Once the entity and object decisions have been made with respect to all (realistically, most) different applications (including analysis models and/or queries), then the logical design of the database can be performed according to the constructs of the database management software chosen to support the GIS. Every data management software has a selected set of constructs that define the way in which the data will be stored. Most systems use the concept of a data layer (also called data theme, overlay, map layer) to store different entities, but this depends on the system implementation. These constructs are implemented using a set of schema constructs, because a schema is used to define the data storage framework of the database. The selection of schema constructs for storage of data depends on the number of spatial objects implemented in the system and the type of attribute data manager being used. The result of this stage of the design process is called the logical model of the database.

The third stage of database design is called physical database design. During this stage of design decisions are made that concern how the files will actually be structured for access on a disk. Many GIS vendors do not provide this level of design for locational characteristics because preselected access mechanisms for indexing geographic space are used, hence the physical design is accomplished automatically. However, most attribute database management software does provide this feature so that this portion of the database can be customized at the physical level. The result of this stage of the design process is called the physical model of the database.

Paths between locations on the same string are easy to build, e.g. A to B
Paths between locations on different strings are difficult to build due to lack of topological connection.



Paths between any two locations are easy to build when topological connections are stored as part of the data., e.g. A to D.

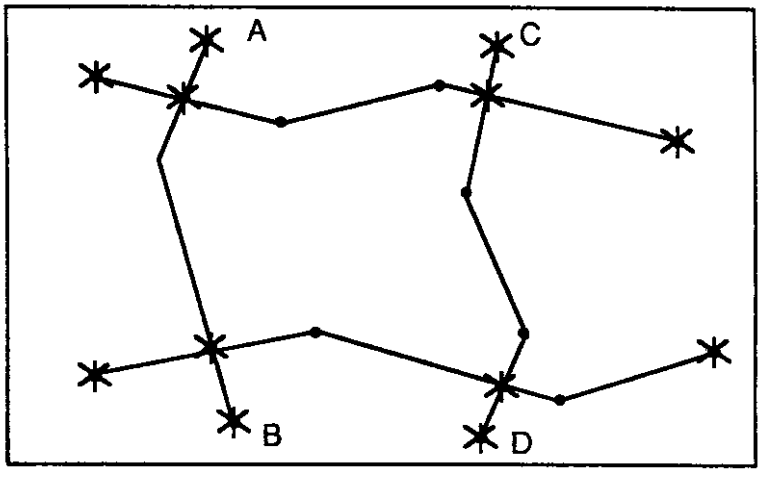


Figure 6. Path creation using string and chain data.

4.2 Database Management Issues

The requirements for geographic information management differ from the traditional management of information in Management Information Systems (MIS). The main reason is the importance of spatial proximity in storing and retrieving the data. What is located together in geographic space should be stored and retrieved together by the system. This process is called spatial indexing. Spatial indexing enhances analysis and display performance. (See Section 4.2.5.1 for a discussion of spatial indexing.)

Although much transportation related information involves location in geographic space, certain topical areas are, by necessity, managed administratively by different parts of an organization. Data management can follow the practices of administrative management by assigning custodial responsibility for different data layers to the parts of an organization most responsible for the data. This might be true for either the locational and attribute data or both. The idea of a central database can still be maintained, and data shared among users, by tying all layers to a common georeference framework. Hence, the technical characteristics of a system can be integrated with the organizational structure of the institution (Chrisman and Niemann 1985).

4.2.1 Locational Data

During conceptual design, a decision is made as to whether an entity is to be stored as a point, line or area. Some of these decisions are obvious, but with different types of point forms and area forms, the decision may require more thought. Decisions about locational data are critical to spatial database design. Locational information for spatial objects includes metrical, topological and graphical information.

Metrical data describes the coordinate space. Although many coordinate systems are possible, a GIS coordinate system should have an explicit (and known) relationship to some earth-oriented coordinate system. Latitude/longitude and State Plane are two fundamental types of coordinate systems most useful for transportation data. The system of latitude and longitude coordinates depends of the datum being used. This is discussed in Section 4.2.4.1. State plane coordinates are set up by the National Geodetic Survey (formerly U. S. Coast and Geodetic Survey) of the National Oceanic and Atmospheric Administraion. State plane coodinates are based on a rectangular (Cartesian) coordinate system, thus allow the use of plane geometry calculations. Each of the states has their own zone(s) which provide for engineering level accuracies across fairly large distances on the surface of the earth.

Topological data describe the connectedness of the spatial objects in terms of nodes, lines and areas. When dealing with transportation related information, nodes represent intersections and physical ends of the highway; lines represent the highway connections between nodes; and areas are those physical spaces bounded by lines that are connected and closed. Without topology, strings of locational information about roads cannot be connected easily into roadway networks for analysis. Strings (as a sequence of points) can be graphically displayed, but routes cannot be traced. It is much better to represent the network connectivity explicitly rather than implicitly by coordinates.

Graphical data are those that enable the visual portrayal of the objects on a display device. Point, line and area symbolization have several variations which make some symbolizations better than others, depending on the requirements of the visual display.

4.2.2 Attribute Data

Attributes are those descriptive characteristics other than location pertaining to an entity stored as a spatial object in a database. Attributes can be measured on four levels: nominal, ordinal, interval, or ratio.

A **nominal** level of measurement is one that considers an attribute value as being a difference of a kind or type of thing. For example, a road is a different kind of an entity than is a stream, but both are lineal in nature.

An **ordinal** level of measurement concerns a difference in rank order in terms of larger or smaller. For example, as a transportation corridor, an interstate highway ranks as being more dominant than does a State Primary highway.

An **interval** level of measurement concerns a measurement of a characteristic whereby the counting units used are fixed, but the zero point to start counting is arbitrary. For example, date of road closure/openning can be set, but when dates are compared it cannot be said that one date is twice as long as another, or shorter than another.

A **ratio** level of measurement is like an interval level, where fixed counting units are involved, but the zero point is fixed so that when zero is used it indicates the absence of the element being measured. For example, zero distance means that there is no distance, or zero traffic accidents means that there are no traffic accidents.

Nominal and ordinal levels are called qualitative levels, whereas interval and ratio are called quantitative levels of measurement. All measurements of attributes for spatial objects could be classified using these levels. They are important when performing analyses on data, as well as choosing an apporpriate symbology for a map.

4.2.3 Linkage of Locational and Attribute Data

Although both locational and attribute data are used in describing spatial objects, they are stored separately (as depicted previously in Figure 3) for two reasons:

1) coordinates need to be accessed rapidly for display, and

2) attributes of spatial objects need to be modified rapidly.

Mapping systems based on computer-aided design and drafting system principles generally treat attribute data in the same manner as locational data. The attributes are stored for display as graphic text in separate data layers, positioned to display at or near the spatial object when the two layers are displayed. This type of attribute description does not support data analysis of the attributes for the spatial object because the data are stored as graphical, stroked characters.

Another strategy for facilities management stores attribute data in a separate DBMS, one record for each spatial object. The technique supports data analysis because data are stored as characters/numbers in a database. The characters/numbers are then used to generate the graphical stroked characters at display time.

A linkage identifier (usually the spatial object ID) is needed to maintain a one-to-one correspondence of the locational data to the attribute data. This technique is shown in Figure 3 assuming the use of control sections. Maintenance of this one-to-one correspondence is

straight forward with respect to point, fixed segments and area spatial objects, but more difficult for line spatial objects whose attributes vary. Lines may not be homogeneous with respect to all attributes -- accidents, culverts, and signs occur at various locations along highways; pavement condition, type, depth, and width begin and end at various locations along the highway. A GIS for transportation must accomodate these relationships (Dueker 1987).

When attribute values are assigned to lineal objects they are done so on the basis of a segmentation scheme. Segmentation schemes take different forms. Two common ones are relative distancing run length and homogeneous control sections. A run length segmentation is based on the continuous observation of an attribute value along the highway starting at any location the attribute is observed until the attribute is no longer observed.

The linkage of point and line data to handle non-homogeneous lineal data requires a combination of spatial referencing systems. Lineal spatial objects must be: 1) topologically represented, 2) represented as a string of x,y coordinates, and 3) represented by route and milepoints corresponding to the beginning and ending points of the string. This enables interpolation along the string to display points of accidents or beginning point of pavement type, and obviates having to segment lines apriori (See Dueker 1987). This is referred to as dynamic or run-time segmentation, and can be used to support different types of segmentation schemes. Figure 7 depicts the dynamic segmentation scheme for retrieval and display of data.

The control section scheme is based on a fixed length of the highway (sometimes as short as 0.01 of a mile) being characterized by homogeneous attribute values. This simplifies the problem of georeferencing, eliminating the need to compute coordinates based on relative distance. However, using fixed length segments looses the capability to discriminate any finer than the length of the control section, and causes considerable data redundancy. Different application groups in an organization may have different control sections, one for pavement management, and another for highway performance monitoring. Each segmentation is homogeneous with respect to the attribute of interest to that application group. Unfortunately, this makes integration of data difficult because of the different segmentations.

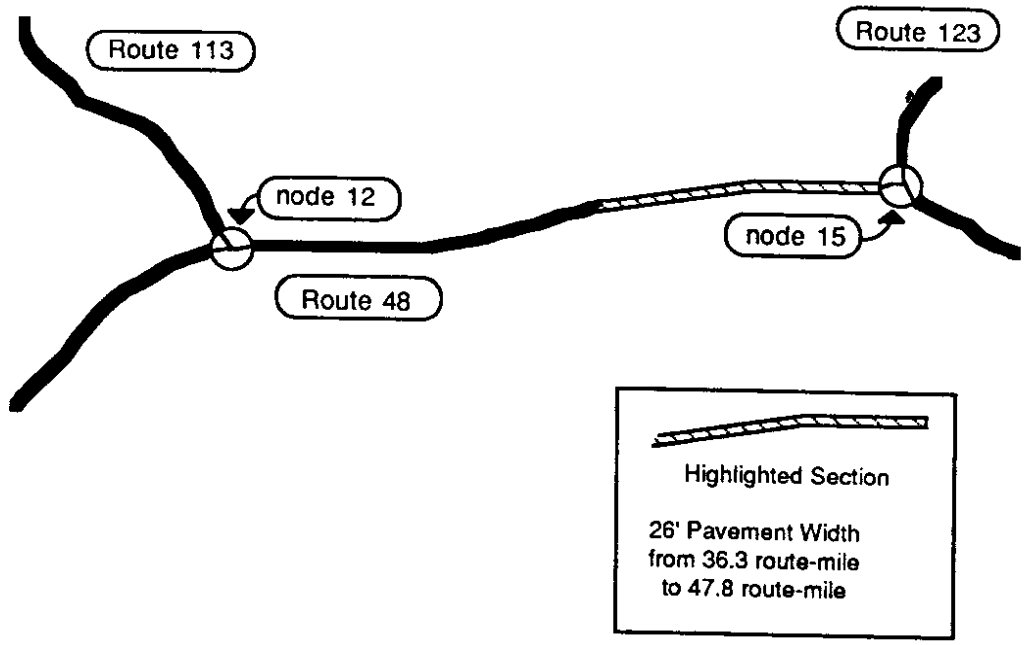
4.2.4 Relating Data Across Layers

Some applications require comparison or analysis of data layers on the basis of location. This requires a reference framework that is based on location, called a spatial reference framework or georeference system. The number of applications that require a comparison of data from one layer to another influences the sophistication of the reference framework needed.

Labeling point, line and area objects for easy reference by location is called geocoding. Many styles of geocoding can be used; some are coordinate based but most rely on names or locational codes other than coordinates. When many layers are geocoded to the same spatial reference framework, they can be more easily cross-referenced to support different types of displays and analysis.

Route-Mile	ROW Width	Pavement Width	Pavement Condition	Intersection	Culvert Distance
0.00	100	24	3		
24.20				113	
36.30		26	2		
47.80		24	3	123	
63.21					48
121.11					24

Flat File for Route 48



Equations at nodes

Node	Route	Rte-mile	Route	Rte-mile	x,y
12	48	24.2	113	151.2	.
15	48	47.8	123	131.3	.

Nodes and Associated Route-mile points

Figure 7. Example of retrieval and display using dynamic segmentation.

4.2.4.1 Spatial Reference Framework

Different types of spatial reference systems exist, e.g. a highway network or a coordinate system. The former could be used to provide relative locational control. The latter can be used to provide absolute locational control.

Many times funds are not available to seek out the best coordinate control information possible. Relative control can be used on small geographic areas, i.e. on an individual map basis, but should not be used if absolute control is available.

A situation where data are referenced to the same coodinate system leads to locational compatibility which facilitates data sharing. Epstein and Duchesneau (1984) refer to locational compatibility based on a geodetic reference system as universal locational compatibility.

A geodetic reference system is a systematic area coverage of control points. The control points are expressed with reference to latitude and longitude coordinates (or global coordinates convertible to latitude and longitude). The coordinate control information is converted from latitude/longitude to state plane when used within an individual state plane zone within a state.

A remeasurement of the horizontal network of geodetic control describing horizontal location for North America has been completed. The new horizontal datum, called the North American Datum of 1983 (NAD83), will supercede the NAD27, eventually. A vertical datum for elevations is in the process on being completed. The new vertical datum is called North American Vertical Datum of 1988 (NAVD88), and is scheduled for completion in 1988 - but may not take place until shortly thereafter. From these data, new state plane coodinates for each state can be computed. Several States have undertaken, or are in the process of revising, legislation defining and establishing the datum for state plane coordinates.

Most highway related data is still referenced to the NAD27. A transformation between NAD27 and NAD83 should be performed. The NAD83 provides a more accurate horizontal spatial reference framework for a GIS than does the NAD27, for coverages as large as a state. All latitude and longitude positions developed as a result of projects involving the National Geodetic Survey are being expressed in the new coordinates.

Latitude and longitude provide a single coordinate system to reference all geographical features no matter where they might be located on earth. However, due to the nonplanar character of the coordinate system, the mathematics are cumbersome when using for calculations of area or length. State plane coordinates are preferred for most MPO and DOT mapping applications because the mathematics are simpler, and most organizations only deal with a selected few zones.

Conversions between different coordinate systems are possible with most GISs and should be part of most GISs used for transportation applications. A software package called the General Cartographic Transformation Package that converts between several coordinate systems is available at modest cost from the National Oceanic and Atmospheric Administration, Charting and Research Development Laboratory in Rockville, Maryland (Elassal 1987).

4.2.4.1.1 Base Maps

In addition to a control framework, an organization needs a base data layer, which is used like a base map. The definition of a base map is by no means universal, but an operational definition is: a **base map** is any set of information that provides spatial orientation (background information) for another set of information of primary focus. The same set of information can at one time be considered base map information and at another time be considered the primary information, depending on context.

The most common base map information for DOTs and MPOs in mapping has been USGS topographic quadrangles where available. The map scale depends on the nature of the study. The USGS 7.5' or 15' quadrangle maps often provide the base for highway inventory systems or county highway maps. For a GIS application, the base map information may be the highway network itself, plus georeference control, administrative boundaries, and hydrographic features. In some instances, the highway information can provide sufficient locational orientation such that the network is all that is needed.

A highway network that shows the true character (shape) of the highways is good for visual examination to provide spatial orientation. However, this is dependent on the amount of orientation neeeded. When a geodetic reference framework is available, various types of background information needed for visual orientation may be requested on demand depending on the nature of the study. Consequently, it does not really matter what elements appear on a base map for the purpose of spatial orientation. However, a systematic selection of certain base data for spatial orientation is recommended over random selection. Data layers commonly included are: streets/roads, railroads, airports, rivers/streams, major governmental jurisdictions and place names. Buildings would be included in data layers compiled from larger-scale sources. Inclusion of any of these on a particular map might depend on the use of the map.

4.2.4.2 Geocodes

A geocode is a data value assigned to a spatial object that provides information on the geographic location of the spatial object. A coordinate, a street address, a route-milepoint, a control segment, and a census tract number are all considered geocodes. Place names, e.g city and county names, are nominal level geocodes that require users to know relationships among named places, whereas coordinates are ratio level geocodes that enable spatial relationships among geocoded places to be calculated.

Attribute data can be geocoded to points, such as route-milepoints. Milepoints might carry a coordinate value describing its position on the earth. Alternatively, a milepoint could be referenced strictly by the distance along the road from the beginning of the highway. This geocoding would be based on a relative distance, locational reference. The beginning or ending points of the highway might carry coordinate values which are used to determine the coordinate values for milepoints along the highway.

An areal geocoding of attributes usually involves an areal unit of sufficiently small size to capture the locational characteristics of the attributes. The smaller the size of the areal unit the finer the level of analysis. Areal units can always be aggregated to larger units and attributes generalized, but the reverse is not possible unless the finer degree of measurement was made in the first place. Thus, census blocks being smaller than tracts, are better for more detailed analysis. For regional MPOs, traffic zones can be created from cenus blocks with a finer locational discrimination than creating traffic zones from census tracts. However, the aggregation depends on the needs of the study.

Many entities could be assigned the same geocode, hence the geocode need not be unique. For example, the same value could be assigned to all persons living in the same municipality or house. A city code would be a geocode for a municipality, a street address would constitute the code for persons in a house. Area geocodes are hierarchical in most cases, i.e county codes are unique within a state and city codes are unique within a county.

4.2.4.3 Locational Cross-Referencing System

Cross referencing of different geocoding systems is an important function to facilitate integration of geographic data. A locational cross-referencing system, sometimes referred to as a geographic base file, enables the conversion of one geocoding to another, for example street address to emergency service zone or route and milepoint to coordinates. This is an example of relative location cross-referencing, i.e. locations are specified relative to some spatial object. Briggs and Chatfield (1987) suggest the primary linkage among files for transportation data are the locations of points, or segments of the roads in a system. An absolute cross-referencing framework consists of geodetic control and the coordinates based on this geodetic control.

The U.S. Bureau of Census TIGER files represent the best starting point for a locational cross-referencing system for relative referencing. TIGER already contains a topologically structured network of roads and boundaries, census defined small areas, street and road names with address ranges, and coordinates of nodes. With the addition of route and milepoint referencing, and additional area unit codes of state and local interest, a powerful locational cross-referencing system would be available.

A geodetic reference framework provides a basis for multiple agency spatial registration of layers. Such a framework works best when dealing with inter-organization concerns such as in multipurpose land information systems. This is a critical concern when objects cannot be referenced to a common feature structure such as a highway network because each organization uses a different set of spatial objects as a basis for orientation.

4.2.5 Spatial Data Organization and Spatial Search

Organizing and searching spatial data is particularly important in a GIS. These functions must be performed efficiently, particularly when data become voluminous.

4.2.5.1 Spatial Data Organization Issues

It is important to partition data for efficient retrieval. Data about geographic features need to be indexed and partitioned for both spatial and attribute searches. Although virtual maps and seamless maps seem to obviate the problem, large data volumes make it necesary to organize spatial data for efficient access. Geographic space must be partitioned into files or spatial indexes must be developed. Data that are located together in real space should be located together in files for efficient access and retrieval. Figure 8 depicts a spatial data partitioning of a geographic area based on the density of data across the area. Equal volumes of data promotes equally rapid access to data.

The need to search by attribute or type of data precludes reliance on geography as the only file organization strategy. Consequently, single attribute files rather than multiple attribute files are most often used for spatial data. One theme, or layer, per file is preferred. Then,

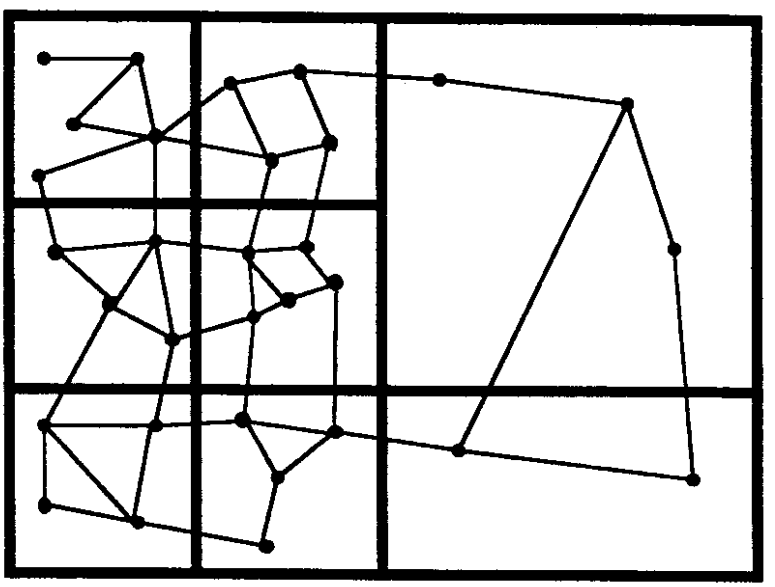


Figure 8. Geographic partitioning using variable size areas sometimes called: tiles, design files or facets.

appropiate themes or attributes can be selected for comparison to one another, geographically. An alternative to single files is integrated files or interleaving data of different types at the same location. Although interleaving is very difficult to construct and maintain, because it requires continual merging of data items, it is very efficient for spatial searches.

4.2.5.2 Spatial Search

There are two types of spatial search:

- **knowing the type of an object or attributes of a type; where is it?** Spatial comparison, or overlay, of different types of spatial objects, or layers; looking for specific relationships, e.g., points in polygons, high accident locations in relation to intersection lighting or vertical grade.

- **knowing location; what object is there and what are its attributes?** What is at a selected geographic location, e.g., display selected spatial objects or occurrences at a particular intersection.

4.2.5.3 Query Optimization

Most queries have both spatial and attribute components. Consequently, it is important to optimize how queries are performed. Whether the spatial query precedes the attribute query or vice versa depends on the nature of the data and the nature of the query. Performing a spatial search first is done when the search area is small in comparison to the area covered in the database or is small in comparison to the objects that would be found using the attribute search criteria. Similarly, performing an attribute search first is done when the attribute search defines a smaller set of possible matches than does the spatial search. Persons experienced with GIS make these kind of judgements, routinely. In the future we can expect more of this expertise to be handled by the software.

4.2.6 Transportation Data Environments

Organizations that have responsiblilty for managing land or infrastructure operate simultaneously in three data environments:

- **applications databases** that are shallow in detail, but spatially extensive, such as maps of the organization's jurisdiction or service area,

- **project databases** that are deep in detail, but spatially constrained, such as project area analyses or construction plans, and

- **subject databases that are both deep in detail and spatially extensive, but** not tied to any one specific application or project.

Databases grow and evolve as the applications and projects, hence subject needs of an organization grow.

Transportation agencies, like most organizations, function in a project mode to accomplish most tasks, while drawing upon application databases such as accidents, permitting, highway inventory and traffic. A GIS can support project, applications and subject oriented-databases if designed properly. Transportation organizations are likely to evolve from an

applications and/or project database orientation to a subject oriented geographic database (from which applications and project data are retrieved). The reason for this likely change is that subject databases are less costly to maintain over a long term. The key question is: "What degree of subject integration of data is needed?" For instance, should highway inventory data be integrated into a single file containing geometric, sign, pavement, etc. data; or should these kinds of data be maintained separately, but with similar spatial referencing, by the units responsible for them? Although the latter approach is preferable in a relational database management environment, some degree of integration may be desired to reduce the amount of overlay analysis that would otherwise be needed. (See Section 4.2.4)

4.3 Data Capture

The principal objective of the data capture process is to digitally encode data into a form that is usable by applications programs. The encoding includes identifying spatial objects to be captured and labeling them such that they can be stored and retrieved by the DBMS for the applications programs. The encoding occurs at different times during the data capture process, depending on the method of data capture.

The initial step in a data capture process involves defining the data requirements of a project. These requirements include the coverage and quality of the data to be used for each of the layers. The coverage is the geographic area of concern. Any given project probably will not require all areas in the jurisdiction, nor all layers of eventual concern to an organization. As project areas of the same content and quality are added to the database, a subject-oriented database with respect to that topic takes shape.

In many cases the attribute information already exists, and only the locational data need be captured. In some cases both types of data must be captured. However, in all cases, the locational and attribute data must be linked to achieve the full benefits of a GIS.

Data availability and cost must be researched. Data might be available in either hardcopy or digital form. The most desireable data is digital data that conforms to all of the criteria set out in the requirements document as well as fits the system format in use by an organization. Such data are desireable because no work is required to make the data useful. Purchasing already compiled, digital data is often less expensive than trying to automate it from scratch.

If digital data cannot be found that conforms to the requirements, then the only choice is to automate hardcopy maps, plot design or survey data, or reformat digital data. The best strategy depends on the amount of data needed.

In the case of a small amount of map data, digitizing the data might be less expensive than reformatting if data interchange software is not readily available. For the case of a large volume of digital data, reformatting might be the less expensive option. When digital data interchange software is available, the decision requires more careful assessment of time and other costs.

Regardless of whether hardcopy maps are to be digitized or digital data are available, some amount of preprocessing can be expected such that the correct feature codes are assigned to the correct spatial objects. Preprocessing is different for each of the types of data capture and is discussed in the sections to follow.

Map data can be captured from hardcopy maps in two ways, either using manual digitizing or through automated digitizing.

4.3.1 Manual Digitizing

Manual digitizing is still the most common method for capturing map data because software (and to a lesser extent, hardware) for automatic digitizing is still in its infancy. Manual digitizing is a process whereby a workstation operator depresses a button on a hand-held cursor to capture data from a map, aerial photograph or stereo model. The process involving a map or photograph is performed with a device called an electronic digitizing table. The process using the stereo model is accomplished with a digital stereoplotter. The strategy in manual digitizing is to reduce the number of conscious decisions that have to be made during the actual digitizing process, thus speeding up the data capture process.

To reduce the number of decisions, especially involving encoding, manual digitizing requires that elements on a map be labeled using a markup pen previous to setting the document on the table. This preprocessing step is used to indicate the spatial objects to be captured for each of the feature types on a document. Identifying spatial objects can occur "on-the-fly" during the digitizing process for small projects, but normally occurs previous to digitizing for large projects. When interpretation decisions must be made "on-the-fly" for large projects, the process of data captured is slowed considerably. Too often manual digitizing results in unidentified layers of data, e.g. roads, streams, pipelines, that are not carefully segmented into uniquely identified spatial objects that can be related to attribute data.

As an alternative to the process of capturing unidentified objects, the locational data for spatial objects in a GIS are stored using a topologic data structure. A topologic structure is one that stores the connectedness of nodes to lines and lines to areas to form either links of the highway or closed, district boundaries. This is done in an explicit fashion, rather than having the connectedness appear in a visual fashion only, as is the case in map drafting systems. Figure 2b depicts topological elements on a simple map.

An operator should not be required to make decisions about encoding the topologic information; the software should be smart enough to do this. The topologic information can be created by software on-line or in a postprocessing session. Thus, digitizing should proceed without the operator being required to make decisions about the connectedness of the elements. Very little additional training is needed to use such software. In fact, in some cases the training is reduced.

Once the locational information has been captured, the attribute information can be linked to the locational data. This implies that discrete spatial objects are digitized separately. This is particularly important with respect to lineal features. Indiscriminate digitizing of lines from a map is not appropriate. Individual spatial objects must first be encoded. That encoding then dictates the order in the digitizing process.

4.3.2 Automated Digitizing

Three types of automated digitizing are: 1) line following, 2) scanning and 3) video digitizing. Line following techniques are used to capture long lines on map documents, e.g. stream networks, highways and contours. An operator of a line following system positions a laser light source on a line to be captured. The laser follows along a line until one of the following occurs: 1) the laser cannot detect which direction to take, 2) the laser encounters an edge of a map or 3) a line closes back onto itself. Several things may cause the laser to lose direction. Among them are line weight fluctutation, breaks in labeling, and density of line work. For these reasons, map separates are the best source documents for this technique.

Scanning is a process in which a document is placed on a flat bed or cylindrical drum and then viewed in successive, systematic passes (scans) by an optical light source. The light source moves in fixed increments along a gantry. Each scan is broken into very small picture elements (pixels). Device resolution is measured in terms of the number of addressable dot units (pixels/lines) per inch in a linear dimension across the imaging surface. The scans, each with perhaps several thousand pixels, form the raster image. The pixel density may be as great as 1000 or more pixels per inch along both dimensions of a document. The more sophisticated scanning systems can sense colors with line weights thinner than the line following devices, but they can also be more expensive, with prices ranging between $50,000 and $200,000.

The least expensive ($2,000 - $5,000) of the automated digitizing methods uses video digitizing with a video frame grabber. Such a device uses a stationary camera positioned above a document while the document is placed flat on a table. Normally, the resolution for these devices is much lower than the other devices, being 512 x 512 pixels over the entire area of the document being scanned. Consequently, a trade-off exists between the detail (resolution of data capture per area) and the coverage (total amount of area) on a document at a single setting of the camera. When small areas are digitized to obtain finer detail, many frames need to be pieced together. In addition, the frame grabber can be used in real time to display background image information on a display device. Used in this way, an air photo can offer up-to-date coverage of an area which can then be overlayed with a point, line or polygon vector file. The positional accuracy of the background information depends on the amount of area coverage to be displayed and the scale of the photograph. The less coverage to be displayed in each frame, and the larger the scale of the photograph, the higher the accuracy of the image when displayed on the CRT screen.

Automated digitizing requires that clean and crisp lines be available to be read from a document. This often requires redrafting some of the uninterpretable documents. Redrafting takes time. If this is the case with several documents, then maybe the source material should be manually digitized. The cleaner, crisp documents can be automatically digitized. In automated digitizing, spatial object identification occurs after the data have been captured during the process of data capture manipulations. This postprocessing can be a major task if a large number of discrete spatial objects are to be tagged.

4.3.3 Data Capture Manipulations

When the input document for automated digitizing is not extremely clean, extensive edits will be required. This will continue to be the case until more intelligent software can be developed to assist with marginal decisions about what are valid data and what are not.

Edits and tagging from the digitizing process can be performed interactively or in batch mode. Interactive mode is when an operator is involved, giving commands every step of the way. Batch mode is where the operator invokes a command to run a program whereby the entire data file is processed using a programmed procedure, without further operator intervention. Editing might be necessary to filter the overshoots on line crossings, i.e. dangling line segments made intentionally or unintentionally during digitizing. Such a filtering function helps speed both the input and edit process. The software can cycle through a file and retrieve all lines that are below a certain threshold as considered for deletion. This process can occur at less expensive workstations with only a single graphics display monitor.

Pixel data are often too voluminous to be stored in pixel format. Pixels can be converted to line vector format for storage in the system. This raster to vector conversion is a post-

processing activity. The vector data have to be segmented into logical spatial objects and tagged with the appropriate labels for linkage to attribute data. This obviates much of the advantage of scanning.

In all of the digitizing methods, spatial registration with a geodetic (or other) spatial reference framework is essential to interrelate data among the different layers. Consequently, good map document registration techniques should be available with the software packages used for digitizing. The registration software should include a variable weighting transformation to correct for spatial registration based on the distance of a control point to an object location. Closer data points to objects should be weighted more than data points farther from the registration points. Figure 9 depicts this requirement.

Edge matching software should be available to correct for lines digitized on separate documents that should meet at the edge of the map. Either one line could be pulled to another base line, or the location of the two lines could be averaged to provide the average location.

4.3.4 Digital Map Data Available in External Files

Obtaining locational data for spatial objects in digital form can be more cost effective than automating map data from hardcopy maps, as long as the data meets the project requirements. Several agencies offer digital map data, and more digital data will be available in the future.

The U. S. Geological Survey offers digital line graph (DLG) data at several scales. These are described in the USGS DLG Data Users Guides for scales of 1:24,000, 1:100,000, 1:2,000,000. The USGS encourages cooperative programs to share the expenses of building the database.

The U. S. Bureau of the Census will distribute data files produced as part of its Topologically Integrated Geographic Encoded and Referenced (TIGER) information system coming on-line to support the 1990 census. These files will be distributed as TIGER extract files. The files are being built from USGS 1:100,000 scale topographic quadrangle maps; the 1980 Dual Independent Mapping and Encoding (DIME) file will be used in the major urban areas because of time constraints. Later the Census will update these areas with the 1:100,000 scale data.

Imagery data is also very useful for GIS processing. The digital image data from the French SPOT satellites and the U. S. LANDSAT satellites are available currently. There is some movement by the U. S. to declassify imagery data down to the five meter resolution to compete with the ten and twenty meter French data. However, the best resolution of data available from U. S. satellites is currently thirty meters.

A new spatial data transfer specification defined by the Digital Cartographic Data Standards Task Force (1988) might help with the exchange of data between different software and hardware environments in the future. The specification is intended to support many types of point, line and area spatial objects. Many of the GIS vendors now support DLG transfer and several are expected to support the new spatial data transfer specification.

Preprocessing for digital map data files involves determining the type of features that are to be transferred from one digital file to another and the types of labels that will be used to encode these features. Data that have been acquired from an external source may have a different feature coding (data labeling) scheme than the one in use by the receiving

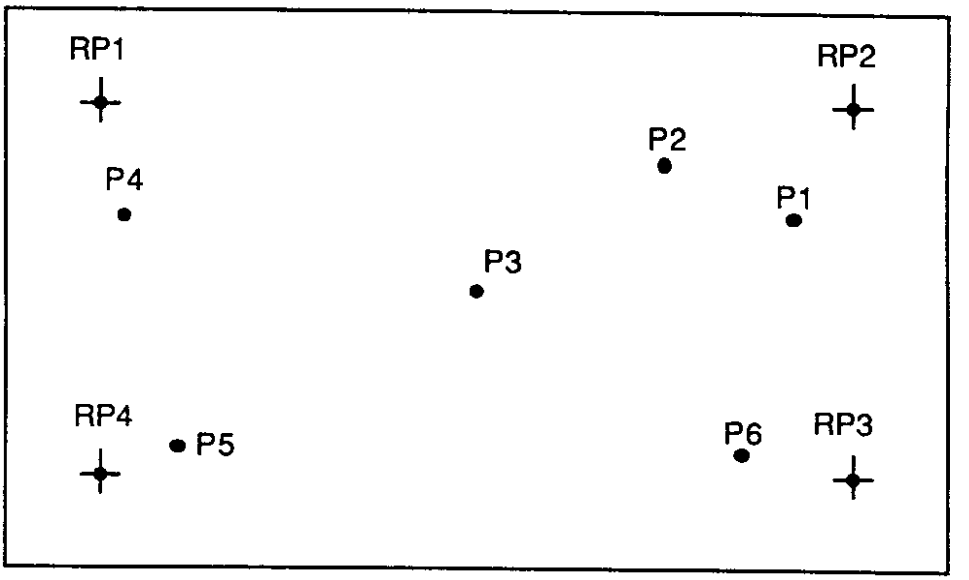


Figure 9. The coordinate location of a data point (P) is computed according to its proximity to all registration points (RP). The coordinate value for data point 3 (P3) receives an equal weighting from all RP's. P4 receives the most influence from RP1, then from RP4, then from RP2 and least influence from RP3. P6 receives the most influence from RP3 and so on...

organization. A feature code is usually a numeric label that is assigned to all features of the same type as a short-hand notation for data processing convenience.

For example, USGS DLG data are labelled using major and minor feature codes. In the 1:2,000,000 scale DLG data, the major feature codes are three digits, e.g. transportation systems is 100. The minor code are four digits, e.g. roads and trails are 5000-5069, and railroads are 5070-5080. When DLG data are transferred to an internal structure of a particular GIS as implemented by a transportation organization, a new coding scheme could be assigned which conforms to the database design labeling scheme of this organization. The receiving system might only use a single number, or desire a smaller range of numbers. For example, urban streets are 765, and rural routes are 775. In the simplest of cases, no relabeling might be needed, but this occurs only rarely.

In another situation, the feature codes might be changed and the spatial object encoding would suffice. In a still more complex situation, different spatial objects might need to be generated from the data received because the spatial object encoding does not conform to the needs of the receiving organization. In the latter case, the transferral of data might be examined with more caution due to the amount of effort involved in resegmenting the data.

4.4 Spatial Analysis

Spatial analysis is concerned with spatial patterns and processes (Unwin 1983). A spatial pattern is the locational relationship of geographically distributed entities represented by points, lines, areas, and surfaces (volumes). A spatial process is the dynamic behavior of those entities. The nature of change in terms of distance, direction and/or connectedness among the entities can be used to characterize the spatial process. (Nystuen 1968)

Spatial analysis is undertaken with the aid of statistical or mathematical techniques embedded in models that capture the essence of the pattern and the process. Spatial analysis can be supported by visual inspection of a map such that this inspection leads to a better understanding of the spatial process that might be causing the pattern, or certain patterns that may affect future processes. In some sense then, spatial analysis can be equated with map analysis. It is not entirely new, for maps have been used for analysis for quite some time. However, combining computer models with maps is relatively new, and should contribute to an extension of our current approach to performing map analysis.

A GIS contains spatial operators with which to perform spatial analysis and models, or hooks to models, for more extensive forms of spatial analysis. Models for spatial analysis are of two types: 1) social science based models for analysis of human behavior and 2) environmental science based models for analysis of physical processes.

4.4.1 Spatial Operators

A GIS must have efficient operators to calculate distance between points, length of line strings, area of polygons and perimeters of areas. These operators may be invoked many times in the conduct of an analysis.

A GIS must work with both raster and vector data. Consequently, operators to convert from one to the other are necessary. Raster data can be processed using a set of operators, sometimes called "map algebra" (Berry 1987, Tomlin 1983), which are necessary for spatial analysis of raster data.

In a GIS, the primary spatial operator is "overlay". Overlay is the operator to interrelate data in different layers. Overlay takes a variety of forms:

- points within a radius of another point,
- lines within the radius of a point,
- areas within the radius of a point,
- points on a line or in a buffer around a line,
- lines on a line of another type or in a buffer,
- areas in a line buffer,
- points in an area,
- lines in an area,
- areas in areas (the polygon overlay problem)

Efficiency in the conduct of overlay is a major issue. For many years polygon overlay was a major problem. One solution was to convert the polygons from vector format to raster format and compare corresponding raster cells for a raster or grid overlay. More recently, vector format polygonal data can be overlayed with reasonable performance due to the introduction of more efficient computer software algorithms and faster processing speeds.

4.4.2 Modeling

Although spatial operators are usually contained in an off-the-shelf GIS, specific applications may also require models for spatial analysis. These have to be incorporated into the GIS or linked to transfer data back and forth between the GIS and the modeling system. This is particularly an issue with respect to travel demand forecasting where extensive models exist.

Complex models may require a GIS to support their data requirements, whereas less complex models may be embedded in a GIS. If a model has potential application to a number of GIS projects it is a good candidate for embedding. If a model is of primary importance and requires a large software system on its own, limited GIS functionality can be embedded in the software system, along with the software for the model.

The combining of interactive computing and computer graphics with equilibrium travel demand modeling as in EMME/2 (Florian 1982) demonstrates the power of interfacing GIS functionality and models. The immediate visual display of model output and the ability of the analyst to interact with the output increases productivity greatly. Operating in a interactive graphics GIS/modeling environment is a significant advance for spatial analysis. The analyst is able to assimilate the results visually and make decisions based on the information.

4.4.2.1 Social Science Issues

The distribution of population and economic activity in a region constitutes the demand for services, including transportation. A GIS is capable of assisting in the monitoring of population and economic activity by small areas that are needed for models to forecast the 1) future distribution of population and economic activity, 2) amount of traffic that will be generated and 3) distribution of trips. Data for these models of locational behavior and spatial choice can be derived from a GIS.

4.4.2.2 Environmental Science Issues

Natural resource agencies are vitally interested in GIS for resource inventories and to model physical processes, such as air or water pollution plumes. Many organizations, including transportation agencies, utilize digital elevation models (DEM), constructed from a regular grid or from triangulated irregular networks (TIN) to analyze topographic data. The TIN is a more efficient form to represent topography for certain types of spatial analysis. Similarly, other applications of spatial data are best served by different data structures.

Land information systems generally use area data represented in vector form as polygons, which are generated from chains of area boundaries to take advantage of topological encoding. If there is a considerable amount of polygon overlay analysis to be performed, the data may be converted to a raster format to take advantage of more efficient processing. This is normally done for analysis only and the original data continue to be stored in vector form.

Lineal data for natural resource applications, such as stream data are often captured in vector form and stored as networks to accommodate the modeling of flows in networks. However, drainage basins and sub-basins are represented as polygons. These basins are connected to the flow network by topology to add runoff to streamflow.

Airshed models generally rely on raster data processed by a GIS. Principally, the GIS is used to display the results of the three-dimensional spatial modeling. Either the GIS functionality is embedded in the air model or hardware/software hooks must be provided to interface the model and the GIS.

Image processing utilizes raster data and is concerned with pattern and feature identification using density slicing of multispectral data. Image data may be a component in spatial analysis, principally in the identification of features that are then entered into a GIS as spatial objects.

4.5 Output

Although GIS output could be as varied as the types of analyses that are performed, the output usually includes various types of reports, graphs and maps. This output can be produced in softcopy form on an interactive graphics display device as well as hardcopy produced on a printer or plotter device. These devices are usually color graphics, raster-oriented devices.

4.5.1 Reports

Report generators are very useful in a GIS environment and usually come as available options in an off-the-shelf GIS. The particular styles of reports supported depend on the database management software. A special feature of a GIS report generator is that it produces reports on the basis of geographic area as well as the standard non-spatial criteria of other business-oriented report generators.

Reports can be produced in both on-line interactive and batch modes. An interactive mode is where a computer operator is continually making an input at the request of the computer program. A batch mode is where the operator invokes a program and lets it run to completion over an extended period of time without entering any input. Consequently, the choice of mode is based on the amount of processing time involved for a particular function. Mainframes tend to be batch oriented computers, and mini and micro computers tend to be

interactive. However, there is no hard and fast rules about use. An example report appears in Figure 10.

4.5.2 Graphs and Charts

Business graphics or chart packages are useful options available with some GIS. These are usually not highly integrated into the functional offering of a system because of the variation in packages from a single vendor.

4.5.3 Maps

The present emphasis in GIS maps and displays is on depicting spatial patterns and modeling spatial processes with both vector and raster data. Being able to display vector and raster data on a single graphics display facilitates visual synthesis of the spatial patterns and enhances a feedback process for modeling. Displays can be produced for interactive feedback on a CRT monitor, as well as for plotter output. A raster-oriented color graphic output device can support both the vector and raster data. The more pixels per unit measurement across the screen, the higher the resolution of the device, hence the sharper the image produced.

Displays of geographic patterns can be generated from two types of database requests. The first is to select the location or geographic area of interest and have the system display all the entities/features of a certain type, perhaps with a selected attribute. For example, display all of the highways within a maintenance district that are of a certain pavement condition. A second approach is to select a certain entity type with associated attributes and display all the elements regardless of the geographic area in which they are located. For example, display all highways in all maintenance districts and show the pavement condition.

Two-dimensional and three-dimensional mapping techniques can be used to portray the results of database requests for patterns or the results of spatial analysis. Use of a particular technique is based usually on the category of spatial object, the level of the measurement of the attributes for the object(s), and the purpose of the display.

For each of the categories of spatial objects, access to various thematic map types can be beneficial to suppport the pattern and process investigation. The types of maps are classified as point, line, area, and surface maps, in line with the categories of spatial object types. For each of these categories of data, several different types of map symbolism can be used to generate an effective thematic map. For example, for point-oriented traffic accident data, a dot mapping technique or a graduated symbol mapping technique could be used. A dot map could depict accidents with each dot representing one accident; or a dot could represent multiple accidents depending on the density of accidents in a geographic area. Alternatively, a graduate circle symbol could be used to depict accidents, with the size of the circle in visual proportion to the number of accidents in various locations (See Figure 11). In this case, the data are differentitated by fatal and minor accidents. Several other techniques could be used in a similar way for lines, areas, and surfaces depending on the level of data measurement.

Having access to a variety of thematic mapping techiques maximizes the opportunity to get the most out of the data and the graphic display.

ACCIDENTS AT INTERSECTIONS - DISTRICT 5

Route-	milepoint	Cross street	Number of accidents	Type of accident	Reporting time frame
US3234	128.01	Greenly	5	fatal	4/1, 5/1
US3234	128.01	Hobart	7	minor	4/1, 6/31
County24	34.80	Greenly	2	fatal	4/1, 8/1
County24	34.80	Hobart	10	minor	4/1, 7/31
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.

Figure 10. A traffic accident report.

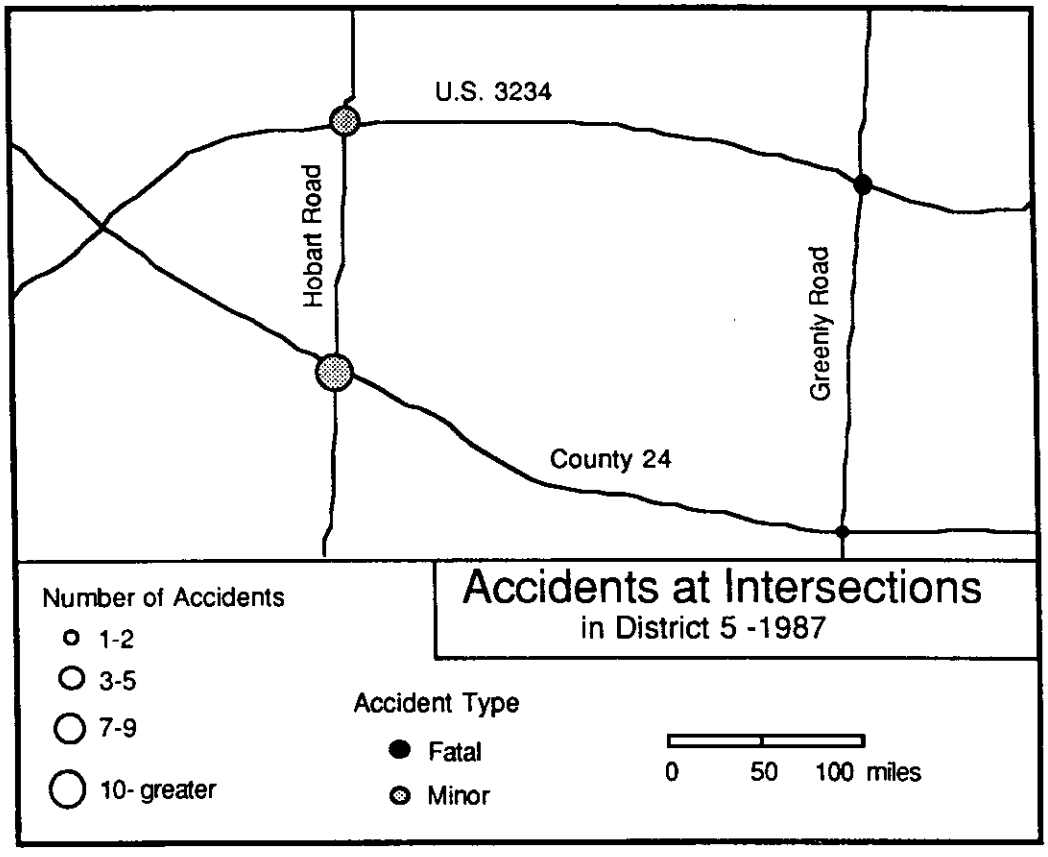


Figure 11. Traffic accidents at major intersections.

4.6 Computing Environments

The manner in which hardware and software are configured with regard to the size, number and connection of computers is called a computing environment. Three computing environments are in use today: centralized, decentralized and distributed.

A **centralized** computing environment consists of a single, large mainframe computer, operated and maintained by a data processing department. User departments are connected to the mainframe by a series of terminals that provide for remote access, but not remote processing.

A **decentralized** computing environment involves several computers, perhaps a combination of mainframes, mincomputers and microcomputers. These computers are not interconnected on-line; data can be passed from one computer to another, but typically involves ad hoc connection (dial-up) or magnetic media transfer. Each user department has responsibility for its own system.

A **distributed** processing environment consists of peer nodes operating on a network with perhaps a central computing facility acting as a main source of computing power as well as a data library for remote minicomputers and/or microcomputers. The computers are interconnected on-line so that data can be accessed from wherever a user has privileges, such as from a mainframe, minicomputer or microcomputer. The access differences among types of computers should be transparent to the user, but sometimes this is not always the case.

Centralized environments are necessary because of the economies of scale realized by many repetitive applications, e.g. payroll and accounting. Batch mode computing for day-to-day operational activities is subject to fixed time schedules. Because of these fixed time schedules, the computing resources are usually kept in use. Housing a GIS in a centralized environment is difficult because of the competition for computing resources, especially when GIS interactive graphics is used. For these reasons, a GIS is more likely to perform well on a minicomputer or powerful microcomputer in a decentralized or distributed environment.

Decentralized environments come into being because of the autonomy among different parts of an organization who independently maintain databases and direct the use of resources on different computers. This is often due to differences in projects and/or applications, e.g in planning and engineering applications. Unfortunately, a decentralized environment encourages protectionism and duplication of resources (including separate database development and maintenance) because it is more difficult to transfer data. Data transfer can be performed technically, but administrative difficulties often do more to inhibit data transfer than do technical ones.

A distributed environment supports the advantages of both centralized and decentralized environments. Users can maintain separate databases, but when data is needed by different processors it can be made available more readily than if the computers are not connected. Microcomputers and minicomputers connected to a mainframe can access large data libraries, while taking advantage of protected computing resources for interactive grarphics. Much of the processing can be handled locally on the micro or mini, but when large models are run, the mainframe provides an important data processing resource.

5. ORGANIZATIONAL ISSUES

5.1 GIS and an Organization's Mission

The applications of GIS concepts and technology in DOTs and MPOs must be made to fit their individual missions and organizational structures. GIS concepts and technology can help integrate the separate views of an organization into a wholistic view by linking the separate data to a common framework. Briggs and Chatfield (1987) identify benefits of integrated highway information systems and discuss the impacts on organizational structure. If GIS technology necessitates or results in organizational change, the impacts need to be anticipated, and through strategic planning, ameliorated. Data integration might be inhibited by organizational structures that dictate separate files of attribute data rather than one integrated file. In these situations, the physical separation needs to be overcome by a logical means of linking data as needed.

5.2 Organization of Computing

A GIS approach should be compatible with current computing environments in DOTs and MPOs. Many DOTs and MPOs have existing commitments to mainframe computing, and mapping is performed on microcomputers or minicomputers with little interaction. More so than mapping, a GIS approach can help to integrate data across an organization.

A GIS approach can incorporate a mainframe with a bridge or gateway to a mapping system to support various tasks of the overall mission and existing mapping effort.

Alternatively, a distributed processing approach combines a number of computer workstations into an integrated computer network that mirrors the organizational structure. Each workstation would have separate files according to mission responsibility. This might mean a workstation for traffic data, one for highway inventory and a third for design construction. In this case there is a need for a fast, transparent data interface among the workstations. Most data transmission lines still operate at 9600 bits per second. This is going to change as fiber optics cabling are introduced.

For most large organizations, attributes are kept in mainframe databases, managed in a separate DBMS. This is not likely to change. Getting access to the attributes is a systems integration problem which requires a thorough evaluation of a particular data environment. The major consideration involves how the data stored in one environment can be linked to data in another environment despite the fact that the data are probably not stored in compatible structures and/or formats.

5.3 Computer Use

Several intra-organizational factors can impede effective computer use in any environment. These include : differing goals, different modes of operation, unrealistic expectations from the host and user groups, lack of communication, and organizational restrictions. Familiar, repetitive tasks such as the weekly payroll are considerably easier to run than a one-time, special purpose task requiring unknown resources. The former are characteristic of a fairly well-understood use of computing resources. The latter, characteristic of GIS projects, are as yet more difficult to schedule because the use of resources is not fully parameterized. Consequently, the two types of applications might not be compatible, and perhaps run in different computing environments.

6. FUTURE TRENDS OF GIS IN TRANSPORTATION

A well-designed GIS can enhance the communication among user groups within a DOT or MPO. To do this transportation organizations will need to emphasize compatible spatial referencing systems and GIS concepts and technology as part of a trend toward better information integration.

6.1 Database

A georeference approach makes it easier to integrate spatial data. Research in database management systems is leading toward continued data integration across different databases having different database structures. This stems from the inherent spatial character of data. Currently, data are represented and stored in terms of an organization task-oriented view, i.e. what an organization is doing with the data. A subject-oriented view of the world could enhance the consistency of data by identifying and reducing (if not eliminating) data redundancy.

Development of standard data dictionaries describing the characteristic of transportation oriented data will assist in data integration across divisions. Clarification of different views by explicitly defining the nature of the entities in these views for each division can assist in cross-referencing data, which today is not relatable. This can proceed by cross-referencing highway descriptors using the physical linkage characteristic of a highway network as a model to interrelate data across different databases (Fox 1988) as in Figure 12, in addition to a dynamic segmentation scheme (described in section 4.2.3) as a basis for producing graphic displays.

Better data dictionaries with georeferencing could enhance data sharing between systems within a department that rely on different scales. Although those departments may continue to work with different scales, the data dictionaries of roadway design can assist the planners in detailing the estimates for roadway improvement generated using geographic area analysis techniques in the GIS. For example, planning with large-area, small-scale spatial object data having little detail can be enhanced on an area by area basis with roadway design small-area, large-scale spatial object data having more detail. In this way, the transportation infrastructure information can be interfaced to highway planning information to assist in making better planning projections for highway improvement.

6.2 Software

Software will continue to become more functional and easier to use in the future. Currently, few GIS vendors provide a workable solution to the dynamic segmentation problem. However, some are begining to examine the requirements for a solution, and will incorporate it as software technology advances. Another area of improvement will be the evolution of spatial database management systems to handle the storage and retrieval of logical linkages across spatial partitions in a spatial indexed database. This will reduce the need to merge maps into a single map in order to perform route analysis. Spatial indexing research is continuing to develop such that better performance for spatial retrievals can be expected.

Trends will continue to focus on systems integration - getting one spatial system linked with another. For example, the spatial database management aspects of a engineering survey data collection system could be linked to the roadway design system, as well as the mapping system, so that all are linked to the same georeference system. This is starting to happen

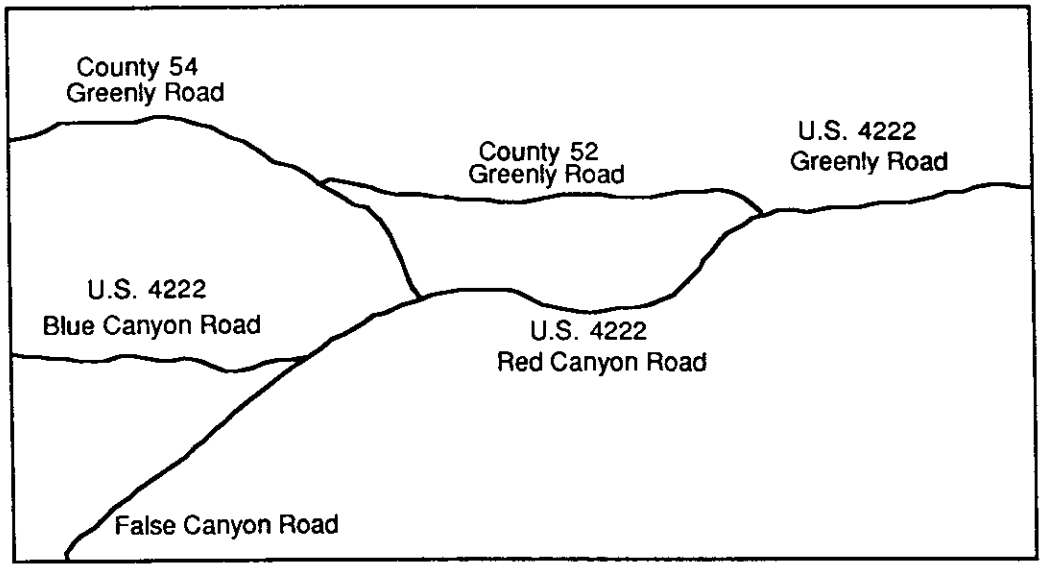


Figure 12. Different road naming systems.

now using the Global Positioning System (GPS) of satellites to collect more accurate survey coordinate data in less time.

The systems integration problem is one of the most difficult problems due to the idiosyncracies of many data processing environments. Standards for computer networking have been developed for open systems interconnection and products to support hardware connections are available. However, products to fully support a software connection at the applications level are not available commercially. Getting data from one system to another in exactly the right form does take some time, effort and expertise. Consequently, some degree of customization is still required to interface large systems that do not have the same database structures.

6.3 Hardware

Computers are less expensive and more powerful than ever before. Within two years we can expect to see super microcomputers that are far superior than the micros of today in terms of price/performance ratios because of new general purpose microchips and graphics processors.

Distributed processing is expected to continue gaining favor due to the flexibility and power offered. The next generation of GIS may well be supported on intelligent local workstations (super microcomputers) connected to a large mainframe processor, with perhaps special processors such as image (array) or database processors for undertaking those special tasks. This will eliminate the need for what has been known as the minicomputer with "dumb" graphics terminals.

7. CASE STUDIES

7.1 Introduction

The GIS case studies consist of a comparison of how systems in selected states might handle a class of problems. Examples include dealing with spatial analysis issues: routing hazardous wastes; locating highway maintenance facilities; and selecting spatially stratified sites for traffic, vehicle classification, or truck weight data collection. These problems have common data and GIS requirements. Each requires the integration of the following types of data:

- a link-node network;
- link and node attributes, such as HPMS segments and highway logs referenced by route and milepoint;
- cartographic strings to aid in analysis and presentation of results.

GRIDS (Geographically Referenced Information Display System) developed by the Caliper Corporation of Newton, Massachusetts, is an example of a system that integrates these data in an interactive graphics environment. FHWA provided financial support for the development effort and the program is licensed for use by all state DOTs. GRIDS has been optimized to analyze the HPMS data of each state.

Various strategies can be used to create a GIS capability to build and maintain data to address the types of spatial analysis problems identified here. One strategy is to build from scratch an integrated file with a network, link and node attribultes, and link cartography.

Another approach makes use of existing data, but which is not in compatible form and requires specialized programming to bring it together for effective use.

The purpose of the case studies is to assess how easy or difficult it would be to integrate the required data in selected state DOTs. One could think of the problem as adding data about the primary and secondary systems to GRIDS. Assembling and integrating the data involves the following steps:

- identify intersections and ends of highways as nodes and represent the connecting highways as links in a topological network;
- determine for each node the route and milepoint references of intersecting highways;
- collect HPMS universe sections for each link in the network using the route and milepoint references at nodes;
- assign attributes to HPMS universe sections by interpolating between HPMS sample sections;
- collect or cut cartographic strings for each link using the route and milepoint references at nodes and route and milepoint references at points in strings;
- assign highway log attributes to cartographic strings by interpolation from route and milepoint points in strings.

Each state would have to develop software to build these data sets, not once and forever, but as needed, because the detail of the network may vary and the attributes for a particular problem may also vary. Routing of heavy equipment would utilize different attributes than routing of hazardous wastes, which would generate different networks.

The States of Alaska, Oregon, Washington, and Wisconsin have been selected as cases to determine the ease or difficulty that might be encountered in integrating data for a GIS in addressing the class of problems identified above. These states were selected to illustrate how the problem could be addressed using their different approaches to handling highway inventory and cartographic data.

7.2 Alaska DOT&PF

The State of Alaska Department of Transportation and Public Facilities is implementing a Highway Analysis System (HAS) involving a Department-wide integration of highway-oriented databases (Fox 1988) into a single database residing on a mainframe computer. The resident data includes highway inventory, pavement condition, traffic volume, traffic accidents, and project history.

The Alaska Dot&PF has the first two of the elments in place for the kind of data needed for integration as described in Section 7.1, and intends to implement the last two elements. The second two elements are not currently under consideration because of the sampling currently being done for interstate (100%) and urban federal-aid (90%), but data exists within HAS to implement them.

The HAS contains a topological segment/node representation of the physical road network. A node can be representative of a beginning/ending of a road or intersection. A segment is a

portion of physical highway, coded from node to node in the direction of the inventoried highway.

At the present time, the segments are logical links without earth-oriented coordinate information. Thus, topology on the network is represented, but the coordinate information has been constructed to satisfy interim requirements. Earth-oriented coordinate information is to be added later as part of a highway system georeference project to commence during 1988.

Attribute data associated with segments are stored in the HAS topological model by referencing locations according to a relative distance offset from the beginning node of each segment. HPMS data are contained within the HAS for HPMS sample and universe sections.

A microcomputer based mapping system that stores topological highway line objects (chains) is being linked to the HAS. Maps are being digitized and digital data is being acquired from U.S.G.S. to provide coordinates for highway geometry until the georeference project is complete. Every line in the mapping system is referenced to a corresponding stretch of highway in the HAS database. This linkage is maintained as part of an ongoing effort to suppport thematic mapping of highway attributes at multiple map scales from mainframe based attributes.

The topologic structure of the HAS will enable minimum path and routing analysis.

7.3 Oregon DOT

The Oregon DOT has two of the elements in place for the kind of data set needed. The highway log data are referenced by route and milepoint as are the cartographic strings. Nodes could be created by searching the highway log and selecting intersections of specified types of roads, such as interstate, primary, and secondary. The low numbered route and milepoint could serve as a unique node number and a connectivity matrix created.

In Oregon, the beginning and ending milepoints of HPMS sections may not correspond with the intersections. Consequently, the closest HPMS beginning and ending points would have to be "snapped to" nodes. This would introduce a small error.

Cartographic strings are segmented between tiepoints (coordinate locations) referenced by milepoint for various features including intersections, county boundaries, bridges, etc. Display of continuous information such road condition or road surface type involves cutting or assembling segments between user specified milepoints and changing the color, line weight, or line type as desired by the user.

Oregon would have to construct a link/node network from the highway log data and interrelate it with the HPMS data.

7.4 Washington DOT

The Cartographic Section of the Department of Transportation is developing a means of linking attribute data residing in mainframe databases with mapping capabilities on a minicomputer. This will make it possible to produce maps "on demand" from a wide variety of sources.

A database is being generated from digital base maps maintained by the Cartographic Section that assigns a geographic coordinate to each 0.01 mile segment of roadway, which is referenced by state route and milepoint. This apriori segmentation of the highway system into 0.01 mile sections allows for considerable detail, but at a cost of redundancy and data volume.

To handle the identified problem, it will be necessary to collect the 0.01 mile segments to links of the network, or assign a link code to the segments. This will be needed to perform routing. Similarly, it will be necessary to collect HPMS sections for links and add a HPMS code to the 0.01 mile segments.

7.5 Wisconsin DOT

The Wisconsin DOT has systematically examined GIS feasibility. Fletcher (1987a) describes the integration of photolog data into a GIS. Fletcher (1987b) describes the integration of other highway attribute data into a GIS using a line overlay approach.

The approach to integrating photolog data into a GIS consisted of registering three disparate frameworks, the log-mile reference scheme employed by the photlog, the map reference (state plane coordinates), and the host based inventory and operational data location scheme (reference points). Log-mile and reference point flags were inserted in the cartographic strings to calibrate the map to the photolog images and the inventory and operational data. However, initially as described (Fletcher 1987a) the cartographic strings were not placed in a link-node network, which would provide integrity for purposes of routing and locational analysis. However, they are now creating a geographic base for the State including complete topological relationships of the highway network (Fletcher 1988).

Wisconsin is pursuing a strategy of using the GIS to integrate highway inventory data from a number of separate databases. They do not want to impose the requirement of integrating the highway inventory data. Separate files will continue to be maintained by different units of the organization. It is the job of the GIS to integrate the data as needed. Their approach is to use the topologically structured cartographic chains with reference point and log-mile flags as the means to determine portions of chains having attributes of interest from the separate inventory files. For multiple attribute searches the portions of chains will be compared by "line overlay" to determine sections of highways meeting the joint criteria. This approach relies on a link-node network, and will handle routing problems.

7.6 Conclusions from Case Studies

This analysis was not detailed enough to draw many conclusions. Nevertheless, our analysis shows divergent approaches to the integration of data.

It is surprising that there is not greater agreement as to the means of integrating cartographic and attribute data. Perhaps, this is due to the lack of a solution to the "assignment of attribute data to line data" problem by the major vendors of mapping systems for state DOTs. Every state has had to solve the problem independently. Better coordination is needed.

As experience with using analytical systems, such as GRIDS, increases, so will the demand for combining analytical applications with graphics. DOTs and MPOs will come to the realization that a topologically-oriented network GIS is essential.

8. CONCLUSION

The challenge of the future is to examine more problems, or the same problems in more detail, in less time at lower cost. One way to do this is the through a GIS approach to data processing. This approach will foster the integration of information across a transportation organization.

Collective developments in several sciences are responsible for bringing about a GIS approach, most notably those in the mapping sciences that focus on spatial processes and patterns. A GIS approach has been developed to integrate large amounts of spatial data in a map based form, using computer based models to analyze this data.

GIS concepts and technology are beginning to be used for many applications. Using them for transportation systems analysis, whether this be inventory or modeling, is fully possible now. A few transportation organizations have embarked on this path. It is up to each organization to learn more about these concepts and tools to realize the promise that GIS offers.

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GIS GLOSSARY

BASE MAP -- any set of information that provides spatial orientation (background information) for another set of information of primary focus. The same set of information can at one time be considered base map information and at another time be considered the primary information, depending on context.

COMPUTER-AIDED MAPPING SYSTEM -- an information system that focuses on map design and map information management (hence sometimes referred to as MAP INFORMATION MANAGEMENT SYSTEM (MIMS). This is the principal type of system used for automated mapping and infrastructure facilities management (AM/FM) tasks. This focus satisfies the basic requirement for locational inventory as well as the production of maps. Such a system is very useful in fulfilling a need for information in an operational setting where detailed map documents are required as tools to support daily decision making. In addition, such systems can support the production of high-quality images needed for map publishing.

COMPUTING ENVIRONMENT -- the manner in which hardware and software are configured with regard to the size, number and connection of computers. Three computing environments are in use today: centralized, decentralized and distributed.

COMPUTING ENVIRONMENT, CENTRALIZED -- consists of a single, large computer, operated and maintained by a data processing department. User departments are connected to the mainframe by a series of terminals that provide for remote access, but not remote processing.

COMPUTING ENVIRONMENT, DECENTRALIZED -- involves several computers, perhaps a mixture of mainframe, mincomputer and microcomputer. These computers are not interconnected on-line; data can be passed from one computer to another, but typically involves ad hoc connection (dial-up) or magnetic media transfer. Each user department has responsibility for its own system.

COMPUTING ENVIRONMENT, DISTRIBUTED -- consists of a central computing facility acting as a main source of computing power as well as a data library for remote minicomputers and/or microcomputers. The computers are interconnected on-line so that data can be downloaded from a mainframe to a minicomputer or microcomputer, or uploaded from the mini or micro to the mainframe.

DATA CAPTURE -- the process of digitally encoding data into a form usable by applications programs. The encoding includes identifying spatial objects to be captured and labeling them such that they can be stored and retrieved by the DBMS for the applications programs. The encoding occurs at different times during the data capture process, depending on the method of data capture.

DATA ENVIRONMENTS -- Three types have been identified: 1) applications databases that are shallow in detail, but spatially extensive, such as maps of the organization's jurisdiction or service area; 2) project databases that are deep in detail, but spatially constrained, such as project area analyses or construction plans; and 3) subject databases that are both deep in detail and spatially extensive, but not tied to any one specific application or project.

DATA LAYER -- a mass storage file consisting of entities of a topical nature stored in terms of points, lines or areas.

DATABASE DESIGN -- a process usually performed in three stages: conceptual, logical and physical. A conceptual design is software and hardware system independent, i.e. a description of what should exist in the database in terms of entities such as highways, rivers, maintenance stations. A logical design is software system specific, but hardware independent, i.e. the database design conforms to a specific software package, but not to any particular computer. A physical design is both software and hardware system dependent, i.e. it conforms to a specific software package as well as a particular computer.

DIGITAL LINE GRAPH (DLG) DATA -- digital map data available from the U. S. Geological Survey at several scales (1:24,000, 1:100,000, and 1:2,000,000). These are described in the USGS DLG Data Users Guides.

DIGITIZING, AUTOMATED -- encompasses three technologies: 1) line following, 2) scanning and 3) video digitizing (q.v.).

DIGITIZING, MANUAL -- a process wherein a workstation operator makes a conscious decision to depress a button on a hand-held cursor to capture data from a map, aerial photographs or stereo model. The process involving a map or photograph is performed with a device called an electronic digitizing table. The process using the stereo model is accomplished with a device called a digital stereoplotter.

GEOCODE -- a data value assigned to a spatial object that provides information on the geographic location of the spatial object. A coordinate, a street address, a route-milepoint, a control segment, and a census tract number are all considered geocodes. Place names, e.g city and county names, are nominal level geocodes that require users to know relationships among named places, whereas coordinates are ratio level geocodes that enable spatial relationships among geocoded places to be calculated.

GEOGRAPHIC INFORMATION SYSTEM -- an integrated database containing information about georeferenced spatial objects -- points, lines and areas -- plus the software and hardware used by personnel to manipulate these objects. The essential components of a GIS are its personnel, georeferenced database, graphics-based software and hardware. Without any one of these components a system cannot function. A GIS is often thought of as concepts and technology, or a tool box of software and hardware to manipulate geographic data objects. However, without the personnel to build, maintain and use the database in a particular organization, the GIS concepts and technology are incomplete. The application of GIS concepts and technology to particular issues or problems results in land information systems, stream information systems, or transportation information systems.

GIS FUNCTIONALITY -- consists of: 1) the ability to create, edit, and delete geographically structured data; 2) the ability to link locational and attribute data; and 3) the ability to perform analytical map overlay of separate data themes.

GIS PROCESSES -- consist of: 1) the data acquisition process, which can be subdivided into document and/or data research and collection, document and/or data preparation, digitizing and/or data integration, and data editing; 2) the data management process, which includes storage and retrieval of appropriate data for certain projects; 3) the data analysis process, which includes the use of special application programs to derive information needed in the operational or strategic decision making process of the organization; and 4) the data display process, which includes the generation of reports, graphs, charts and maps for evaluation by decision makers.

LINE FOLLOWING -- an automated digitizing technique used to capture long lines on map documents, e.g. stream networks, highways and contours. An operator of a line following system positions a laser light source on a line to be captured. The laser follows along a line until one of the following occurs: 1) the laser cannot detect which direction to take, 2) the laser encounters an edge of a map or 3) a line closes back onto itself. Several things may cause the laser to lose direction. Among them are line weight fluctutation, breaks in labeling, density of line work. For these reasons, map separates are the best source documents for this technique.

LINKAGE OF LOCATIONAL AND ATTRIBUTE DATA -- Although locational and attribute data are both used in describing spatial objects, they are stored separately in most systems. Separate storage is for two reasons: 1) coordinates need to be accessed rapidly for display; and 2) displays of attributes of spatial objects need to be modified rapidly. A linkage identifier (usually the spatial object ID) is needed to maintain a one-to-one correspondence of the locational data to the attribute data.

MAP INFORMATION MANAGEMENT SYSTEM (MIMS) -- See COMPUTER-AIDED MAPPING SYSTEM.

OVERLAY -- a spatial operator (see definition herein) to interrelate data in different layers. Overlay takes a variety of forms: points within a radius of another point; lines within the radius of a point; areas within the radius of a point; points on a line or in a buffer around a line; lines on a line of another type or in a buffer; areas in a line buffer; points in an area; lines in an area; areas in areas (the polygon overlay problem).

SPATIAL ANALYSIS -- one of the four GIS PROCESSES (see definition herein), spatial analysis is concerned with spatial patterns and processes . A spatial pattern is the locational relationship of geographically distributed entities represented by points, lines, areas, and surfaces (volumes). A spatial process is the dynamic behavior of those entities. The nature of change in terms of distance, direction and and/or connectedness among the entities can be used to characterize the spatial process. Spatial analysis is undertaken with the aid of statistical or mathematical techniques embedded in models that capture the essence of the pattern and the process. Spatial analysis can be supported by visual inspection of a map such that this inspection leads to a better understanding of the spatial process that might be causing the pattern, or certain patterns that may affect future processes. In some sense then, spatial analysis can be equated with map analysis.

SPATIAL INDEXES or SPATIAL INDICES -- Identifiers for partitioning of mass storage of data organized by location.

SPATIAL OBJECT -- a digital representation for an entity that can be described by a set of locational information and attribute information. Spatial objects are stored in a system using a data structure suitable to the types of object. Locational information for spatial objects includes: 1) metrical; 2) topological; and 3) graphical information. Metrical data describes the coordinate space. Topological data describe the connectedness of the spatial objects in terms of nodes representing intersections and physical ends of linear entities, lines representing the connections between nodes and areas bounded by lines that are connected and closed. Graphical data are those that enable the visual portrayal of the objects on a display device. Attributes are those descriptive characteristics other than location pertaining to an entity stored as a spatial object in a database. Attributes can be measured on four levels: nominal, ordinal, interval, or ratio.

SPATIAL OPERATORS -- instances of algorithms to calculate distance between points, length of line strings, area of polygons and perimeters of areas. These operators may be invoked many times in the conduct of an analysis.

SPATIAL REFERENCE FRAMEWORK -- global coordinate system for the entities of a spatial information system.

SPATIAL REGISTRATION -- The capability of a spatial information systm to allow spatial interrelation of data among different layers; an essential element for a GIS or computer-aided mapping system with more than one data layer or theme Consequently, good map document registration techniques should be available with the software packages used for digitizing. The registration software should include a variable weighting transformation to correct for spatial registration based on the distance of a control point to an object location.

SPATIAL SEARCH -- There are two general types of spatial search. 1) Knowing the type of an object or attributes of a type; where is the object or type? Spatial comparison, or overlay, of different types of spatial objects, or layers; looking for specific relationships, e.g., points in polygons, high accident locations in relation to intersection lighting or vertical grade. 2) Knowing location; what object is there and what are its attributes? What is at a selected geographic location, e.g., display selected spatial objects or occurrences at a particular intersection.

TOPOLOGICALLY INTEGRATED GEOGRAPHIC ENCODED AND REFERENCED (TIGER) INFORMATION SYSTEM -- A map information system under development by the U. S. Bureau of the Census, which will distribute data files produced as part of the systems coming on-line to support the 1990 census. The files will be distributed as TIGER extract files, and are being built from USGS 1:100,000 scale topographic quadrangle maps; the 1980 Dual Independent Mapping and Encoding (DIME) file will be used in the major urban areas because of time constraints. Later the Census will update these areas with the 1:100,000 scale data.