A COORDINATED HIGHWAY DATA SYSTEM FOR MICHIGAN

(Development of Computer-Based Storage and Retrieval System
for State Highway Road & Bridge Construction Data)

MICHIGAN
HIGHWAY RESEARCH LABORATORY SECTION

MICHIGAN DEPARTMENT OF STATE HIGHWAYS

A COORDINATED HIGHWAY DATA SYSTEM FOR MICHIGAN

(Development of Computer-Based Storage and Retrieval System
for State Highway Road & Bridge Construction Data)

C. D. Church

Final Report on a Highway Planning and Research Investigation
Conducted in Cooperation with the U.S. Department of Transportation
Bureau of Public Roads

Research Laboratory Section
Testing and Research Division
Research Project 65 G-139(2)
Research Report R-728

State of Michigan
Michigan State Highway Commission
Charles H. Hewitt, Chairman; Wallace D. Nunn, Vice-Chairman
Louis A. Fisher; Claude J. Tobin; Henrik E. Stafseth, Director
Lansing, September 1970

INFORMATION RETRIEVAL DATA

REFERENCE: Church, C. D. A Coordinated Highway Data System for Michigan: Development of Computer-Based Storage and Retrieval System for State Highway Road and Bridge Construction Data. Michigan Department of State Highways Research Report No. R-728. Research Project 65 G-139(2).

ABSTRACT: A coordinated highway data system for Michigan is proposed using computer storage and retrieval. Data to be included are delineated by construction projects. Comprehensive or selective retrieval by project, route, county, type of pavement, or data items either singularly or in various combinations, is recommended. Data to be included under construction and design categories are listed for illustrative purposes. Location referencing alternatives are discussed and general input - output requirements are outlined. Recommendations are included for implementation of the system in order to efficiently handle the growing mass of highway-generated information needed for technical and administrative planning and research.

KEY WORDS: data acquisition, date processing, data retrieval, data storage, data systems, construction data, design data.

SUMMARY

This study was undertaken to arrive at recommendations for a system that would utilize up-to-date computer storage and retrieval capabilities to facilitate optimal Department-wide use of highway-generated information. Initial focus, for demonstration purposes, is on road and bridge construction and design data. A modular approach is suggested in order to allow the subsequent addition of other data sectors (traffic, maintenance, etc.)

A system is proposed that would allow comprehensive or selective data retrieval by project, route, county, type of pavement, or particular class of data. All data are to be keyed to--or delineated by--construction projects and the whole to be designated as "project record." Each project record is indexed by accesion criteria necessary to the retrieval of data on the above mentioned bases. Following this, a project abstract of general non-quantifiable or unique information is included. Finally, a sequentially ordered file of all point data and data applying to various lengths of roadway within a construction project complete the project record. Data within a project will be located by a distance from the beginning of the project in miles or by stationing. Various other location referencing schemes are also discussed.

The study's advisory committee developed a list of road and bridge data categories to be included in the system and this is included in the report. Example data for these categories are used to show a possible comprehensive output, in computer format, for a particular road and bridge.

The main feature required of the system is flexibility. This is to be achieved in three ways: 1) by making use of existing coding and referencing procedures thereby allowing inclusion of a broad range of existing data, 2) by providing for the addition of new data categories not initially called for by the system format, and 3) by allowing the option of comprehensive retrieval for a project, route, etc., or selective retrieval of specific data categories for a set of projects, a route, etc.

Data acquisition is discussed and several logical and convenient points in time for capturing input data are suggested. Keying all information to construction projects provides advantageous use of these opportunities.

Personnel requirements and duties are briefly alluded to; however, any forecast must be considered tentative at this time.

Input - output formats satisfying computer requirements are discussed in a general manner. Specific recommendations pertaining to exact data field sizes, record lengths, etc., are to be determined at the programming stage of development by experts in this area. To achieve the input - output objectives as set forth in the report, programmers may use whatever means that will maximize computer efficiency.

This report suggests that an effective data storage and retrieval system requires a genuine need and high-level administrative commitment.

Although many policies and details remain unspecified, the report recommends that such a system be adopted by the Michigan Department of State Highways in order to efficiently manage the rapidly increasing mass of data needed for technical and administrative planning and research.

A COORDINATED HIGHWAY DATA SYSTEM FOR MICHIGAN

INTRODUCTION

In order to discharge its responsibilities, a Highway Department requires various kinds of information. Further, the information must be presented in a form suitable for technical and administrative appraisal. Frequently, however, data are neither readily available nor in a useful form.

Information--its availability, accuracy, completeness, timeliness, and format--plays an essential role in policy making, planning, decision making, operations, program evaluation, and research. Thus, the effectiveness of the Highway Department depends, to a great extent, on quality and ready availability of information. Information should be considered a resource to be managed, aiming at improved technical and administrative efficiency (1).

The Michigan Department of State Highways undertook a study whose objective was to arrive at recommendations for a system that would utilize up-to-date computer storage and retrieval capabilities to facilitate optimal use of necessary information.[1] The general objective is to eliminate the commonly experienced inability to digest the growing mass of information in time to use its relevant parts to proper advantage, and to effect efficient dissemination of pertinent information. Data should be stored in such a manner to allow comprehensive or selective retrieval of information for use in various analyses, investigations, histories, and publications.

A Highway Department's knowledge is largely based on experience. Yet to make the most of the experience it is necessary to know how the pavement or structure was designed, how it was constructed, what materials were used, whether they were borderline or clearly within the specifications, etc. Thus, to effectively utilize the vast experience which is being established by Department operations, it is essential to have a completely factual basis on which to relate performance. The primary benefit

---

(1) As this report was undergoing final Departmental review, the Management Services Division independently took steps to initiate a "Highway Data Bank." This report will provide information that will be useful in the development and implementation of that system.

from a coordinated highway data system will be to systematically establish certain critical data which are essential to properly interpret performance experience. Once these critical data are established, numerous analyses can be performed to improve operations by examining performance experience with respect to design, construction, or materials variables.

General benefits to the Department would include the following:

1. Greater access to more data, with increased availability to more users within the Department, and systematic control of the supply of data outside the Department.

2. Time and labor savings in comprehensively or selectively obtaining current and historical data on Michigan's highway system.

3. Rapid preparation of up-to-date reference summaries for ready use by Department agencies.

4. A broadened basis for planning, based on more timely and accurate engineering evaluations of project performance.

5. Improvement of records-keeping by centralization, and detection of possible duplicate or erroneous records.

6. Preparation for possible future demands on the Department to participate in external information systems.

PROJECT DEVELOPMENT HISTORY

As initially proposed by the MDSH and approved by the Bureau of Public Roads, the original Highway Planning and Research project had a much broader scope. The main objective was to develop an information retrieval system that would include Departmental testing and research investigations. Although somewhat less sophisticated, the technical information system was to use the Highway Research Information Service (HRIS) established by the Highway Research Board in Washington as a model, without duplicating its material. Technical information originating outside the Department was also proposed to be included as well as significant records of State Highway construction projects.

Following a period of uncertainty which lasted approximately two years (at one time the project was dropped completely by the Department's Research Pôlicy Committee), including the project leader's resignation and various proposal modifications, it was finally established that only road and bridge design and construction data would be initially included for computer assisted storage and retrieval. Accordingly, a revised proposal was written and met with approval by all concerned. Work was to officially begin July 1, 1967.

The general objective of this revised proposal was to investigate ways to provide quick and easy access to the vast amount of past and current highway construction data generated by the Department. Specific objectives were to seek means to:

1. Place data within easy reach of Departmental personnel.

2. Avoid duplicate and unnecessary record keeping.

3. Provide a review of records for completeness and accuracy.

4. Develop a format that would provide efficient means for comprehensive or selective retrieval of data on a single project, or on common items of information on many projects.

Since the system was to serve the entire Department, it was deemed desirable to form an Advisory Committee to establish some policy regarding the nature and extent of data to be included in the system. A tenet that seems to be generally held is that a system of this nature works best when users participate in its design. In addition, computer programmers have a tendency to force-fit data to existing general maintenance programs rather than bother creating new data-handling programs adapted to specific needs. This attitude unnecessarily limits the flexibility and options one might desire in a system of this nature. For these reasons the proposal called for such a committee.

It was not until about ten months into the 24-month schedule that the Advisory Committee was designated and the first meeting held. Since the committee approach was deemed the most desirable, little could be accomplished in the interim.

DATA CATEGORIES INCLUDED

Two general criteria regarding time-related interest value were followed in the selection of specific data categories to be included in the retrieval system. First, the particular category should not have to be updated any more frequently than on an annual basis. Second, the information should have lasting interest value for a period of at least two years.

Using these criteria and considering the needs of the Department, the following list of categories for pavements and bridges was established by the Advisory Committee:

PAVEMENTS

1. Year of applicable specifications
2. Contractor (prime and paving)
3. Pertinent dates: (award, work started, paving, extension, open to traffic, final federal payment)
4. Population density (rural or urban)
5. Amount paid (including percent over or under)
6. Liquidation damages (if assessed, and reason)
7. Participating agencies, by percent
8. Project Engineer
9. Type of mixer
10. Description of paving equipment train and finishing equipment
11. Other unique or descriptive information
12. Location of document record microfilms
13. Stationing (POB-POE)
14. Type
15. Length (miles)
16. Design year traffic
17. Design hour volume
18. Design speed
19. Lanes (width, number, direction)
20. Reinforcing (type, percent)
21. Thickness in inches (surface, select subbase, subbase)
22. Shoulders (class [A, B, C, D] , width, thickness)
23. Crown
24. Mix design
25. Method of curing
26. Coarse agg. (source, class)
27. Fine agg. (source, class)

28. Cement (source, brands)
29. Speed limits
30. No passing zones
31. Accident rates
32. Average daily traffic
33. Culverts (location, type [pipe, box, slab])
34. Guardrail (location [POB] , length or POE, type [double or single steel beams])
35. Curb (location, type [roll, barrier, straight, gutter])
36. Ramp (location type [Exit-Entrance])
37. Rest area (location)
38. Percent air (amount, date of test)
39. Beams (strength, age, location)
40. Cores (location, thickness, strength, reinforcement depth)
41. Air temperature during pour (range per pour)
42. Roughness (location, value, date)
43. Skid coefficient (location, value, date)
44. Vertical curves:
    - length
    - grades (G_1 and G_2)
    - P.I. (elevation)
    - P.I. (location)
45. Horizontal curves:
    - external angle
    - degree of curve, D
    - length of radius, R
    - length of tangent, T
    - external distance, E
    - length, L
    - point of curvature, PC
    - point of intersection, PI
    - point of tangency, PT
    - rate of superelevation (full or transition)
46. Grade (percent, POB and POE)
47. Backslopes (ratio, POB and POE)
48. Foreslopes (ratio, POB and POE)
49. Median (width, type)
50. ROW width
51. Maximum height of fill slope (ratio, POB, and POE)

Categories Specific to Flexible Pavements

1. Quantity spread

2. Application rate (lbs/sq yd)
3. Surface type (wearing, leveling, binder course, etc.)
4. Mix design type (bit. agg., bit. conc., sheet asphalt, non-skid surface treatment, etc.)
5. Prime coat (designation and rate [gal/sq yd])
6. Mix materials (type and source)
   a. coarse aggregate
   b. fine aggregate
   c. mineral filler
   d. asphalt cement
   e. asphalt emulsion
   f. special admixtures
   g. synthetic binders
7. Type of spreader
8. Number and type of rollers
9. Type of bituminous plant (batch or continuous)
10. Prior surface (type and year built)
11. Thickness of individual courses
12. Subbase thickness and type of material

BRIDGES

Identification

1. Bridge and control section No.
2. Old bridge No. (when applicable)
3. Project and contract No.
4. Federal Project No.
5. Mile post No.
6. District No.
7. Highway No. (direction if applicable)
8. Over or under
9. Facility or feature crossed (hwy. No., road name, direction, RR name, river name, etc.)

General

1. No. of spans
2. Total length (ref. to ref.)
3. Roadway width ([f-f curbs] if divided give both and direction)
4. Bridge type (deck plate girder, I-Beam, prestressed concrete bridge beam, etc.)
5. Design loading (and/or H rating when available)

6. Operating rating (with 50 percent overstress)
7. Year built - superstructure (R-if replaced slab or deck, W-if widened) keep old date if major portion left
8. Year built - substructure
9. Vertical clearance (above road) field measurement
10. Underclearance (to bed of stream)
11. Horizontal clearance under (perp. to piers or abut. N or EB, S or WB)
12. Sidewalk width, curb height; each side
13. Raised median width (curb height)
14. Bridge railing type - (concrete parapet, aluminum fab., etc.)
15. Median barrier type - date
16. Deck area in sq ft
17. Contract cost - superstructure - substructure - total
18. Cost per sq ft - superstructure - substructure - total
19. Type of plans on file (if any), where filed
20. No. of plan sheets and standard plans.

Span Data (where applicable)

1. Span No. (or numbers if identical, e.g., 1 & 4, of 1, 2, 3)
2. Type (continuous, cantilever, etc.)
3. Length c-c bearings (each span of continuous units)
4. Size of beams (stringers) min. and max. depth, in. and wt. per ft (steel or concrete)
5. Beam spacing, ft. (number and spacings)
6. Floor beams - size
7. Floor beams - number and spacing
8. Trusses or Girders - min. and max. depth
9. Trusses or Girders - No. and spacing
10. Calculated live load deflection ratio, e.g., L/1380 = 0.52 in.
11. Shear connector type (if any)
12. Expansion joint type
13. Joint sealer type, and size if preformed neoprene
14. Expansion bearing type (sliding plate, rocker, neoprene)
15. Average roughness per span
16. Average grade per span (indicate if sag)

Substructure Data (for each unit)

1. Unit No., or numbers
2. Abutment or pier type
3. Foundation type

4. Height of unit (road crown to footing bottom)
5. Length of unit (out-to-out excluding retaining walls)

Special Design Data

1. Deck slab thickness range
2. Type of support
3. Minimum cover of top re-steel
4. Deck surfacing type and thickness
5. Skid coefficient (by lane)
6. Angle of crossing (Rt. or Lt.)
7. Degree of horiz. curve (if any) Rt. or Lt.
8. Rate of superelevation
9. Percent grade (if vertical curve, give data and show average grade of each span)
10. Crown inches (Rt. and Lt.)
11. Drain casting size, number, and spacing
12. Type downspouts
13. Bridge lighting
14. Provision for utilities support under deck
15. Utilities supported in sidewalks
16. Waterway area provided below high water
17. Design squad or consultant
18. Man hours for design
19. Design costs

Materials

Concrete & Reinforcement

1. Contractor
2. Contract No.
3. Concrete total vol., cu yds
4. Concrete suppliers
5. Type of mixers (transit, control, etc.)
6. Method of placement (crane, buggies, conveyors, pump, etc.)
7. Mix data - cement factor (sacks per cu yd)
8. Design air content
9. Design consistency (slump)
10. Cement (type and source)
11. Sand (type and source
12. Coarse agg. (type and source)
13. Retarders (type and source)

14. Air-entraining agent (type and amount)
15. Other admixtures (type)
16. Type of vibrators
17. Deck forms (wood, stay-in-place, buckleplate, etc.)
18. Low temp. protection (heating and housing, insulated substructure forms, etc.)
19. Curing-initial (type)
20. Supplementary curing
21. Type of deck finishing
22. Strike-off machine
23. Air temperature range during pouring
24. Concrete temperature range during pouring
25. Modulus of rupture (average and range in strengths, psi)
26. Yield point of steel reinforcement
27. Total weight steel reinforcement

Structural Steel

1. ASTM Specification and year
2. Minimum yield point
3. Design stress
4. Fabricator's name
5. Paint system preparation
6. Paint system, number of coats
7. Paint system, color

Prestressed Concrete Beams

1. Type (I or box) and size
2. Fabricator
3. Design strength, concrete
4. Test cylinders (average and range, psi)
5. Prestressing strand type size and manufacturer
6. Prestressing strand ultimate strength, psi
7. Design prestress force per beam (no. of strands)
8. Total lineal feet of beams

Maintenance Work

1. Deck resurfacing type and thickness
2. Deck waterproofing type
3. Deck patching type (slab, beam, joint)
4. By district or by contract

5. Deck repairs: latest year
6. Deck repairs: cost
7. Deck repairs: cost to date
8. Railing repairs: latest year
9. Railing repairs: cost to date
10. Substructure repairs: latest year
11. Substructure repairs: cost
12. Substructure repairs: cost to date
13. Painting steel: year (for type see 5b, 5)
14. Painting steel: cost
15. Painting steel: cost to date
16. Misc. repairs (slope paving, machinery, etc.)
17. Misc. repairs: cost to date
18. Total maintenance: cost to date
19. Safety inspection date
20. Condition factor-deck
21. Condition factor-beams
22. Condition factor-substructure

<u>Agency Responsible for Maintaining:</u>

23. Agency superstructure
24. Agency substructure
25. Agency lighting

<u>Planning and Traffic</u>

1. Highway system
2. Rural or urban
3. Population group
4. Approach pavement width (or f-f curbs)
5. Number of lanes

<u>Sufficiency Rating</u>

6. Number, H-Load factor
7. Number, bridge width factor
8. Number, condition or age factor
9. Number, vertical clearance factor
10. Total Sufficiency Rating
11. Date opened to traffic
12. Average Daily Traffic and year
13. Percent commercial traffic

It is not intended that this be an exhaustive list of what data might ultimately be contained in the system. Certainly detailed traffic accident and maintenance information is desirable and would be included. However, considering the time involved and the objectives of this study, it was felt that the general format and advantages of a coordinated data retrieval system could best be demonstrated by limiting initial discussion to design and construction data categories.

Figure 1 shows the flow of data within the system. Four general categories for data are given which are indicative of possible sources for the information.

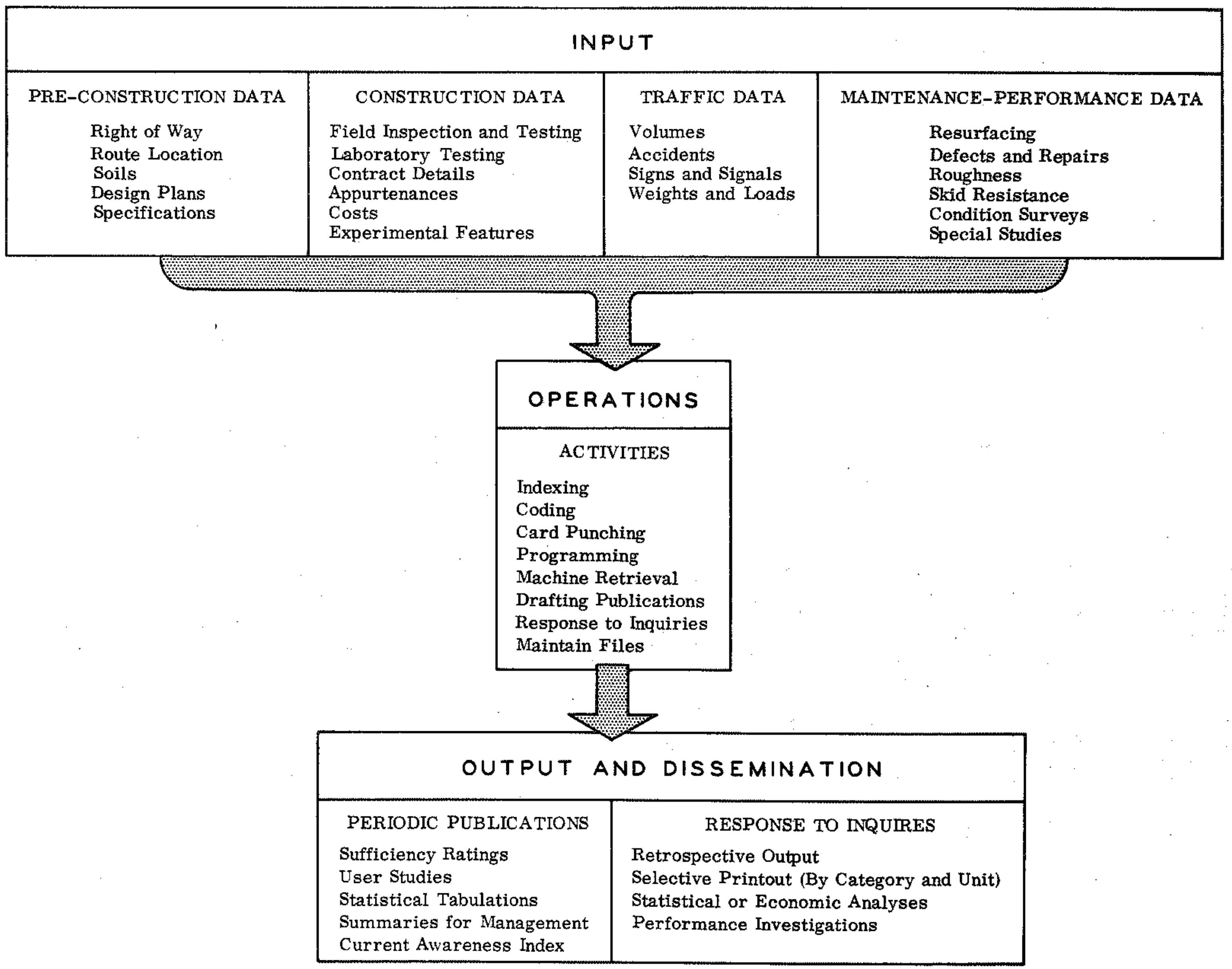

Figure 1. Information flow diagram.

STATEMENTS OF OBJECTIVES

The members of the Advisory Committee were cooperative and demonstrated an interest in the proposal; although there wasn't always unanimous agreement on a specific issue, advice or criticism was always constructive.

Members were appointed so that a broad Departmental representation was accomplished. Potential user groups represented included: Research Laboratory, Construction Division, Transportation Planning Division, Design Division, Traffic and Safety Division, Maintenance Division, and Management Services Division. In order to ascertain any unique interests, each member was asked to submit a statement concerning the objectives of a data retrieval system from the point of view of their Division's operations. Representative statements from these areas were as follows:

> Research Laboratory: The general objective and responsibility of the Research Laboratory is to formulate and execute a definite program of highway research directed toward solution of technical problems concerned with the improvement in the design and performance of state highways. To the extent that historical and current design and performance data are utilized in carrying out this program, the ability to rapidly locate and retrieve this data is a vital necessity. Due to the diversity, complexity and rapidly expanding volume of such information of potential use to the laboratory, it is desirable to have an automated system to digest, order, and summarize the data for efficient recall.
>
> Briefly, then, the Research Laboratory's objective or interest in a comprehensive information retrieval system is to provide quick and easy access to data basic to its mission.
>
> Design Division: The objective and responsibility of the Design Division is to survey proposed highway routes, prepare detailed designs, plans, proposals and cost estimates for constructing economical, safe, and durable highways, including pavements, bridges, pumphouses, drainage structures, lighting facilities and related structures.
>
> To facilitate the determination of the most economical designs a comparison of design factors of the various components can be most efficiently studied by the use of computer based tabulations of the design data. Summaries of much of the data are

also required for annual reports and special questionnaires on design characteristics of the highways.

Management Services Division: There are divisions which have the responsibility for creation and collection of data, and supplying this data to various users. In many cases, data from different divisions are being recorded, stored, or processed on electronic data processing equipment. Sometimes data from these different divisions cannot be correlated electronically because of different coding systems used.

The objective of the Management Services Division in participating in an information retrieval system is to establish a Departmental standard coding system and data base so that information can be correlated, and meaningful reports produced from a common data base.

Maintenance Division: For some time now, the Maintenance Division has felt that an exchange of data between Divisions would be beneficial, especially if the data were compatible. It would be necessary to develop a common reference base or provide for a conversion table in the computer process. The Maintenance Division is presently reporting on a control section basis by activity for all maintenance except structures and pumphouses. In the case of the latter we are reporting directly to the structure or pumphouse. Beginning July 1, 1968, it is our intent to add modern rest areas and weigh stations to the direct reporting system.

Our objectives in information retrieval are twofold.

1. Obviously, such things as pavement thickness, material, age, width, traffic volume, resurfacing, etc., affect maintenance expenditures. Therefore, it follows that these items should be considered in budget preparation. Ultimately, we will want to computerize our budgeting process through development of work units and work standards. Work load input as determined by field survey, extended by standard cost units, and adjusted by the above factors (through previously determined values), could combine to produce a preliminary field operating budget.

2. Secondly, we hope that through a constant input of compatible cost data that maintenance costs would become an influencing factor in future design and construction.

There were, of course, some dissenting opinions. One representative criticized the scope, which appeared to him to be limited and to contain very little information that would satisfy his Division's daily working needs. A further suggestion was that the basic system be designed by a skilled systems engineering group and that a consultant specializing in systems engineering be retained to design the system.

The first criticism does point to a possible limitation of systems such as we envision in this report. That is, in attempting to design the system to be of use to the Department as a whole (in terms of data included) it may become of lesser value to a particular user group for their day-to-day working needs. In other words, the information may be too general.

If, on the other hand, a single coordinated system is developed to meet the highly specialized needs of each group, it may become unwieldy and inefficient.

This dilemma seemed to cause little concern among the Committee members as a whole; however, it is something that should be borne in mind when developing such a system. It appears that a compromise will have to be made between oversimplification and overcomplexity in order to obtain maximum usefulness.

Apparently, the key resolving the dilemma is to develop a flexible system in which new data categories can be included if and when the demand arises.

It may be, however, that for users in a particular operating Division, such a system will function at best as a limited source of supplementary information from other Divisions rather than as a means for optimum use of their own data. Of course one primary purpose for a highway data retrieval and storage system is to aid upper level management. This objective must also be borne in mind during development as it would be a major influence on the final details of the system.

Regarding the second criticism, it is not intended that the skills of the systems engineers be ignored. Quite the contrary, full use of capable Department personnel in this area will be required prior to implementation. In order to establish individual user needs regarding the extent and scope of coverage, however, it seems desirable to take preliminary steps within the Advisory Committee. It should be pointed out that a spokesman representing the systems and programming personnel was included on the Committee.

Location Referencing

One of the initial and perhaps biggest hurdles to be overcome is that of determining the indexing scheme or location reference system to be used as a denominator common to all data. The problem is that all potential participating groups within the Department do not code roadway-related data using the same location reference system, although theirs may be well suited to their specific needs. Unless a completely new and uniform location reference system is adopted through the Department, compromising decisions must be made. Thus, completely detailed service to each must be sacrificed to obtain general service to all. This may be the best solution since in many cases it would appear to be very inefficient, if not meaningless, to alter present indexing systems.

Thus, a search must be conducted for the compromise solution for the location reference criteria that will provide the broadest possible data coverage and at the same time effect maximum usefulness to all concerned. The particular approach decided upon for a given system will undoubtedly be tailored to a large extent to fit the way in which data are currently being indexed in the Department. The ultimate scheme will in all likelihood be unique to a given organization.

Various types of location reference systems, singly or in various combinations, currently being used to locate points of data observations include: mileposts, control section logs, milepoints, grid coordinates, route number, construction project number, etc. Quite likely a combination of these identifiers would be needed in an automated system to adequately retrieve a given piece of information. Some location reference systems representative of those that have been proposed are discussed below (2).

Mileposts, Reference Posts, etc. These are not currently or traditionally used on all Michigan highways. Using these as a reference base would thus require unnecessary policy change. Under this system, changes in route length would require information correction on each post. Moreover, installation of posts might create a traffic and maintenance hazard.

Control Section Logs. Current Control Section Log Records may be a useful adjunct to a system but can hardly be used as a basis for retrieval nor serve as an acceptable alternative system. As a straight line diagram depicting special features with related mileposts, it is simply not complete enough for the goals we are anticipating. Certain information may be taken from a log and incorporated into the system. The reverse is more likely to happen, however, i.e., control section logs, including more than one construction project if desired, would be produced from information contained within the proposed system.

Grid Coordinates. Specifying the use of state plane or other coordinates for location reference would again necessitate major policy changes affecting all current data coding practices. In addition, special training for many persons would be required in order to use a coordinate reference system. It would also be difficult to develop a coordinate reference system sensitive enough to precisely locate point data. Even if this were accomplished, use in the field would be administratively difficult. Coordinate reference systems may be appropriate for certain types of data collected by geographical area, e.g., population groups, accident rates, etc. For these special cases the data could be converted to length data if desired and included in a system based on a compatible location reference principle.

MICHIGAN COORDINATED HIGHWAY DATA SYSTEM

A system may be defined as a collection of parts or components each having a specific purpose in relation to the others. Although each component has certain unique properties of its own, they all are interconnected in a pattern which allows them to function in a coordinated and integrated manner as a unified whole (3). "Coordinated," as used in this report to describe a proposed Michigan Highway Data System (HDS), is to be interpreted as meaning "to bring into a common action, movement, or condition so as to act together in a smooth and concentrated way." In essence then, a Department-wide information system must coordinate and facilitate the exchange of data that takes place among the various Divisions by interconnecting component data bases.

Record Identification

Although many policies and details are still unspecified, the proposed Michigan system will use construction projects as a basic record unit (hereafter designated "project record"). Construction project numbering is most familiar and already essentially established. All the characteristics for a given length of roadway that are to be included in the system will be contained within a construction project. (Appropriate point data will be located precisely within a project by a distance from the beginning point of the project.)

Each construction project and appropriate data (project record) will be indexed where applicable by the criteria listed in Table 1. Any combination of indices may serve as accession criteria for selective retrieval by project, route, district, etc. County identification is part of the State and Federal Project numbers and provides an additional basis for retrieval.

TABLE 1

INDEX	EXAMPLE
State Project	SS 17172-004
Federal Project	S 17 (11)
Route	M 129
District	2
Type	24-ft bituminous aggregate (coded)

The project identification will be followed by administrative and general free-field (not limited to specific length) information some of which may be independently retrieved but in general would be meaningful only in regards to an individual construction project. Such information, which might be called a project abstract, would include, for example, pertinent dates, contractor name, cost data, Project Engineer, etc. This would, in addition, be information that applies to the project as a whole or is constant throughout the length of the project. Also, any additional geographical information locating the beginning of the project would be included here. Descriptions of intersecting roads, distance and direction from nearby community, etc., would be appropriate. Data items in the abstract for which inter-project correlations or tabulations may be desired will be coded and referenced for individual retrieval.

A sequentially ordered file of all point and variable length data will complete the information for a given construction project. The point data will be located by a distance from the beginning of the project in miles or stationing (which can be easily converted into miles). Most data collected by the Department can be located within a construction project by stationing, and the required distances established without any change in field recording procedures. Individual data categories will have to be coded in order to facilitate selective retrieval by type.

Since stationing is not necessarily in strict increasing or decreasing order along a route, procedures will be established to insure correct sequential ordering of construction projects. Such procedures would perhaps involve a manual operation which might include transforming station numbering on a given project in order to make it compatible with any existing sequence. Ordering by station numbering would automatically sequence projects by county.

For storage and handling convenience, information may be broken into separate files or sub-files, each covering a specific area, e.g., pavement, bridges, and appurtenances. When necessary, however, data from the separate files, whether on magnetic tape or disc file storage, may be pooled for comprehensive information needs.

Using this method of location and identification for HDS provides optimum flexibility for three reasons. First, it makes use of established coding and referencing procedures. No revolutionary new system would have to be learned and practiced and which, moreover, would possibly render much previously recorded data valueless for potential inclusion into the system.

Second, new data or new data categories, or both, can conceivably be added to the existing record with ease. It is most certain that during implementation or after a short period of operation, requests for broader data representation will arise. As long as such data (length or point) meet certain minimum requirements (i.e., lasting interest value) and can be classified as belonging to a construction project, they can readily be included in the system.

It should be mentioned that changes in route length or designation will cause no problem. With the speed and flexibility of today's computers a simple program to revise locations accordingly can be written that would readily accomplish the task.

Third, this system provides for selective or comprehensive information retrieval. The coding and indexing will permit retrieval of all the data for a construction project or projects, route, district, county, etc., as well as tabulations of selective categories of information. In addition, large scale inter-project statistical studies can be made.

To a certain extent, the best system will evolve in time with user experience and feedback on an initially imperfect system. In order to foster this evolution, statistics will be maintained on the type and frequency of inquiries. Some statistics may be built into the system and accumulated automatically while for others hand tabulations will be necessary. Measures of success or relevancy will also be computed by determining user satisfaction with the response to his inquiry. By evaluating these statistics and conducting other subsequent studies, improvements in service are bound to occur.

Data Acquisition

There are points in time during the history of a construction project that provide a greater opportunity than others for capturing data to include in this system. Keying all information to construction projects allows advantageous use of these opportunities. The various phases of project development and construction activities provide logical and convenient data capture points. In general, data will be accumulated over a period of years and, in some specific cases, not available until the roadway has been in service for some time. Examples of initially unavailable data would include ADT, accident rate, performance, maintenance, etc. It is desirable, however, to acquire data soon after generation or possibly suffer the consequences of losing the information altogether. Certain stages in construction development do provide convenient access points. Other applicable data such as those mentioned above will have to be added as they accrue.

There appears to be little advantage in logging a construction project into the system until the contract has been awarded. At this time a majority of the desired data will be determined. Certainly the design characteristics, as well as much of the general information, will be available.

The next point for gathering data with which to update the file will be at the end of the construction phase, or when the road opens to traffic. By now all quality assurance test results, material sources, dates and costs should be known and available.

From this time on, information pertaining to a given project will be accumulated either by scheduled periodic updating or added as it is generated. Depending on the specific data, both methods will likely be practiced.

Modular Approach

One approach in the development of an automated information retrieval system is implementation on a "modular" basis. Using this procedure, the area that would provide the greatest immediate benefit is implemented first. Time and financing permitting, the second most needed area of data or "module" would then be added, etc. HDS is amenable to this type of an approach as long as the basic indexing scheme remains consistent. Certain modules may already have been identified, namely; rigid pavements, flexible pavements, bridges, and appurtenances. If it is undesirable to wait for the complete system, concentration can be focused on one of these data areas. The remaining areas can be added to the system as they are created.

Personnel Requirements

It is suggested that responsibility for maintaining and operating the system be assigned to the Management Services Division which includes Systems Analysis, Programming, and Information Service Units. In order to keep the system up to date additional personnel, under existing supervision, will be required. The actual number of personnel initially needed will depend on the extent of backlog data and the rate at which it is to be included. If much historical information is to be included, more personnel (perhaps part-time) will be required for collecting and coding the data.

For routine, continuous operation and maintenance of the system it is anticipated that at least five additional employees, whose duties would be restricted to this system, would be necessary. The work load would depend on the level of construction activity, thus, additional temporary personnel may be needed during peak construction periods. Perhaps, in addition, employees in construction-related jobs could also be utilized during the off-season period.

The core group of five, consisting of individuals having various backgrounds and respective duties would be on permanent assignment. Some would be involved with tabulating data, others with collecting data. In addition, in order to efficiently interpret design plans, material reports, etc., personnel with experience in these areas would be highly desirable candidates for staff membership, for obvious reasons. In addition, the system manager should also be a staff member of the Management Services Division and, in this capacity, facilitate the necessary associated computer processing.

The method of operation of this group will be active rather than passive. It is meant by this that they will be obligated to seek out required data from the various sources at the proper time rather than having to rely on users to submit their data. When contracts have been awarded, the system managers will see that the appropriate data are obtained. Once a construction project has entered the system, periodic status checks can be made to assess the completeness of information. Furthermore, to insure the flow of needed information, copies of forms on which pertinent data are recorded will be routed to the HDS personnel.

Output Format

Figures 2 and 3 show samples of actual data for various categories together with a possible output format arrangement. The output format is, of course, subject to change and most likely would be altered to allow the most efficient use of automatic data processing procedures and to produce the most readable output. This would be established in discussions with computer programmers when and if implementation is undertaken. It is anticipated that, in general, the format for comprehensive output would be somewhat similar in appearance.

It turns out that for most data, a fixed, maximum field width[2] can be established. This would be desirable from a coding standpoint in that some degree of standardization is achieved. Moreover, standard field widths are convenient to computer manipulate the data. However, in terms of classes of data, complete standardization would limit flexibility; and flexibility is a

---

(2) Length of data in terms of number of alphabetic or numeric characters needed for description.

STATE NO.	FED. NO.	ROUTE NO.	TYPE	SPEC.	LENGTH(MI)	STATION	MILE POST
55 I7072-004	SI7(II)	M-I29	24-FT.BIT.AGG.	I965	1.4	523+00-896+79.08	239

CONTRACT FOR: G & DS & 24 FT.BIT.AGG.SURF.
LOCATION: FROM TONE RD. NORTH TO DAFTER RD.

CONTRACTOR	AMOUNT PAID				P.E.	POPULATION	ROW WIDTH(FT)
	TOTAL	FED(%)	STATE(%)	LOCAL(%)			
PRIME-THORNE CONST. CO. PAVING - U.P. ASPHALT	500000.00+2%	0	I00	0	JOHN DOE	RURAL	I50

PLANT	PAVER	ROLLERS	PRIOR SURFACE	QUANTITY SPREAD(TON)	APPLICATION RATE(LBS/SYD)
AUTO.BATCH	VIBRATING SCREED	STEEL WHEEL(2)	BITUMINOUS	I3862	250

PRIME COAT	DESIGN SPEED		ADT	DHV
0.25 GAL/SYD.,MC-70	65	I963	800	250
		I968	I900	390

LANES

NUMBER	WIDTH	DIRECTION	CROWN(IN)
2	I2	N&S	1.275

THICKNESS

SURFACE	BASECOURSE(IN)	SELECT SUBBASE(IN)
250#/SYD	7	3

SHOULDERS

CLASS	WIDTH(FT)	THICKNESS(IN)
AA	8	7.5

MIX(SOURCE & SPEC.)

COARSE AGG.	25A	PIT I9-20
FINE AGG.	3NS	FERRYSBURG
MINERAL FILLER	3MF	CONNERS CREEK
ASPHALT CEMENT	85-I00	ACE OIL CO.

VERTICAL CURVES

STATION	GI	G2	P.I. (STA)	P.I. (ELEV.)
552+00-556+00	+0.03	+0.42	554+00	69I.87

BACKSLOPES

STATION(NB)	RATE	STATION(SB)	RATE
523+00-528+30	I:2	523+00-528+30	I:4VAR
528+30-545+00	FILL	528+30-539+50	FILL
. . . .	. . .	. . . .	. . .
85I+00-896+79.08	I:4	894+00-896+79.08	FILL

GUARD RAIL

STATION	TYPE
528+62.50-53I+00 RT	DOUBLE
529+00-53I+50	DOUBLE
550+90-55I+65	SINGLE
552+20-553+20	SINGLE
55I+60-552+60	SINGLE
552+20-553+20	SINGLE
. . . .	
847+50-849+75	SINGLE
848+50-849+50	SINGLE

CULVERTS

STATION	TYPE
540+30	PIPE
605+20	CLASS B(CONC.)
645+20	CLASS B(CMP)
894+00	CONCRETE BOX (2)

Figure 2. Possible output format for selected roadway information.

IDENTIFICATION-LOCATION

BRIDGE NO.	OLD NO.	FEDERAL NO.	MILE POST	DISTRICT	HIGHWAY	LOCATION
S02-II0I5 A	B7 OF II-23-5	I-94-I(I0)3	4.0	7	I-94 WB OVER US-I2	0.7 MI. NE NEW BUFFALO

FED. ROAD SEC. NO.	LATITUDE & LONGITUDE	
2A	41.7 N	86.8 W

SPANS	LENGTH(FT)	ROAD WIDTH(FT)	TYPE	DESIGN LOADING	H-RATING	YEAR BUILT	UNDERCLEARANCE(FT)
4	240	42	WF	HS20+AML[(I)]		I962	I5.8(EB),I6.0(WB)

HORIZONTAL CLEAR(FT)	SIDEWALK WIDTH(FT)	CURB HEIGHT(IN)	MEDIAN HEIGHT(FT)	RAIL TYPE	DECK AREA(SQ.FT.)
65.25	2.50	I2	1.50	RII	I35I8

CONTRACT COST				PLANS				
TOTAL	SUPER STR.(SQF)	SUB-STR.(SQF)	TOTAL	YEAR	SHEETS	FILED	BID-DATE	CONTRACTOR
I30733.00	8.5I	2.84	II.35	I959	70I-72I	M&T[(2)]	6-I0-60	GARAVAGLIA

SPANS

	I	4	2&3	2&3
TYPE	CANT.	CANT.	CANT.	SUSP.
LENGTH(FT)	38.50	44.00	5.00	73.75
SIZE OF BEAMS	36WFI50	36WFI50		36WFI70+I

SPANS

	I	4	2&3	2&3
BEAM SPACING(FT)	6.5	5.75		
SHEAR CON.	NO	NO		YES
EXPANSION JOINT TYPE	PIER I&3:STEEL		PIER 2:0.50 IN. HPRAT[(3)]	JOINT FILL, 8IN.CWS[(4)]
EXPANSION BEARING TYPE	ABUT: STL.PL.		PIER I&3: STL. ROCKER	PIER 2: STL. PED.

SUBSTRUCTURE

	ABUT. A	PIER I	PIER 2	PIER 3	ABUT. B
PIER TYPE	CANT.	5 COL.&GIRDER	5 COL.&GIRDER	5 COL.&GIRDER	CANT.
FOUNDATION TYPE	7' SPR. FTG.	9' SPR. FTG.	9' SPR. FTG.	9' SPR. FTG.	TR. TIMB.
HEIGHT (FT)	I3.04	25.65	27.04	26.75	I3.04
LENGTH (FT)		28.25	28.25		

DESIGN

DECK THICKNESS(IN)	7.50	
COVER-RESTEEL(IN)	I.50	
CROSSING ANGLE(DEG)	60.I46	
RATE OF SUPER	0	
VERTICAL CURVE(FT)	I400	
CROWN(IN)	3.25 RT	6.375 LT
DESIGN CONSULTANT OR SQUAD LEADERS	MICH. ASSOC.	

MATERIALS

BEAMS(STRUCTURAL STEEL) ASTM SPEC.	MIN. YIELD POINT	DESIGN STRESS
A-373 STEEL BEAMS	32000	I8000

PLANNING AND TRAFFIC

HIGHWAY SYSTEM	RURAL-URBAN	POPULATION GROUP	APPROACH(WIDTH - LANES)	
1	R		36	3

SUFFICIENCY RATING FACTORS[(5)]

LOAD CARRYING ABILITY	TRAFFIC CAPACITY	CONDITION	MINIMUM GEOMETRICS	TOTAL RATING	ADT
40	20	I8	20	98	49000

(I) ALTERNATE MILITARY LOADING
(2) MICROFILM AND TRACINGS
(3) HOT POUR RUBBER-ASPHALT TYPE
(4) COPPER WATERSTOP
(5) AS DEFINED BY TRANSPORTATION PLANNING DIVISION

Figure 3. Possible output format for selected bridge information.

feature of the system to be encouraged. Certainly there will be unique information about a given project that should be included in that project's record. Project complexity is another factor that will contribute to variation in the type and extent of data to be included, thus inhibiting standardization of data classes. So it doesn't appear that there can be a uniform, cut-and-dried input - output format for all projects for all time. It should be noted that not all categories are represented by sample data. For instance, there are no materials data for either the road or bridge projects presented. For the purpose of illustration, however, the amount shown should be sufficient. An exhaustive table would add little to an understanding of what is envisioned.

Input Formats and Computer Programs

Up until now nothing has been said about the way in which data will be coded for computer input. At this stage of development it is impossible to set down exact formats. Again these would have to be worked out with programming personnel at the proper time.

Specific recommendations regarding the composition of "data blocks," record lengths, and data field sizes to meet computer requirements are beyond the scope of this study and are left to be determined at the time of implementation. We feel that in this way computer programmers can best make use of computer efficiency in order to accomplish the objectives set forth herein. Whatever format evolves, necessary for efficient computer processing, it would be acceptable as long as the output flexibility desired is provided. Thus, in general, only ends are specified in this report, the means are left to computer experts.

Even though we can't be specific there are some general comments that can be made pertaining to coding requirements. These relate to the needs for selective retrieval of information.

If a complete listing of the data for all projects was our only desire, our problems would be simple ones. However, to allow retrieval by various location, type, or data criteria, appropriate coding must be provided. One way to accomplish this feature would be to build and maintain a separate tape or file of accession data. In this accession file would be the project number along with all associated numerical codes for particular data for that project. When projects which have a certain characteristic or combination of characteristics are requested, the accession file is computer-searched and the relevant projects selected. Now, by either indirect or direct methods, the master file of project records is computer-searched for the matching projects. These are then printed out either in total or--based on some predetermined computer program--partially, with only the relevant hard data listed. Perhaps the accession data itself could become part of the project record and hence the master file.

The extent and complexity of rather unique computer programs that will be required should now be somewhat apparent. The file maintenance or update procedures are one class of necessary programs. Programs for the various output requirements are another. In each case, different programs will be required, depending on whether or not the output is selective or exhaustive and whether or not the update is general or specific. Furthermore, various programs for selective retrieval will be required if only specific data are desired as opposed to the whole record for a project which contains the data. So it can be seen that one standard or routine input program and one standard output program would not allow the flexibility desired.

CONCLUSION

The keys to an effective data storage and retrieval system are: 1) genuine need, and 2) high level administrative commitment. Without a real need the system will not be used advantageously and development and implementation will be an economic waste. Administration commitment is required in order to command cooperation among user groups. Lacking these requirements, a data storage and retrieval system will become an inefficient assortment of objectives and procedures, each aimed at what seems important to a particular individual or group.

Assuming these prerequisites can be met, this report has discussed some of the technical and organizational considerations that will have to be solved.

In addition, since such a system will result in a Department-wide service, representatives of the various Divisions must participate in the ultimate design. A clear definition of what input - output capabilities are required must be established prior to the developmental assignments. System characteristics should not be dictated by the manner in which data are routinely or traditionally processed.

Also, the more future users are involved in preoperational development, the greater their confidence will be in the system, which, in turn, should assure optimum use.

To overcome the problem of putting such a system into operation at a given date it would be most feasible to move forward from a given date placing new project information into the system and then only as time permits adding the past project data. Once acquired, the information should be permanently retained, albeit in less convenient access as the frequency of use decreases. However, a more complete study of the various needs and objectives of the Divisions would be required to determine the reasonable limit for inclusion of past data. Some items of past project data, now desired, might not now be obtainable, and therefore diminishing returns can be expected from the effort expended. The items of information to be obtained from each project may be drastically reduced as older project data are put into the system since less of this information would be of current interest.

Finally, we have attempted to establish in this report some characteristics or capabilities that a coordinated data retrieval system might possess. In summation, the features of the proposed HDS would include the following:

1) Construction projects used as the basis for indexing or location reference for data.

2) Selective retrieval by roadway location, type, or specific data category, or any of these.

3) Where necessary, within-project data are indexed by distance from beginning point of project.

4) Flexibility: to add new data categories; in-file maintenance; and input - output formats.

5) Susceptibility to modular approach to implementation.

6) Operated and maintained by full-time staff whose duties are concerned exclusively with HDS.

Alternative Approach

An alternative approach may be considered if the unified system proposed in this report is not developed. This approach would allow multiple independent sub-systems for data storage and retrieval. That is, each Division in co-operation with computer personnel would design and maintain its own automatic data storage and retrieval to satisfy their individual requirements. To a certain extent this practice is already established. This approach would undoubtedly be considered heretical by those schooled in modern computer systems planning. Nevertheless, considering various traditions, attitudes, interests, and needs, it may be a practical one.

This approach would not eliminate the need for coordination, however. Coordination would still be necessary to avoid duplication or overlapping of data collected and to standardize indexing practices in order to facilitate interrelating data from the various Divisions. The distribution of notices advising user groups of the availability and form of data would have to be provided. Using this approach, an interest user would select relevant data from other storage banks to merge with his own for a desired analysis.

This method would be less efficient to a certain extent perhaps, since each Division would have to maintain its own sub-system. This is done now, however, and probably would continue even though a larger unified system existed. Some problems would develop in maintaining all sub-systems equally up-to-date.

The main disadvantage with this approach, however, is that a certain Division might not maintain data in their files of specific interest to other Divisions. What has lasting interest value for one Division may not be of lasting interest to the Division that initially collects or creates the data. Hence, these data would not enter the originating Division's data retrieval sub-system.

The centralized data collecting function of the staff for the unified system would obtain and include the data, however, thus making it available to all interested Divisions.

REFERENCE

1. "Interagency Information Reconnaissance Study," Technical Report No. 4, State Resources Planning Division, Prepared by Technology Planning Center, Inc., Ann Arbor, Michigan.

2. "Coordinated Data System for Highway Planning," Report No. 7, U. S. Department of Transportation--Highway Planning.

3. Ellis, J. B., "Outdoor Recreational Planning in Michigan - Systems Analysis Approach," Technical Report No. 1, State Resource Planning Program, Michigan Department of Commerce, University of Waterloo, Waterloo, Ontario.

4. "Proposed Data Bank System for Road Related Data," Unpublished Manuscript, State of Illinois, Highway Department.