NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP Report 401

Guidance Manual for Managing Transportation Planning Data

Transportation Research Board
National Research Council

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Report 401

Guidance Manual for Managing Transportation Planning Data

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with
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and
Mid-Ohio Regional Planning Commission

Subject Areas

Planning and Administration
Energy and Environment
Highway and Facility Design
Highway Operations, Capacity and Traffic Control
Public Transit
Freight Transportation

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state and local governmental agencies, universities, and industry; its relationship to the National Research Council is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

Note: The Transportation Research Board, the National Research Council, the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the individual states participating in the National Cooperative Highway Research Program do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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The project that is the subject of this report was a part of the National Cooperative Highway Research Program conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council. Such approval reflects the Governing Board's judgment that the program concerned is of national importance and appropriate with respect to both the purposes and resources of the National Research Council.

The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the American Association of State Highway and Transportation Officials, or the Federal Highway Administration, U.S. Department of Transportation.

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FOREWORD

By Staff
Transportation Research Board

This guidance manual contains procedures for identifying, collecting, organizing, and using data for transportation planning purposes. Specific discussions are included on strategic assessments of data needs, a framework for organizing data, cost effectiveness of data, and the integration and consistency of data. The guidance contained herein will be of interest to planners in state departments of transportation (DOTs) and metropolitan planning organizations (MPOs). Two additional project reports are available on the Internet's World Wide Web: the agency's (1) Final Report and (2) Compendium of Data Collection Practices and Sources.

Interest in planning and decision-making processes prompted by the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and the Clean Air Act Amendments of 1990 (CAAA) resulted in new and expanded data requirements for passenger and freight multimodal transportation planning activities of state DOTs and MPOs. As multimodal planning methods evolve and are applied, the availability of data must keep pace.

Under Project 8-32(5), "Multimodal Transportation Planning Data," Jack Faucett Associates, Inc., conducted research that resulted in guidance on (1) strategic assessments of data requirements to support statewide and metropolitan multimodal transportation planning; (2) the availability of current data from primary (i.e., collected directly by the user) and secondary (i.e., collected by others) data sources; (3) analytical techniques and the data required; (4) economic assessments of transportation data programs; and (5) the integration of data within and among jurisdictions.

Of special interest to state DOTs and MPOs should be the discussions on strategic assessments and the framework. The discussions on strategic assessments highlight the need for incorporating this activity into the planning process to ensure that the right data and most cost-effective data are used. The suggested framework for transportation data—analzyed around four main components: system supply, performance, demand, and impacts—can be used individually or nationally to help organize, coordinate, and standardize data within and among agencies.

The project was successfully completed and is documented in three separate reports: the guidance manual published herein; the agency's Final Report documenting and supporting the research effort; and a supplemental agency report titled, Compendium of Data Collection Practices and Sources. The latter two reports are available through the NCHRP homepage (www2.nas.edu/trbcrp) on the Internet's World Wide Web as NCHRP Web Documents 3 and 4, respectively. Individuals checking the homepage should look at the write-up on Project 8-32(5) or the listing of NCHRP Web Documents.

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CHAPTER 1

INTRODUCTION AND SUMMARY

INTRODUCTION

New planning and decision-making processes prompted by the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and the Clean Air Act Amendments of 1990 (CAAA) have resulted in new and expanded data requirements for passenger and freight multimodal transportation planning activities of state departments of transportation (DOTs) and metropolitan planning organizations (MPOs). As new multimodal planning methods are being developed and applied and as social, economic, and environmental issues are addressed, the availability of data must keep pace.

There is little guidance to assist data users in strategically assessing their own data collection programs in light of the new planning requirements. Much ongoing and currently planned research is designed to address data needs regarding specific aspects of the new requirements. However, there is no one convenient and comprehensive source of information about data needs, sources, and collection techniques for strategic assessments.

This manual sets forth the needs for data on the basis of the mission of each transportation planning agency; how to establish priorities in meeting these needs; and how to collect, organize and make data available. The manual addresses data needs at the state DOT and MPO planning agencies. Federal and nationwide data needs have been addressed in "Data for Decisions: Requirements for National Transportation Policy Making," *Special Report 234*, Transportation Research Board (1992).

Each planning agency (federal, state, and MPO level) deals with the current status of the transportation system now in place, how it performs, changes that are now developing and forecasts of the future system attributes that will be needed. The system attributes needed will depend on the future transportation needs of the users of the system, and the ability and willingness of the users to pay for achievable performance.

Thus, data are needed on transportation attributes by mode and intermodal connections:

- Network and services,
- Demand,
- Performance, and
- External impacts on communities and the environment.

Emerging and forecasted changes in social and economic organizations and in transportation technology will affect the data needed. Data-collection methods and procedures for organizing and disseminating data will also be affected by new information technology. Therefore, systems and procedures for data collection, organization, and dissemination must be flexible and adaptable to cost-effective developments. Thus, it is logical to deal with the "building blocks," or modules, of data needs separately because inherent details are subject to change.

These modules are as follows:

MODULE 1. Strategic assessment of data needs,
MODULE 2. Frameworks for organizing data,
MODULE 3. Cost/effectiveness of data collected, and
MODULE 4. Issues of data integration and consistency.

This manual is organized by these modules. A summary description of each module is given below, followed by a suggested data program implemented at the state level.

MODULE DEVELOPMENT

Strategic Assessment of Data Needs

Strategic planning in each planning organization must be concerned with the internal operations and the external interface relationships with which the local agencies must cope. The emphasis is on the consolidation of data needs on the basis of the mission of the specific planning agency and the necessity to reduce overlap in data detail. However, the decision on the detail with which the internal data is organized by the planning agencies is left to each agency. We have simply recommended an organization that can save resources. Any decisions on implementation and the time schedule remain flexible in the operations affecting data internal to planning agencies.

Frameworks for Organizing Data

The external concerns of the planning agencies are the elements of strategic planning that require interchange of data and information. This requires cooperation among the planning agencies in defining and standardizing the data exchanged. This activity facilitates data exchange and enhances the efficiency of the cooperative planning processes. Therefore, it is essential that a standardized data system be established to include any data of interagency concern. The system outlined classifies data into four components: supply, demand, performance, and impact. Data elements and data items under each component are illustrated. Planning agencies should understand that this system or some other standardized system should be agreed upon and only the appropriate data cells implemented.

Cost/Effectiveness of Data Collected

Transportation planners often are faced with frustrating yet critical requirements for more and better information. Such decisions require accurate information that often is unavailable and costly to collect. Making the best planning decision requires the best information. Planners must be able to trade off the quality of their information with resources required to collect and verify it. This section organizes transportation planning needs into the four principal components: supply, demand, performance, and impacts; provides discussion of their relative importance; and offers a method for applying a cost-effectiveness analysis to data-collection activities. Because *demand* data reflect the attributes of users of the transportation system—an *external* environment faced by the system designers and internal operators—this represents a large amount of information for sharing among transportation planners. Hence, the analytical procedure is illustrated by an application to collections of demand data. The proposed procedure would allow planners to apply their data-collection resources in those areas that would provide the greatest payoff in the transportation planning process.

Issues of Data Integration and Consistency

Data-integration issues and data-collection technology are discussed and illustrated. Integration issues apply to both internal administrative data primarily under the control of the planning organization as well as the data interchanged among planning organizations. Interchange is concerned largely with collection of demand data and system attributes, especially technology advances. Principles of information storage and dissemination of internal data within the planning organizations are discussed and are determined by disparate planning organizations.

PROPOSED DATA PROGRAM

To successfully meet the objectives of this study, the researchers have suggested a data program that embodies a coordinated, organized, consistent, and integrated approach to assessing data needs, developing data organization frameworks, collecting data, and disseminating data among all data users. (See Figure 1.)

Data Task Force—The development of a data task force is needed to ensure coordination across all transportation planning groups within a state. Given the state's role in resource allocation and its place in the hierarchy of geographic coverage, the development of the data task force should be led by the state DOT. Other members of the data task force should include representatives from state DOT functional offices (e.g., operations), MPOs, other transportation data-user groups such as air quality planning agencies, and other public and private stakeholders. The mission of this task force can be articulated as follows:

> *To ensure coordination and collaboration in the assessment of data needs and in the organization, collection, and dissemination of data across all user groups within the state.*

Each of the elements of this mission (i.e., needs, organization, collection, and dissemination) comprises one of the other components of the proposed data program and reflects an objective of this research.

Data Needs Assessment—The data needs component involves the application of a strategic planning platform to assess data needs associated with multimodal planning. The so-called Business Model is recommended to strategically

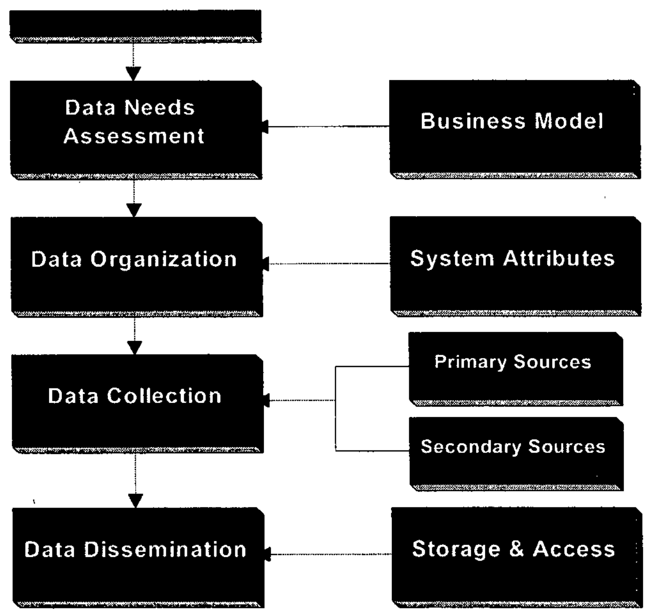

Figure 1. Suggested data program.

assess data needs of planning agencies. One objective of the data task force is to urge each planning agency within a state to implement the Business Model in defining overall data needs including internal data under its control. A compelling objective is to coordinate and standardize data to be exchanged among the planning agencies.

Data Organization—Once data needs have been assessed, the organization of data must be considered. Given the large quantity of data necessary for the development, evaluation, and implementation of transportation strategies that support planning objectives, the manner in which data are grouped impacts the efficiency and stability of the planning process. To ensure stability and efficiency in the planning process, we recommend that transportation data be organized along the four major attributes of the transportation system (i.e., supply, demand, performance, and impacts).

Data-Collection Priorities—This component of the proposed data program delineates primary and secondary data-collection activities that should be undertaken by planning agencies to support planning functions. A primary objective of the data task force will be to assign data-collection responsibilities across planning agencies on the basis of priority needs, economies of collection, geographic scope, resources, and data uses. Data-collection activities should be organized for the most efficient collection of data on the basis of priority of data needs.

Data Dissemination—Data dissemination addresses the need for data integration and the use of available technologies for data storage and sharing. This component involves the identification, evaluation, and implementation of data-integration strategies—such as GIS—to relate transportation supply, demand, performance, and impact data in the context of multimodal planning models. An important objective of the data task force will be to implement the most cost-effective, data-integration system that optimizes the storage, maintenance, and retrieval process across user groups.

CHAPTER 2

STRATEGIC ASSESSMENT OF DATA NEEDS

BUSINESS MODEL

The Business Model framework for assessing data needs and understanding data organizational structures is applicable regardless of data-collection and storage techniques or computer automation platforms. Using strategic management planning tools, application of the Business Model involves six steps, as shown in Figure 2.

DESCRIPTION OF BUSINESS MODEL STEPS

Step 1

Identifying the Organization's Mission

This step can be achieved by obtaining documentation existing within the organization. Such documentation might include a state DOT's or MPO's transportation plan. This documentation can be further expanded by issuing a questionnaire executed to all management participants within the organization. Questions might include those related to the mission and purpose of the organization, mission and purpose of the area of responsibility, concerns and issues, organizational policies, objectives and strategies, and program priorities. Questionnaires are useful in identifying people or groups that traditionally have been omitted from the strategic planning process, in obtaining various perspectives usually constrained by management hierarchies, and in perpetuating vertical participation within the organization with respect to the identification of information and data needs.

Steps 2, 3, and 4

Defining Goals and Objectives, Developing Strategies to Meet Goals and Objectives, and Mapping Strategies to Specific Functions

These steps can be achieved using goal analysis, which involves the following tasks.

First, quantifiable goals and objectives (that have a measurable attribute, a target level, and a time frame) are identified from the mission statements of the organization. Goals represent long-term targets for achievement, while objectives are more short term in nature. For example, one MPO goal may be to improve air quality. An objective associated with this goal would be to reduce carbon monoxide-type (CO) pollutants.

Second, issues that impede the achievement of the goal or objective are identified. For example, issues that impede the attainment of lower CO emissions include too much congestion, high vehicle miles traveled (VMT) growth rates, and climate encumbrances.

Third, strategies that will effectively allow the organization to overcome the issue-related impediments are developed. Whereas goals and objectives describe *what* an organization wants to achieve, strategies and tactics describe *how* to achieve them. For example, one strategy for *reaching* CO attainment is the *construction* of high occupancy vehicle (HOV) lanes.

Fourth, strategies are mapped into organizational functions to define functional responsibility for strategy implementation and evaluation. In the above example, the strategy of constructing HOV lanes to enhance CO attainment may be the responsibility of the highway engineering division of the state DOT, while the evaluation of the strategy's effectiveness may be conducted by the MPO. At this point in the Business Model process, it is possible to assess, via a strategy-function matrix, which organizational needs are not being met and where any overlap in responsibility might exist.

Finally, internal and external strengths, weaknesses, opportunities, and threats that may impede or facilitate the implementation of chosen strategies are assessed. For example, although the addition of HOV lanes may appear to be the best strategy for reducing CO emissions, exogenous impediments may exist to the construction of these lanes.

Step 5

Assessing Information Needs for Strategy Evaluation and Implementation

This step of the Business Model begins with the redefinition of an organization's strategic focus. There are three major tasks associated with this redefinition process: an internal appraisal, an external appraisal, and the evaluation of strategic alternatives.

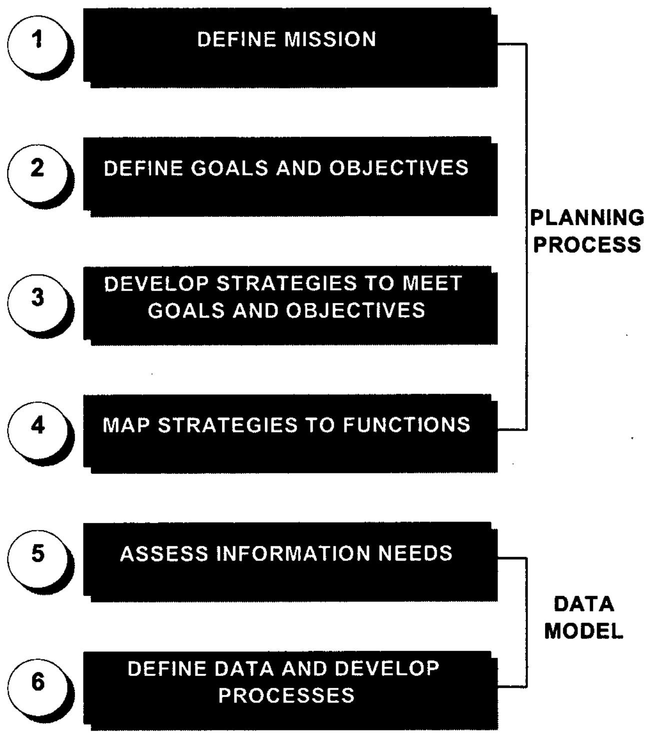

Figure 2. Six-step Business Model.

Internal appraisals constitute assessments via performance indicators of how well the organization is meeting its goals and objectives. For example, a performance indicator depicting the success of an MPO's travel demand modeling group may measure the accuracy of current forecasting techniques in predicting commuter travel patterns. Such appraisals facilitate the implementation of internal policies that increase the efficiency of functional operations.

External appraisals involve an assessment of economic, political, social, technological, competitive, and geographic factors that affect the effectiveness or implementation of a given strategy; a stakeholder analysis to identify issues that affect the success of the strategy; and a technology assessment to identify the most cost-effective technologies for evaluating and implementing alternative strategies.

Once all strategies have been identified, and the strengths, weaknesses, opportunities, and threats of those strategies have been evaluated, it is necessary to evaluate the sum of strategic alternatives. This involves strategic gap analysis to define the strategic agenda. For government organizations, it is essential to determine what strategies are feasible to employ (as defined during the internal appraisal), but may be difficult to implement based on exogenous factors (as determined during the external appraisal). If a designated strategy has a low probability of implementation due to exogenous circumstances, additional strategies must be defined. If multiple strategies are defined or required, it is necessary to make an assessment of alternatives to establish priority of implementation. Once the gap analysis is concluded, strategies can be selected relative to all alternatives. One method for selecting among alternatives is the development of a strategic alternative evaluation matrix where each alternative is assessed in terms of feasibility, advantages, disadvantages, threat exposure, and probability of achievement.

The final step of a strategic evaluation of alternative policies or programs involves the development of strategic statements, which help to identify the information required to meet objectives or evaluate and implement strategies. Determining what types of information are required dictates the data that are needed to meet those objectives.

The strategic statement documents exactly *what* needs to be done, *when* it needs to be done, *how* it should be done, *why* it is being done, and *how much* it will cost. Note that all information requirements necessary for the implementation and evaluation of the chosen strategy also will be contained in the strategic statement.

Step 6

Define Data and Develop Processes

The final step of the Business Model addresses the types of analyses and analytic tools necessary for strategy development, evaluation, and implementation. For example, many types of congestion management analysis activities must be undertaken by MPOs. These include, but are not limited to, the following: identify existing and future congestion on points along the system; identify congestion problems and causes; evaluate strategies to solve congestion problems occurring within a region, corridor, or subarea; predict system performance given a set of strategies; and evaluate strategy effectiveness. The types of analytic tools available to practitioners to evaluate and implement various congestion management strategies include travel demand models, traffic simulation models, and analytic techniques for measuring the effectiveness of transportation control measures (TCMs).

Summary

In this study, the application of the Business Model identified information and data types necessary for multimodal transportation planning that can be grouped into a data-organization framework. This framework was expanded to identify specific data sets that support the development, evaluation, and implementation of most transportation strategies and planning objectives. The resulting data-organization framework is described next. The recommended framework is hierarchical and designed to ensure flexibility in its implementation, thereby accommodating specific needs of different planning organizations.

CHAPTER 3

EVALUATION OF FRAMEWORKS FOR ORGANIZING DATA

DATA NEEDS

In this study, data needs for transportation planning have been grouped into four principal components: supply, demand, performance, and impacts.

- Supply data include information on the physical networks and services provided by commercial modes and their associated costs.
- Demand data include information on needs for moving people and goods over specified distances and routes and the associated costs of these movements.
- Performance data include measures of how well supply is fulfilling transport demands at affordable cost and with achievable efficiency.
- System impacts measure the external effects of the transportation system on the physical and social environment.

Data organization is fundamental to the successful performance of transportation planning. As discussed in Chapter 2, given the large quantity of data necessary for the development, evaluation, and implementation of transportation strategies that support planning objectives, the manner in which data are grouped affects the efficiency and stability of the planning process.

- Stability is affected because the time and cost of collecting data, as well as the need for systematic and reliable monitoring over time, work against constant modification of databases.
- Efficiency is affected because practitioners rely on timely access to information in the development of plans and projects.

Stability and efficiency needs suggest that transportation data may be best structured not by planning issues, which tend to vary spatially and temporally, but by the major attributes of the transportation system, which remain relatively constant and facilitate the data-retrieval process. The suggested hierarchy for the data-organization framework is described below.

Major Data Components—Multimodal transportation planning can be defined by the supply and demand attributes of the transportation system. Together, the supply and demand components provide information on the quantity of travel by mode along the various facilities of the transportation system. Furthermore, the interaction of supply and demand at any given moment in time defines system performance, and externalities associated with travel define the resulting impacts of this interaction. As a result, the four major attributes of the transportation system are supply, demand, performance, and impacts, each of which is either directly or indirectly addressed by ISTEA and the 1990 CAAA. Therefore, to ensure stability and efficiency in the planning process, transportation data should be organized along these broad data components (see Figure 3).

HIERARCHICAL CLASSIFICATION SYSTEM

The hierarchy in the data classification system includes data components, data elements, data sets, and data items in progressive detail. This hierarchy is illustrated by the detail for highway supply (data component), highway supply attributes (data elements), and detail on highway attributes (data sets). Detail on specific items that constitute the data sets are not shown but are generally the very detailed building blocks from which usable relationships are calculated from the data items (e.g., performance by HOV lane). This hierarchy is illustrated in Figure 4, which reproduces the beginning of the classification system in the Appendix.

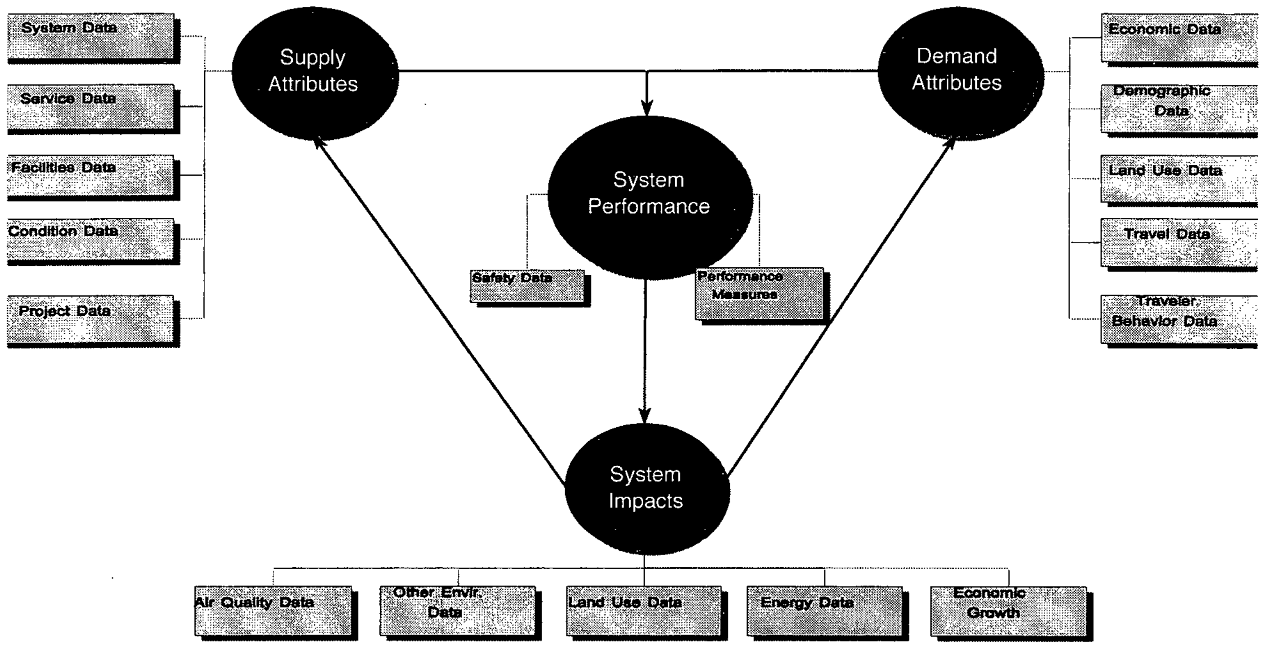

Figure 3. Data-organization framework.

Illustrated Hierarchy in Data Classification System

(F) - Denotes freight data

Data Components

Supply Attributes (S)
Demand Attributes (D)
System Performance (P)
System Impacts (I)

Supply Attributes (S)
S.H. Highway

(data element) S.H.1 Systems Data

(data sets)

S.H.1.1 Mileage and lanes (total lane miles and number of lanes, lane miles of HOV, intercity highway miles)
S.H.1.2 Capacity (including highway link capacities)
S.H.1.3. Functional road class
S.H.1.4 Nodes and segments (GIS or highway route)
S.H.1.5 Land use data for system expansion
S.H.1.6 (F) Intraurban truck routes (by route number)
S.H.1.7 Other

Figure 4. Illustrated hierarchy in data classification system.

(data element)	<u>S.H.2</u>	<u>Service Data</u>
(data sets)	S.H.2.1	Access (connections to other modes, highways, and roadways)
	S.H.2.2	(F) Interurban access (GIS or highway route numbers; principal routes for trucks entering and exiting urban areas carrying interurban freight)
	S.H.2.3	Intermodal access (rail, water, air, by highway route mile)
	S.H.2.4	Data on service providers
	S.H.2.5	Fare or fee structure data (tolls, parking)
	S.H.2.6	(F) Drayage services
	S.H.2.7	Other
(data element)	<u>S.H.3</u>	<u>Facilities Data</u>
(data sets)	S.H.3.1	Inventory of facilities (bus terminal and stops, rest areas, park and ride lots, truck terminals, intermodal facilities, cargo transfer equipment, etc.)
	S.H.3.2	Land use data for use in planning for route modifications, terminal and warehouse locations
	S.H.3.3	(F) Delivery and Pickup (On-street, off-street parking by principal intraurban routes).
	S.H.3.4	Other
(data element)	<u>S.H.4</u>	<u>Condition Data</u>
(data sets)	S.H.4.1	Pavement data by highway route (pavement serviceability rating, long-term pavement performance counts)
	S.H.4.2	Any data pertinent to condition of routes, bridges, ramps, etc. that affect the efficiency of interurban truck access to the urban area or truck pick-up and delivery activities
	S.H.4.3	Age of various road classes
	S.H.4.4	Other
(data element)	<u>S.H.5</u>	<u>Project Data</u>
(data sets)	S.H.5.1	List of all state projects proposed for the next 3 years (minimum) -including funding data
	S.H.5.2	List of all metropolitan (MPO) projects proposed for the next 3 years (minimum) - including funding data
	S.H.5.3	Major investment data (planned supply augmentation projects)
	S.H.5.4	Project history data (past capacity expansion and maintenance, project information such as project dates, type of construction, rehabilitation, etc.)
	S.H.5.5	Project evaluation data
	S.H.5.6	Planned expansions and modifications
	S.H.5.7	Project maintenance data
	S.H.5.8	Other

Figure 4. Illustrated hierarchy in data classification system (continued).

CHAPTER 4

ECONOMIC ANALYSIS OF TRANSPORTATION DATA COLLECTIONS

The economics of data collections involves an efficient allocation of scarce resources in meeting competing and complementary needs of data for transportation planning. Issues involve assessing the marginal costs of specific data elements and data sets against their marginal contribution to understanding and modeling the behavior of suppliers and users of the transportation system.

Today we have too much data and too little analysis related to its usefulness and cost-effectiveness in supplying the information needed for transportation planning. It is easier (but perhaps more expensive) to collect lots of data with the intent that it can be used somehow than it is to analyze carefully the salient needs and to design efficient ways to collect data to fill specific needs. This approach requires assessing total needs rather than compartmental needs since there can be large economies in combining data requirements in data-collection activities.

Moreover, much of the available data are not tailored to specific needs and are often redundant. Having too much data not well organized and not directly useful makes it more difficult to identify the useful data and it wastes resources that could be allocated to improving more directly usable data. Hence, we need to develop more limited data sets that are more cost-effective in meeting the salient needs for transportation planning. Guidebooks and manuals would be more useful if they identified cost-effective, data-collection approaches after an analytical evaluation rather than presenting a smorgasbord of unevaluated data sources.

Historically, most of the transportation planning was done in terms of the separate modes: rail, water, air, pipelines, and highway. The need for more coordination in planning across modes has gradually become apparent and is now recognized formally in terms of intermodal planning. The awareness of the benefits of higher living standards resulting from economic efficiency in transport has partly led to deregulation that permits greater competition among suppliers in some modes but requires more cooperation in multimodal planning. Multimodal planning has been applied more to intermodal passenger travel than to intermodal freight. Because the nation's bill for transport of freight is estimated at over $400 billion (compared with over $700 billion for passenger travel), there is a large potential payoff in improvement in freight transportation efficiency. (Of course, the cost of time by passengers is not included—difficult to estimate; furthermore, the loss in productivity due to inefficiencies in intermodal freight transport is also not included.) Data for analyzing this potential, and what transportation improvements financed by the public sector can be effective, are a priority. This analysis can also point out changes in public regulation of private carriers that will result in more cooperation among private carriers and healthy competition.

Very few studies have tried to quantify the benefit/costs of selected transportation strategies for either passenger or freight movements. A seminal report, directed by Dr. Dudley G. Anderson at the Stanford Research Institute and published by AASHTO in 1977, is one example of such a study that exhibited a very laborious and painstaking effort at quantifying benefit/cost.[1] A less detailed study by Todd Litman of the Victoria Transport Policy Institute measured benefits and costs associated with public transit.[2]

Of course the importance of such studies is associated with economic policy objectives. Thus, the planner places value on data sets that are most efficient in the analysis needed for the objectives decided upon. This suggests that planners may wish to set their sights on data needs for analyses beyond the immediate problems that require their attention. They may be best equipped to educate the decision makers on the value of dealing with more fundamental logistics problems.

In any event, planners can best identify data sets that are most useful in analyzing the specific problems confronting them. Of course there is a tradeoff in the value of the best data and their collection costs relative to other data sets. These data sets have alternative values in analyses of supply, demand, performance, and impacts. The values and cost tradeoffs differ across MPOs because of differences in the scenarios and data-collection costs associated with immediate problems to be analyzed.

The following procedure is recommended to assess relative benefit/cost options:

1. Appoint a small data committee (not more than 2–3 persons). The committee will identify data sets currently used in short-term and long-term planning functions, as

[1] AASHTO, *A Manual on User Benefit Analysis of Highway and Bus Transit Improvements*, American Association of State Highway and Transportation Officials, Washington, D.C. (1977).

[2] Todd Litman, "Defining and Quantifying Public Transit Benefits," Victoria Transport Policy Institute, Victoria, B.C. (April 15, 1996).

well as data not now available but deemed essential, by planning function or purpose (e.g., congestion management in specific corridors, evaluation of potential effectiveness of projects in the transportation improvement program (TIP), longer term forecasting of network loadings by corridor, etc.). The committee will ask top planners to assign values to planning purposes based on a scale of 0 to 10, 10 representing the highest priority.

2. Ask the planners/users of the data sets to assign a value to each data set for each planning purpose on a scale of 0 to 10. These assignments would be made based on the explanatory power of the data set in the models used by the planners/users, or by their judgment as appropriate.
3. Multiply the values assigned for each data set under each planning purpose by the value assigned for the planning purpose under which it is needed.
4. Develop a unique list of data sets identified for any and all planning purposes along with the values assigned under each planning purpose as calculated in Step 3 above. Add the values assigned to each data set under each planning function to derive an overall value for each data set. Review these final values with the top planners and adjust the values if appropriate by judgment.

These four steps will provide a rough value ranking for each data set. At this point, the efficiency of the alternative collection systems that might be used to collect the data should be evaluated in conjunction with time priorities for the data sets. This could lead to resource savings as well as provide a measure of cost-effectiveness of collecting the data sets. The suggested steps for calculating these cost-effective measures in view of time priorities are described in the following steps.

5. Strategic Evaluation of Collection Methods. There are a number of tradeoffs that must be evaluated when calculating the most cost-effective ways to collect data. There are economies of scale savings to be realized if all of the data assigned relatively high values can be afforded within the budget for data collection and associated data processing. As a general rule of thumb, the greater the number of data sets that can be collected from a single source, the smaller the collection cost per set. In addition, collecting as many data sets as possible from one source ensures the integrity of relationships calculated from the data (e.g., autos owned by income group). These advantages favor collecting data at the source that generates the transportation activity (i.e., households and shipper and trucking firms).

   On the other hand, time priorities and budget constraints may dictate other collection methods. For example, an immediate problem of congestion in a given corridor may require priority attention. Or, budget constraints may only permit collecting data relevant to specific high-density corridors rather than data on traffic for the total planning area. In these events, it may be more cost-effective to collect data targeted only on these corridors through license plate identification and mail-out-mail-back surveys, roadside interviews, or parking lot surveys. Smaller samples targeted to these corridors would suffice, as contrasted with household surveys that would require larger samples to pick up observations relevant to these specific corridors, and costs would be less.

   These tradeoffs impose a need for flexibility in the data-collection systems and an awareness of the alternative costs among the various collection methods.
6. Alternative Collection Costs. In order to be in a position to minimize costs over, say, a 5-year data-collection plan, and stay within budget each year, several steps are necessary: (a) Identify the data priorities by year and (b) Identify the various collection methods feasible for collecting the priority data needs as identified by planning year. Examples include household survey, employment survey, shipper or trucking firm survey, roadside or parking lot interviews, license plate identification, and mail-out-mail-back survey. (c) Cost out these alternative methods for collecting the data sets programmed for each year. The costs will vary by sample size required in each collection method depending on the size of the area targeted by the data need, response rates and number of data sets covered by each collection method. Estimates of costs may be based on local experience or similar experience in other planning organizations. The following sources are a few examples that provide estimates of survey sample sizes needed and costs. There are many studies by MPOs dealing with their specific areas, especially on congestion problems; these have been reviewed and references are available upon request to the authors of this report. Also there is an invaluable annotated bibliography as part of NCHRP Project 8-32(1), "Innovative Practices for Multimodal Planning for Freight and Passengers," which is available on loan from the Transportation Research Board. The sources are
   —*Travel Survey Manual*, Cambridge Systematics, Inc., for the FHWA (draft).
   —*Short-Term Travel Model Improvements*, U.S. DOT (October 1994).
   —*Traffic Detection Technologies*, FHWA (draft May 1, 1996).
   —Samuel W. Lau, *Truck Travel Surveys: A Review of the Literature and State-of-the-Art*, Metropolitan Transportation Commission, Oakland, CA (January 1995).

   (d) Finally, select the combination of data-collection methods that will provide data sets programmed for collection in each year at the least cost.

7. Review and Reevaluate Priorities. Sum the costs estimated for the 5-year period. Examine the effect on this total cost of shifting priorities among the years. Shifting the priorities may allow economies of scale—by collecting a broader scope of data from each source. For example, if a comprehensive database of travel throughout the planning area will be needed during the 5 years for long-term forecasting purposes, switching this activity to the first year may obviate the collection of fragmented needs over the 5-year planning horizon.

   If rearrangement of priorities over the 5-year period affords significant cost savings, then it becomes a matter of judgment as to whether switching priorities is feasible. Technical, administrative, or political considerations may make it infeasible. However, at least the approximate cost of maintaining the original schedule will be known and taken into consideration as appropriate.
8. Calculate Cost-Effectiveness Measures and Reevaluate Data Priorities. After the final ordering of priorities for collection of data sets in Step 7 above, costs per data set can be calculated. This would be done by dividing the estimated cost of each data-collection system employed by the number of data sets collected and assigning the average cost so calculated to each data set. The cost-effectiveness measure for each data set would then be calculated as the cost in relation to its effectiveness or value, as previously assigned back in Step 4 of the initial analysis, which reflects the value assigned by the planner/modelers who are users of the data. This of course is not a benefit/cost measure but a simple measure of the relative "bang for the buck" based on the usefulness of each data set as assessed by the practitioners. (Note: Since there are fixed costs in any data-collection system, when more than one data set is collected from a collection source and some highly valued items are included, marginal cost should be used in calculating the costs for the low-valued items.)

Admittedly, the analysis described may be somewhat cumbersome and subject to much judgment. However, it is believed that useful insights will be gained through the discipline imposed by this exercise:

1. Assigning rough values to data needs.
2. Assessing total data needs priorities over a several-year time period.
3. Examining the possible cost savings in covering as many data sets as feasible in each collection effort.
4. Examining possible cost savings in reordering the time value of specific data sets.
5. Eliminating redundant data collections and data sets with low assessed value.

As is often the case, insights gained through the discipline imposed by such an exercise are more valuable for decision making than the specific results of the calculations.

CHAPTER 5

DATA-INTEGRATION ISSUES

INTRODUCTION

This chapter focuses on the issues and implementation strategies associated with data integration, consistency, and sharing. Specifically the objectives include the following steps:

1. Assess similarities and differences and the needs for consistent data for multimodal planning;
2. Develop a comprehensive assessment of data-integration issues to improve data collection and assembly; and
3. Examine data-integration strategies to relate transportation demand, supply, performance, and impact data.

Included in these analytic objectives is the consideration of locational referencing systems, scale and resolution differences, data sharing and access issues, and tradeoffs between the use of primary and secondary data. It is also the purpose of this assessment to be consistent with the Federal Geographic Data Committee's National Digital Geospatial Data Infrastructure Framework.

As has been true for all aspects of this research effort, the analysis and recommendations regarding integration are not independent of the preceding analysis relating to data needs assessment, organization, collection, and economic considerations. Discussions regarding data integration and other issues should not be the last in the series of issues that follows some linear format. Knowledge of integration issues and organizational, as well as state or regional implementation strategies or guidelines, is necessary feedback as part of all data program issues (see Figure 5). Ideally however, the strategies and recommendations already presented (e.g., Business Model, organization framework, data task force, economic evaluations) will have established a solid framework for the implementation of data-integration and cooperation strategies.

The initial focus of this chapter is on the organizational, rather than the technical (i.e., hardware and software needed to implement integration strategies) issues associated with data integration. Without resolution, or at least discussion, of the institutional impediments to integration, issues such as data inconsistency, redundancy, and incompatibility will continue to plague the transportation planning community and technological advances may only serve to initiate minor improvements in integration.

The latter part of the chapter includes a discussion of the use of geographic information systems (GIS) as a tool for integration and presents some of the recent research in this field. The analysis concludes with case studies that describe organizations where integration strategies have been implemented in recent years and which could potentially be useful points-of-contact for other organizations seeking to do the same.

NEED FOR DATA INTEGRATION AND CONSISTENCY

Definition of "Integrate"—to form, coordinate, or blend into a functioning or unified whole; to unite.

The concepts of integrating data within and between agencies, as well as adopting standards to guide the collection and storage of data, are by no means novel concepts in the transportation community or any other public or private organization that encounters data. With a long-standing knowledge and relative lack of activity regarding integration, the question becomes why focus on data integration and, for the purposes of this study, what are the effects of data integration on data collection and organization?

Without question, the two primary reasons for the implementation of data-integration strategies are money and time. If cost and time were of no concern to transportation managers, data needs would be met through primary data collection to ensure the quality and scope of all data. All required resources would merely be used to meet the data-collection requirements. There would be no need for agencies to adapt similar computing systems or collection strategies because no sharing of data would be necessary.

Although many agencies and organizations operate in a manner that would lead one to believe the above scenario is true, the reality is that there is an ever-increasing constraint placed on transportation managers to function under conditions of decreasing resources with faster implementation time and improved results. As expressed in prior chapters, the implementation of ISTEA and the CAAA have increased the analytical responsibilities of transportation professionals and, in-turn, the amount of data that needs to be collected. In addition, the emphasis on multimodalism has thrust many agencies together (e.g., transit authority, commuter rail,

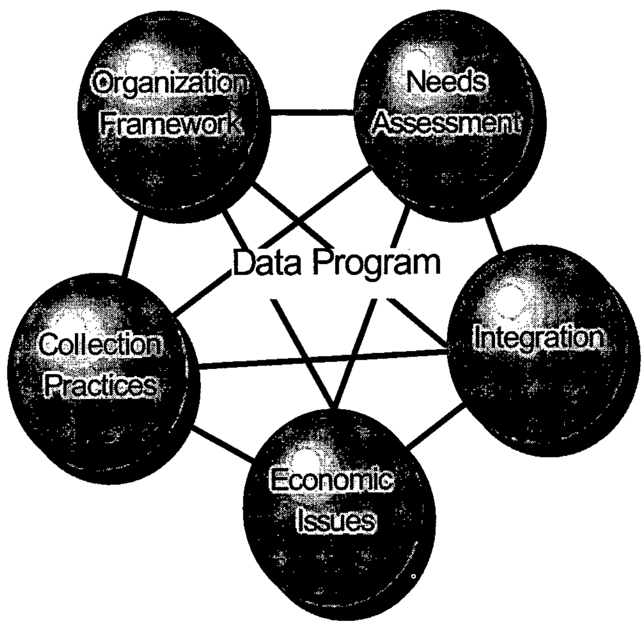

Figure 5. Non-linear format of data program.

MPO) that now must share data to a greater extent than was previously necessary.

This heightened need for multimodal and environmental data that crosses various organizational boundaries has further illuminated the difficulties associated with sharing data within and between transportation organizations. In order to effectively share data, there is an immediate need for the interested parties to be able to access and view each other's data, to understand what is being viewed, and to have confidence in its quality. This need has given rise to various data-integration issues such as data definitions, quality of sampling and collection techniques, and technology applications.

ISSUES RELATED TO DATA INTEGRATION

There exists an extensive amount of literature related to data integration and system integration as they apply to transportation due to the previously mandated Management Systems in ISTEA. Many state, local and federal agencies have spent considerable effort in trying to address data- and system-integration issues. Though the recent regulatory streamlining effort has relaxed the schedule of ISTEA management system design and implementation, there continues to be a need for uniformity and efficiency in both the collection and organization of transportation data, particularly as they relate to intermodal transportation planning.

There are essentially two categories of issues associated with the integration of data: those issues that inhibit data integration and those issues that arise due to nonintegrated data.

The first category of issues relates to

- Data-integration impediments, which include institutional impediments, functional impediments, and technology impediments.

The second category of issues includes

- Unreliable analyses resulting from inconsistent or incomplete data, and inefficiencies in the data-collection, storage, and retrieval processes. The discussion of this subsection focuses on identifying data-integration impediments.

There are multiple problems associated with data integration. For the purposes of this study, constraints to data integration can be categorized into three types:

1. **Institutional constraints**—Multiple organizations within a single jurisdiction often have overlapping data needs resulting in data-collection, storage, and dissemination redundancy;
2. **Functional constraints**—The various hierarchies and cross-types of transportation organizations require disparate though related data, often at varying levels of resolution, to support similar modeling and reporting requirements; and
3. **Technological constraints**—The various hierarchies and cross-types of transportation organizations have different data-storage capabilities, data-dissemination capabilities, and knowledge bases/training resources. Additionally, there is a dynamic evolution of technologies, which makes streamlining the data-acquisition, -storage, and -retrieval processes very difficult. These technologies include the following: networking; low-cost, powerful personal computers; distributed and cooperative computing; client-server network architectures; computer-based graphics; GIS; computer-aided design; object-oriented data structuring; and innovative data-collection technologies.

It is interesting to note the irony involved with the technological constraints. The very technology that has and will enable data integration and sharing to be realized has materialized as a barrier to successful integration. The myriad technologies and software, as well as the increasing power of personal computers, allows individual organizations and departments to operate independent of one another. This can inhibit integration as each entity becomes accustomed to individualized software and hardware.

DATA-INTEGRATION STRATEGIES

There are generally three strategies used to integrate data, each of which addresses, to varying degrees, the three impediments to an integrated system as discussed above. These strategies include

1. A centralized approach,
2. A decentralized approach, and
3. A technology-based approach.

In the first two strategies, data integration relies on the entity that owns and maintains the data. In the centralized approach, one department or group within an organization owns or maintains the data and the user accesses a centralized database system. In the decentralized approach, the user of the data (e.g., the planner) owns, maintains and uses the data. In the third approach, the strategy relies on technology and the entire data collection, maintenance, storage, and user responsibilities are distributed.

The Centralized Approach

Traditionally, data-collection and maintenance responsibilities are turned over to a centralized group, such as a management information system (MIS) department in smaller organizations, or an entire bureau, such as the Bureau of Transportation Statistics, in larger organizations. All data are then accessed via this centralized department.

The Decentralized Approach

The decentralized approach to data collection and storage has been a bottom-up approach where data were collected and stored on an application-by-application basis with the applications largely uncoordinated with each other. This was the approach taken for data collection and organization before the use of computers. With the introduction of, and reliance on, the personal computer, this approach to data storage and retrieval is beginning to once again dictate the decentralization of all data-related activities. From a planning and analysis perspective, decentralized data management may be more efficient. However, there can be gross inefficiencies in both the data-collection and dissemination aspects of traditional decentralization. There is a need for an alternative bottom-up approach or an approach that is decentralized but still workable.

This alternative approach recognizes the requirement for autonomy by the user but provides mechanized centralization. Rather than having an MIS department coordinate data needs and storage, a centralized referencing system could serve much the same purpose. For example, an integrated multimodal information system might include one file with port berthing information and another file with port channel depth information, but the relationship between the two files would be a location reference point.

The Technological Approach

All of the data required by the ISTEA management and monitoring systems, the Hazardous Waste Act, the Clean Air Act, and, in fact, nearly all of the data managed by transportation agencies in general are, or can be and should be, geographically referenced. Therein lies the key to integration.[3]

To date, the most researched technology for integrating transportation-related data is the use of Geographic Information Systems for Transportation (GIS-T). GIS in its narrowest sense refers to specialized software for the management and analysis of spatial data and their attributes. However, in most of the GIS-T-related research performed to date, K. Dueker and D. Kjerne's[4] definition of GIS is cited and expanded upon. Accordingly their definition follows:

GIS is a system of hardware, software, data, people, organizations, and institutional arrangements for collecting, storing, analyzing and disseminating information about areas of the earth.

Thus, the definition includes computing capability and databases; managers and users; and the organizations within which they function and the institutional relationships that govern their management and use of information.

GIS also refers to a new paradigm for the organization of information and the design of information systems. The essential aspect of this paradigm is use of the concept of location as a basis for the restructuring of existing information systems and the development of new ones. The concept of location becomes the basis for effecting the long-sought goals of data and systems integration. Recent research conducted in the area of GIS and GIS-T will be discussed later in this chapter.

It needs to be stated at this point that GIS is not fundamentally necessary to implement data integration. It is merely stressed in this section because much of the related literature and recent management decisions regarding integration have involved GIS-T (see Case Studies). A large centralized relational database that has been inputted with standardized data and has the ability to perform queries that will support transportation planning functions could prove to be an equally successful integration tool. GIS has the advantage of being able to present information and allow data queries at the spatial level. The quote opening this section also points out the additional advantage of GIS, which is that almost all transportation data can be geographically referenced and, therefore, this spatial component can act as the common identifier in a relational database. For this reason, GIS is seen as a logical system when choosing a data management system.

[3] Vonderhoe, A.P., Travis, L., Smith, R.L., and Tsai, V., "Adaptation of Geographic Information Systems for Transportation," *NCHRP Report 359*, Transportation Research Board, Washington, D.C. (1993).

[4] Dueker, K.J. and Kjerne, D., "Multipurpose Cadastre: Terms and Definitions," Annual Convention of ACSM-ASPRS, Proceedings, Volume 5 (1989).

Table 1 Steps to the Strategic Planning Process	
1	Initiate and agree upon a strategic planning process.
2	Identify organizational mandates.
3	Clarify organizational mission and values.
4	Assess the organization's external and internal environments to identify strengths weaknesses, opportunities, and threats.
5	Identify the strategic issues facing the organization.
6	Formulate strategies to manage these issues.
7	Review and adopt the strategic plan or plans.
8	Establish an effective organization vision.
9	Develop an effective implementation process.
10	Reassess strategies and the strategic planning process.

IMPLEMENTATION

Arriving at solutions to institutional impediments will usually prove more difficult than identifying appropriate technological components.[5]

The guidance provided by this research effort should allow individual planning departments to identify and collect the data necessary to optimally perform their transportation planning functions in an isolated environment. Although, as expressed above, the steps which take an organization from data-needs identification to collection to organization to storage are not necessarily linear and mutually exclusive. The logical next step will be to address the issues of data sharing and integration between organizations (e.g., state DOT, MPO, transit authority, etc.) and within organizations (e.g., transportation management, safety, maintenance, etc.).

The focus, however, as stated by the above quotation, should not immediately turn to the technological issues such as the type of hardware and software needed to provide inter/intraorganizational communication and data transfer capabilities. The functional and institutional constraints have been shown through organizational analysis, as well as through conversations and surveys of MPO and state transportation planners, to be, in many cases, the bottlenecks impeding integration, regardless of the technology.

Many issues and obstacles will prove to be more easily overcome once integration strategies have been implemented within and between transportation organizations that address the institutional and functional issues (described above). Further, with technology such as networking, the Internet, software integration (i.e., disparate software being able to communicate and share data with one another), and GIS advancing rapidly, many of the technological problems may be much less overwhelming in the near future. The institutional and functional infrastructure that will allow for successful integration must be in place. Without such infrastructure, there is little chance of integration regardless of the capabilities of the technology chosen.

Organizational Strategy

For the reasons cited above, this section will present an integration strategy that can be applied regardless of the technology that will ultimately be chosen, if any. The strategic process is one that can be applied not only to integration issues, but to most proposed changes contemplated at the organizational level. The strategy or strategic plan,[6] as outlined by J. Bryson, is very similar to the Business Model approach outlined in Chapter 2.

The 10 basic steps to the strategic planning process are shown in Table 1.

Similar to the Business Model approach used for the data needs assessment, the process is iterative and actions, results, and evaluations should occur at each stage. In addition, as eluded to above, the process is technology independent. Regardless of the eventual technology used to implement the strategy, this strategic plan can be used as the tool to implement a desired change. Also similar to the Business Model, the plan is based on an organization's goals rather than processes that are already in place to meet this or other goals or missions. This allows an organization to at least begin the process of establishing the institutional and functional framework necessary for successful integration even prior to the adoption of new technology, if necessary.

[5] Durgin, Paul M., "Issues in Strategic Planning," Proceedings from the Geographic Information Systems for Transportation Symposium (GIS-T), Sparks, NV (April 1995).

[6] Bryson, J.M., *Strategic Planning for Public and Nonprofit Organizations*, Jossey-Bass Publishers, San Francisco, CA (1995).

Task Force

> *When applied to a function or network that crosses organizational boundaries or to a community, the process [strategic planning] probably will need to be sponsored by a committee or task force of key decision makers, opinion leaders, 'influentials', or 'notables' representing important stakeholder groups.*[7]

As was the case with the data needs assessment, the interorganizational and interdepartmental nature of creating an integration environment produces a demand for a committee or task force that has both the ability and the power to make decisions regarding their individual organizations and the integration of all the organizations into a system. In statewide or regionwide transportation planning, problems can arise in establishing a lead role for custodianship of thematic data, creating joint use agreements with local and regional transportation groups, establishing data quality control measures, integrating GIS data from design firms' automated databases, and so on.

In addition, because of the number of organizations that need to be involved and the diversity in their sizes and resources, many state agencies will be reluctant to put in place regulatory requirements for cooperating with network integration. For this reason, the integration process will likely be much more time-consuming and iterative than strategic planning within a single organization and will have to rely more on consent than on authority. Such consent requires interagency cooperation and the role of a task force would be invaluable.

INTEGRATION/COOPERATION/SHARING

As previously stated, integration is not a novel idea in the transportation community. Then given the cost-effectiveness and productivity benefits of sharing data and reducing redundancy and the resulting collecting and processing costs, how can transportation organizations be motivated to begin adopting the organizational, functional, and technological infrastructure and processes that would enable integration to take place?

Funding—One of the obvious answers to this question is to use the one resource that all public organizations are acutely aware of, funding. Linking certain integration requirements (e.g., standardization of data) to federal or state funding requirements should have an overwhelming effect on the participation rate of transportation organizations.

> *Example*
>
> The success of linking funding to integration prerequisites at multiple transportation organizations can be observed in New Mexico's statewide adoption of the New Mexico State Traffic Monitoring Standards (described further under the Standardization section). State and federal funding is contingent on the adoption of these standards by MPOs as well as the state DOT. The standards have been in place for more than 9 years and have been extremely successful at reducing data redundancy, improving quality, and allowing for easier transfer and sharing of transportation data.

Competition for Funds[8]—Competition for available state and federal funding will become more demanding and increasingly dependent upon demonstration of performance in measurable terms. Improvements in data collection, quality, and analysis stimulated through data-integration programs can prove to be an effective advantage in improving the performance of transportation programs.

Cost Effectiveness and Productivity—Although there has been little, if any, work conducted on the costs and benefits associated with data integration, there is an inherent belief that developing an environment that promotes data integration, sharing, and cooperative collection will ultimately reduce or eliminate redundant collection of data, reduce the time spent maintaining data, improve the quality of data, and, therefore, the quality and time spent analyzing data.

> *Example*
>
> An example of the potential improvements that can be realized from a sophisticated and integrated data-collection and storage system can be found in Michigan's recently adopted $20 million management system (described further in Case Studies). Since the adaptation of the system, the percentage of time spent maintaining data has gone from 70 percent to 30 percent, while the time that can now be spent on analyzing the data has increased from 30 percent to 70 percent.

Accountability—Improvements in the public's information access and ability to actively participate (i.e., review and make comments regarding public documents) continue to

[7] Bryson, p. 42.

[8] Southern California Association of Governments, *Monitoring and Information Sharing: An Approach and Conceptual Framework* (Revised September 1994).

advance nationwide. In coordination with this is the increased need for cost-effective and efficient transportation. The result will be increased public pressure to hold the government—state or local—more accountable regarding the use of public funds and expenditure of other governmental resources.

Air Quality and Congestion—If regional air quality fails to improve or degrades, there will be an increase in both public and regulatory pressure to improve air quality and reduce the congestion causing it. If improvements in decision making and analysis can be engineered through improvements in data integration, it could help to avoid some of the unpopular management tools such as pricing mechanisms and lessen the public pressure. In addition, improvements in air quality could lead to a relaxing of regulatory requirements (e.g., lower attainment status) and a freeing up of resources for other management goals.

Implementation by Dominant Data Controllers—In many states, there are only one or two transportation organizations, usually the state DOT and a large MPO, if any, that collects and organizes most of the data for the state. The smaller local and regional organizations play a minor role in the collection process and may rely heavily on state data and resources. In such situations, these major players have the opportunity to shape the data management system into a coordinated and integrated system merely by changing their own system. Their influence over the minor organizations will force them to come on-line with the new system or be left to find other sources for their information needs.

Systemwide Improvements—There are even reasons for data integration that are solely self-motivated. Tangential transportation organizations (e.g., New York State and New Jersey DOTs), as well as state and regional organizations, can benefit from data sharing and cooperation because many of the congestion and air quality problems flow from one region to the next. For example, poor congestion management in Manhattan can cause similar congestion on the in-bound New Jersey side. Data cooperation between the transportation organizations involved (e.g., Port Authority, Path, highway departments, local planning agencies, etc.) can improve congestion on both sides and relieve some of the public pressure caused by congestion.

TECHNICAL APPROACH: GIS RESEARCH

Once some of the institutional and functional constraints have been addressed at each organization and systemwide, attention should focus on the technological systems that will be most useful in meeting the integration goals of the transportation community. This subsection describes some of the recent research conducted in the area of GIS and GIS-T. As was previously expressed, GIS is not vital to the success of an integration system. Rather, GIS is discussed because of its basis in locational referencing and the logical connection to the geographic components of transportation data. In addition, GIS's ability to display data in a geographic environment allows for a more comprehensive and understandable analysis and communication of the transportation data.

National Digital Geospatial Data Framework

The impetus toward GIS has been so pronounced that the USGS has formed a committee known as the Federal Geographic Data Committee. It is the mission of this organization to develop a framework within which to collect, store, and disseminate digital geospatial data. Essentially, the federal government is in the process of developing a large-scale data-integration framework for spatial data. This framework is described below.

The framework is a basic, consistent set of digital geospatial data and supporting services that will

- Provide a geospatial foundation to which an organization may add detail and attach attribute information,
- Provide a base on which an organization can accurately register and compile other themes of data, and
- Orient and link the results of an application to the landscape.

The framework should be widely used and widely useful:

- Framework data should be data you can trust and should be certified as complying with standards.
- Framework data should be the best data available.

Along with these high-resolution data, the framework should contain consistently generalized, lower-resolution data to support regional and national applications:

- Users must be able to integrate framework data into their applications while preserving their existing investment.
- Framework data should be accessible at the cost of dissemination, free from use criteria or constraints, and available in nonproprietary forms.

Additionally, framework data must include geodetic control; digital orthoimagery; elevation data; and transportation (roads, trails, railroads, waterways, airports, ports, bridges, and tunnels). Attributes include a permanent feature identifier and name. Where available, linear referencing systems will be used as the identifier. In addition, roads will have the attributes of functional class and street address range; hydrography; governmental units; and cadastral.

This framework would be operated and maintained by a group of participants who agree to provide digital geospatial data that meet content, quality, policy, and procedural criteria including a data producer, area integrator, data distributor, theme manager, theme expert, and policy coordinator.

Currently, work is underway to develop an implementation strategy. The implementation will be phased, with the goal to have an initial implementation of national geospatial data framework by the year 2000.

GIS-T Research

Within the past 5 years, there has been an increasingly widespread effort to research the applicability of GIS to transportation modeling. Some of the basic differences between the GIS approach to networks and the transportation modeling approach are depicted in Table 2.

Two of the larger GIS-T-related research efforts are described below.

NCHRP Project 20-27—NCHRP Project 20-27 was initiated in response to the need to define the basic structure of GIS-T based on current and anticipated needs and characteristics of transportation agencies. A number of different reports were published in conjunction with this project including *NCHRP Report 359*, and *NCHRP Research Results Digests 180* and *191* (available from the Transportation Research Board, Washington, D.C.).

Pooled Fund Study—The DOTs of 39 states and the District of Columbia combined resources under the sponsorship of the FHWA and the New Mexico State Highway and Transportation Department to create a Pooled Fund Study. The title of the study is "Geographic Information System for Transportation ISTEA Management Systems Server Net Prototype." The purpose of the study is to create a systems architecture and demonstration prototype to address the requirements of the management systems mandated by the 1991 ISTEA within the context of a GIS environment.

The systems architecture will consist of a set of nonproprietary models of the ISTEA statewide and metropolitan planning and project selection and supporting activities from multiple perspectives: data, functional, technological, and institutional. These models will provide an organizational and technology-independent perspective of these functional areas concentrating on providing a consensus-based national framework suitable for individual adaptation and modification. It is intended that these models will be developed using information engineering principles, methods, and tools and will be based on the conceptual framework defined by the NCHRP 20-27 research effort.

There are four phases of this research effort. Phase A has resulted in the following:

1. An entity relationship data model illustrating an integrated database supporting all six management systems.
2. An activity model defining the general areas implied by the scope of the ISTEA systems illustrating an integrated approach to transportation program development.
3. An integrated systems architecture illustrating the data flows between these systems.
4. Evaluation of the Information Engineering methods used in the analysis.

Phase B of this effort, Demonstration and Design, has resulted in the following:

1. A database design, including table and column definitions.
2. System pseudo code outlining an integrated approach to systems development.
3. Evaluation of the software engineering methods used to develop these functional specifications.

The Phase C objective, Demonstration Development, has resulted in the following:

1. Integrated databases, integrated computing networks, integrated software codes, and integrated command and control systems.
2. Specific examples of ISTEA management systems implemented in a GIS-T context.

Phase D, Research Results Transfer, is the method that the Study Team proposes for vendors and consultants to use to sponsor this study.

TABLE 2 Differences between GIS approach and transportation modeling approach

Geographic Information System	Transportation Model
Multi-purpose	Single purpose
Data-driven	Model-driven
Geographic context	Abstract context
Many topologies (point, arc, polygon, network)	Single topology (link-node)
Chain structures	Link-node structures
Spatially indexed	Sort-indexed
Many fields	Few fields

Source: Sutton, J.C. "The Role of Geographic Information Systems in Regional Transportation Planning." Presented at the Fifth National Conference on Transportation Planning Methods Application, Volume 1, Final Report, June 1995.

Benefits of GIS-T and Integration

The most readily apparent benefits of an integrated system arise from the reduced costs of doing business that result from enhanced productivity.[9] The increased productivity is realized through the reduction or elimination of redundant data and the associated collection and organization activities, as well as the updating of multiple databases managed by different units. Other benefits include

- Reduced time/cost of cartographic production and updates;
- Enhancement of thematic maps (e.g., those used for traffic counts);
- Quicker response time in creating new traffic analysis zones (TAZs) or revising existing ones;
- New capabilities (e.g., linking of land use, transportation, and air quality data and models); and
- Increased response time to unexpected events (e.g., emergency evacuation).

The use of GIS can also lead to intangible benefits, which are not immediately apparent until after GIS has been implemented. For example, the mapping and visual display of transportation data (e.g., travel time) can allow transportation professionals to more easily identify problem areas and locations where new data are needed and can ultimately lead to better decision making and better data collection.

Current Limitations of GIS-T[10]

The above discussion of GIS-T and its associated benefits does not mean to imply that GIS is a panacea for all transportation data-collection, -analysis, and -organization problems. The relative newness of GIS as a transportation tool understandably results in some limitations that are associated with the technology and its capabilities.

GIS products provide the means to manage the procedures that link spatial and attribute data. Many of the user-friendly GIS software available are designed as "canned" applications, which give users fewer options or macro tools to develop their own applications, whereas high-performing systems require more training and programming experience.

The following are brief descriptions of common transportation scenarios that may present a GIS system with some difficulty and may prove to be limitations of the system or entail additional GIS editing:

1. Network topology problems—A situation such as a bridge passing over a roadway that does not provide a connection to the road below can present a problem if routing is the primary objective.
2. Network-based route connectivity—Another example where GIS also has difficulty is the situation where multiple transit networks (e.g., bus, light rail, special bus) each operate on the same street with various route constraints. GIS is unable to operationalize the three subnetworks which have different levels of connectivity and topological representation on the base street map.
3. Schematic network integration with GIS—An example of these GIS limitations is evident in situations where HOV lanes are part of the primary highway or freeway. Representing these lanes as offsets would build inaccuracy into the GIS network representation. Problems such as these are enhanced when transit networks are also intertwined (e.g., light rail in the median) and present further difficulties for GIS.
4. Transportation routing—GIS routing is performed node to node rather than at links. If, however, special situations arise such as U-turn, they must be coded individually. The frequency of these special situations can result in an inordinate amount of coding and prohibit GIS routing from being cost-effective.

[9] Vonderohe, A.P., et al., "Adapting Geographic Information Systems for Transportation," *TR News* 171, Transportation Research Board, Washington, D.C. (March-April 1994) pp. 7–9.

[10] Sutton, J.C., "The Role of Geographic Information Systems in Regional Transportation Planning," presented at the Fifth National Conference on Transportation Planning Methods Application, Volume 1, Final Report (June 1995).

CASE STUDIES

Standardization

A necessary first step for successful data integration and sharing involves standardizing the methodologies by which data are collected and organized.

New Mexico—The New Mexico State Highway and Transportation Department has been implementing its Traffic Monitoring Standards since October 1, 1988. The impetus for the development of standards was the problems being caused by multiple definitions for the same data, data being reported from nonworking counters, and incomplete data being filled in various ways and with varying amounts of disclosure.

The standards are annually reviewed and participation is open to all New Mexico transportation professionals in both the public and private sectors. The standards adopted by AASHTO, ASTM, and the FHWA are used as the default standards if a monitoring practice is not addressed by the New Mexico standards. The standards describe acceptable methods for data collection, such as minimum periods for data-collection sessions, sample size, and equipment testing guidelines and operational tolerances.

The key to New Mexico's success in standardizing traffic monitoring practices is its link to funding. In order for traffic monitoring to receive state or federal funding, it must be in compliance with the New Mexico State Traffic Monitoring Standards. If, due to a lack of resources, there is no established standard for a particular monitoring practice, the monitoring must be done at least to the same level as practiced by the New Mexico State Highway and Transportation Department.

The adoption of standards also established an excellent foundation for the rest of the necessary elements for a successful data program. For example, the uniform methods allowed the design and implementation of processing software to be more easily achieved. In addition, the standards provided a common language for characterizing and analyzing statistics in various agency reports.

Data Sharing

Bay Area Partnership[11]—The Bay Area in California covers 7,000 sq mi, includes over 100 cities, and has approximately 6 million residents. The transportation system includes 18,000 mi of roadway and eight primary public transit systems. The complexity of the system was a major impetus for the Bay Area Partnership, which consists of the top managers from 31 agencies responsible for transportation and environmental quality in the region.

The Data Integration Task Force was formed by the Partnership to examine the issues regarding data collected and used for planning and managing transportation, land use, air quality, and other environmental issues. The three primary objectives of the task force included

1. Increase joint use of information and meet multiple needs for data more efficiently,
2. Identify additional data needs and fill data gaps where warranted, and
3. Identify opportunities to streamline current data collection and dissemination processes.

In an attempt to meet these objectives, the task force conducted a survey of many of the agencies within the Bay Area regarding their available data. The result of the survey is a catalog that includes data available from certain agencies and issues related to the data sources such as where the data are reported, the method of collection, and location frequency. In addition, where applicable, it discusses the use of GIS and accessing the information through the Internet.

GIS-T Precedent

Not only are large research studies into GIS-T being performed, but actual GIS systems are being implemented throughout the country. Descriptions of some of these systems being implemented for transportation planning purposes are provided below.

[11] Metropolitan Transportation Commission (MTC), *Data Integration Project Catalog of the Bay Area Partnership*, MTC, Oakland, CA (March 1996).

Michigan DOT—The Michigan Department of Transportation (MDOT) is in the final stages of the development of the most comprehensive Transportation Management System in the country. The project was begun in 1992, and two of its main objectives were to (1) eliminate or reduce duplication and (2) implement GIS. The MDOT has invested approximately $20 million in this two-tier client server system that houses over 600 data tables. The development of the system was a top-down effort designed by users. The data are organized around the management systems outlined in ISTEA and are able to be accessed remotely via modem by other planning agencies in the state.

The new system has already proven to be effective in allowing MDOT professionals to make better use of their time with respect to transportation data maintenance and analysis. The percentage of time spent maintaining data has gone from 70 percent to 30 percent, while the time spent analyzing data has gone from 30 percent to 70 percent.

Similar to the Data Task Force proposed by the researchers as part of the Data Program, the MDOT uses a data committee, consisting primarily of state management system experts, that oversees the cooperation in data collection and decides which organizations are going to collect what data.

Vermont Agency of Transportation (VAOT)—The VAOT is currently developing an integrated transportation information system (ITIS). It is one of the first efforts at an ITIS in a state DOT context. Their goal is to unify databases across separate agency divisions to allow common access to all data and to provide an integrated environment to meet agency needs.

NCTCOG—North Central Texas Council of Governments (NCTCOG) has begun using GIS as part of their long-range transportation planning program for the Dallas-Fort Worth urban area. GIS software is used for spatial analysis, data coding, and attribute display in support of their travel forecasting model. NCTCOG maintains four primary data sets for input to their travel forecasting model: (1) the regional highway network, (2) the regional transit network, (3) zonal attributes, and (4) traffic count data. Prior to implementation of the GIS, maintenance of these data sets required many separate computer programs and considerable manual effort. With the GIS, the data sets can be easily edited and updated using the GIS graphical interface and the results verified using a variety of thematic maps.

Wisconsin DOT—Wisconsin DOT has a expert system-GIS for pavement management. The GIS provides the tools to develop the spatial database required for input to the expert system. The expert system codifies the knowledge and experience of pavement engineers in evaluating pavement condition and making recommendations for maintenance and improvements.

Central Artery/Tunnel Project in Boston—Boston used a GIS as an integral part of the program for automation of project management, engineering, and construction. In addition to preliminary highway design files, final highway design files are produced for the project using a GIS/CADD system. Other GIS applications include generation of soil profiles, identification of right-of-way (ROW) needs and environmental remediation sites, traffic surveillance and control during construction, and identification and mitigation of adverse construction impacts on the community.

Newton, Massachusetts—Newton has been forward thinking in evaluating how to better manage and analyze its planning and engineering data and is currently developing a citywide GIS. Newton built applications within a GIS environment to include traffic assignment, routing applications (such as school bus route generation), network location problems (such as fire station location), and traffic zone reapportionment. In this system, the analytical tools reside as modules within the GIS as opposed to either transferring data through ASCII files to the model or interactively using a common database.

Atlanta, Georgia—The objective in developing a prototype GIS-T was to design a system to help the county agency better manage its transportation program. Application modules included in the prototype are an integrated accident record system, traffic engineering, pavement management, transportation planning and land use, and transit.

Charlotte, North Carolina—A GIS-T was developed to conduct an analysis of inter-area commuting patterns. TransCad was the GIS package modified for this analysis. Traffic was simulated over the network and preliminary forecasts of traffic were made. Additionally, LANDSAT imagery is being used to identify and categorize land uses in alternative corridors for the parkway. The three types of data included in the system are network description and related data, population and employment data, and trip data.

FUTURE OF GIS-T AND INTEGRATION

As exemplified by many of the case studies above, there has been a definite push toward integration and the incorporation of GIS in the transportation community in recent years. Because of the speed with which new technology and software is developed and brought on-line, the future of transportation information systems is somewhat unknown. Some of the possible developments are discussed briefly below.

Movement toward an open system—The diverse number of transportation applications produces a need for tools that can used in coordination with other information technologies to leverage their use most productively, which allow linkages to programs the user desires that may be external to the specific product. In pursuit of this goal, the Federal Geographic Data Committee (FGDC) and Spatial Data Transfer Standards have encouraged GIS vendors to develop software by 1997 that will allow spatial data to be transferred between platforms.

Increased use of object-oriented programs—The Pooled Fund Study described earlier has completed extensive research on adapting an object-oriented approach to GIS. Using the defined objects, the project constructs specific application data models that address transportation problems. One of the primary benefits of the research is that it is providing useful object definitions.

Integration of Intelligent Transportation Systems (ITS) and GIS-T—Although many ITS developers claim that GIS is inadequate for their needs, areas have been identified where the combination of the two technologies may prove beneficial. These include the use of dynamic graphics for traffic monitoring and using GIS as part of real-time customer information systems.[12]

CONCLUSIONS

The regulatory and public pressures demanding cost-effective transportation management to relieve both transportation and environmental problems is rapidly influencing the evolution of transportation information systems. State and regional organizations are quickly realizing that, in order to meet these demands within their diminishing budgets, data integration, sharing, and cooperation can no longer be thought of as a distant reality when technology and resources become available. Steps must be taken today that will initiate the integration process and allow the cost savings and quality improvements in data and analysis to be realized.

Care must be taken not to immediately affix time and resources to addressing the technology issue. Although GIS appears to be where the industry is headed, merely installing a GIS system will not equate to data integration. The main constraints to integration will be found through an institutional and functional analysis, both within organizations and systemwide. The methodology for addressing these issues can be tackled in much the same way as the data needs assessment outlined in Chapter 2. The Business Model and the *strategic plan* to initiate integration outlined above follow the same logical path and it may prove more cost-effective to address and perform both exercises simultaneously.

Integration is also similar to the prior discussions on data needs and organization in that the need for a task force to handle the coordination of the integration process is not only necessary but probably vital to the success of the program. Committees such as the FGDC may handle the standardization of GIS at the national level, but committees are needed to address the institutional and functional constraints at the state and regional levels as well.

[12] Sutton.

Appendix
Suggested Data-Organization Framework

(F) - Denotes freight data

Data Components

Supply Attributes (S)
Demand Attributes (D)
System Performance (P)
System Impacts (I)

Supply Attributes (S)

S.H. Highway

S.H.1 Systems Data

S.H.1.1 Mileage and lanes (total lane miles and number of lanes, lane miles of HOV, intercity highway miles)
S.H.1.2 Capacity (including highway link capacities)
S.H.1.3 Functional road class
S.H.1.4 Nodes and segments (GIS or highway route)
S.H.1.5 Land use data for system expansion
S.H.1.6 (F) Intraurban truck routes (by route number)
S.H.1.7 Other

S.H.2 Service Data

S.H.2.1 Access (connections to other modes, highways, and roadways)
S.H.2.2 (F) Interurban access (GIS or highway route numbers; principal routes for trucks entering and exiting urban areas carrying interurban freight)
S.H.2.3 Intermodal access (rail, water, air, by highway route mile)
S.H.2.4 Data on service providers
S.H.2.5 Fare or fee structure data (tolls, parking)
S.H.2.6 (F) Drayage services
S.H.2.7 Other

S.H.3 Facilities Data

S.H.3.1 Inventory of facilities (bus terminal and stops, rest areas, park and ride lots, truck terminals, intermodal facilities, cargo transfer equipment, etc.)
S.H.3.2 Land use data for use in planning for route modifications, terminal and warehouse locations

S.H.3.3 (F) Delivery and Pickup (On-street, off-street parking by principal intraurban routes).
S.H.3.4 Other

S.H.4 Condition Data

S.H.4.1 Pavement data by highway route (pavement serviceability rating, long-term pavement performance counts)
S.H.4.2 Any data pertinent to condition of routes, bridges, ramps, etc. that affect the efficiency of interurban truck access to the urban area or truck pick-up and delivery activities
S.H.4.3 Age of various road classes
S.H.4.4 Other

S.H.5 Project Data

S.H.5.1 List of all state projects proposed for the next 3 years (minimum) - including funding data
S.H.5.2 List of all metropolitan (MPO) projects proposed for the next 3 years (minimum) - including funding data
S.H.5.3 Major investment data (planned supply augmentation projects)
S.H.5.4 Project history data (past capacity expansion and maintenance, project information such as project dates, type of construction, rehabilitation, etc.)
S.H.5.5 Project evaluation data
S.H.5.6 Planned expansions and modifications
S.H.5.7 Project maintenance data
S.H.5.8 Other

S.R. Rail

S.R.1 Systems Data

S.R.1.1 Miles of passenger and freight track
S.R.1.2 Nodes and segments by rail line (GIS)
S.R.1.3 Capacity and current utilization by principal routes
S.R.1.4 Land use data for system expansion
S.R.1.5 Other

S.R.2 Service Data (Terminals)
S.R.2.1 Access (intermodal access)
S.R.2.2 Cities serviced
S.R.2.3 Percent trains on time by principal routes
S.R.2.4 Passenger service frequency
S.R.2.5 (F) Freight service frequency
S.R.2.6 Data on service providers
S.R.2.7 Fare and fee structure data
S.R.2.8 Other

S.R.3 Facilities Data

S.R.3.1 Number of passenger and freight cars
S.R.3.2 Passenger track miles

S.R.3.3 Inventory of facilities at each stop
S.R.3.4 Inventory of road crossing equipment
S.R.3.5 Intermodal terminals by location
S.R.3.6 (F)Cargo transfer equipment
S.R.3.7 (F)Cargo storage facilities
S.R.3.8 Inventory of infrastructure (e.g., guideways)
S.R.3.9 Other

S.R.4 Condition Data (Systems)

S.R.4.1 Age (cars, tracks, tunnels, bridges, crossing equipment, etc.)
S.R.4.2 Road crossing condition data
S.R.4.3 Bridge condition (by route)
S.R.4.4 Tunnel clearances (by route)
S.R.4.5 Service record (tracks, facilities, cars, road crossing)

S.R.5 Project Data (Systems and Terminals)

S.R.5.1 List of all state projects proposed for the next 3 years (minimum) - including funding data
S.R.5.2 List of all metropolitan (MPO) projects proposed for the next 3 years (minimum) - including funding data
S.R.5.3 Major investment data (planned supply augmentation projects)
S.R.5.4 Project history data (past capacity expansion and maintenance, project information such as project dates, type of construction, rehabilitation, etc.)
S.R.5.5 Project evaluation data
S.R.5.6 Planned expansions and modifications
S.R.5.7 Project maintenance data
S.R.5.8 Other

S.T. Transit Systems

S.T.1 Systems Data

S.T.1.1 Inventory of all routes
S.T.1.2 Capacity and current utilization
S.T.1.3 Route or track miles
S.T.1.4 Vehicle miles
S.T.1.5 Inventory of intermodal connections
S.T.1.6 Other

S.T.2 Service Data

S.T.2.1 Access data
S.T.2.2 Percent on time by transit mode and route
S.T.2.3 Fare and fee structure data
S.T.2.4 Other

S.T.3 Facilities Data

S.T.3.1 Inventory of facilities (garages, park & ride lots, stations, stops)
S.T.3.2 Inventory of transit vehicles (light rail cars, buses, subway cars, etc.)
S.T.3.3 Other

S.T.4 Condition Data

S.T.4.1 Statistics on services performed on all transit mode vehicles (maintenance schedule, service records)
S.T.4.2 Statistics on services performed on all transit mode facilities (maintenance schedule, service records)
S.T.4.3 Historical statistics on services performed on all transit mode infrastucture (e.g light rail guideway)
S.T.4.4 Age of vehicles, facilities, and infrastructure

S.T.5 Project Data

S.T.5.1 List of all state projects proposed for the next 3 years (minimum) - including funding data
S.T.5.2 List of all metropolitan (MPO) projects proposed for the next 3 years (minimum) including funding data
S.T.5.3 Major investment data (planned supply augmentation projects)
S.T.5.4 Project history data (past capacity expansion and maintenance, project information such as project dates, type of construction, rehabilitation, etc.)
S.T.5.5 Project evaluation data
S.T.5.6 Planned expansions and modifications
S.T.5.7 Project Maintenance data
S.T.5.8 Other

S.P. Ports and Inland Waterways

S.P.1 Systems Data

S.P.1.1 Ports (GIS)
S.P.1.2 Inland waterway segments (GIS)
S.P.1.3 Locks and capacity
S.P.1.4 Capacity and current utilization by principal routes
S.P.1.5 Land use data for port expansion
S.P.1.6 Other

S.P.2 Service Data

S.P.2.1 Access by all modes
S.P.2.2 Shiplines/Ferry Service lines serving each port
S.P.2.3 Sailing frequencies by destination
S.P.2.4 (F) Barge lines serving each port

S.P.2.5 Multimodal connections
S.P.2.6 Months river is open
S.P.2.7 Cities/Regions serviced
S.P.2.8 Fare and fee structure data
S.P.2.9 Other

S.P.3 Facilities Data

S.P.3.1 Number of providers (boats/ferries)
S.P.3.2 Number of passenger docking facilities
S.P.3.3 Inventory of passenger facilities at port
S.P.3.4 (F) Cargo transfer facilities by port (including handling equipment)
S.P.3.5 (F) Cargo storage facilities
S.P.3.6 Berth Capacity
S.P.3.7 Other

S.P.4 Condition Data

S.P.4.1 Dredging schedules
S.P.4.2 Docks and berths (age, service records, maintenance schedules)
S.P.4.3 Navigation aids (age, service records, maintenance schedules)
S.P.4.4 Boats and ferries (age, service records, maintenance schedules, U.S. Coast Guard certificates)
S.P.4.5 Channel depth and width
S.P.4.6 Locks (age and maintenance schedule)
S.P.4.7 Other

S.P.5 Project Data

S.P.5.1 List of all state projects proposed for the next 3 years (minimum) - including funding data
S.P.5.2 List of all metropolitan (MPO) projects proposed for the next 3 years (minimum) - including funding data
S.P.5.3 Major investment data (planned supply augmentation projects)
S.P.5.4 Project history data (past capacity expansion and maintenance, project information such as project dates, type of construction, rehabilitation, etc.)
S.P.5.5 Project evaluation data
S.P.5.6 Planned expansions and modifications
S.P.5.7 Project maintenance data
S.P.5.8 Other

S.A. Air (Airports)

S.A.1 Systems Data

S.A.1.1 Runways (number and lengths)
S.A.1.2 Land use data for airport expansion

S.A.1.3 Number of airports
S.A.1.4 Capacity and current utilization by principal routes
S.A.1.5 Other

S.A.2 Service Data

S.A.2.1 Number of providers (airlines serving city)
S.A.2.2 Cities served
S.A.2.3 (F) Freight service frequency
S.A.2.4 Intermodal access and connections
S.A.2.5 Percent on time by airline and route
S.A.2.6 Fare or fee structure (range of prices, prices per passenger mile)
S.A.2.7 Other

S.A.3 Facilities Data

S.A.3.1 Passenger transfer facilities (bus stops, train stations, parking)
S.A.3.2 (F) Cargo transfer equipment
S.A.3.3 (F) Cargo storage facilities
S.A.3.4 Inventory of airport facilities (gates, walkways,etc.)
S.A.3.5 Other

S.A.4 Condition Data

S.A.4.1 Terminal condition data (age, service records, maintenance schedule)
S.A.4.2 Runway data (age, service record, maintenance schedule)
S.A.4.3 Airplane data by airline (age, service record, maintenance schedule)
S.A.4.4 Cargo transfer equipment
S.A.4.5 Other

S.A.5 Project Data

S.A.5.1 List of all state projects proposed for the next 3 years (minimum) - including funding data
S.A.5.2 List of all metropolitan (MPO) projects proposed for the next 3 years (minimum) - including funding data
S.A.5.3 Major investment data (planned supply augmentation projects)
S.A.5.4 Project history data (past capacity expansion and maintenance, project information such as project dates, type of construction, rehabilitation, etc.)
S.A.5.5 Project evaluation data
S.A.5.6 Planned expansions and modifications
S.A.5.7 Project Maintenance data
S.A.5.8 Other

Demand Attributes (D)

D.1 Economic Data

D.1.1 Income data by household and region -- historical, current and projected
D.1.2 Employment data by SIC code and region -- historical, current and projected
D.1.3 Vehicle ownership data by household and region
D.1.4 Travel cost data (e.g., auto operating costs, parking costs, transit fares, tolls, etc.)
D.1.5 Proxy data for projecting income and employment by household, SIC code, and region
D.1.6 (F) Industrial operations (Location, SIC code and employment)
D.1.7 (F) Wholesalers and distributors (Location, SIC code and employment)
D.1.8 (F) Commodity production data by SIC and geographic detail -- historical, current and projected
D.1.9 (F) Commodity consumption data by SIC and geographic detail -- historical, current and projected
D.1.10 (F) Export/import data by point of exit/entry (seaports, airports and highway and rail border points)
D.1.11 (F) Proxy data for projecting commodity production and consumption data (projections of employment, income, etc., by geographic area)
D.1.12 Other

D.2 Demographic Data

D.2.1 Population and labor force data (e.g., population size, density, geographic distribution) -- historical, current and projected
D.2.2 Household characteristics (e.g., household size, number of children, number of licensed members) -- historical, current and projected
D.2.3 Other

D.3 Land Use Data

D.3.1 Acreage data (e.g., acres of land by major use, square footage by major use) -- historical, current and projected
D.3.2 Housing data (e.g., occupancy densities, type distributions, location distributions)
D.3.3 Employment data (e.g., employment densities, type distributions, location distributions)
D.3.4 Access data (e.g., accessibility to services, mix and intensity of services)
D.3.5 Zoning data (e.g., information on zoning restrictions, planned land uses)
D.3.6 Other

D.4 (F) Commodity Flow Data -- (historical, current and projected)

D.4.1 Commodity flow data by O-D
D.4.2 Modal split on commodity flow data by O-D
D.4.3 Factors affecting modal split
D.4.3.1 Relative modal rates
D.4.3.2 Delivery time by O-D
D.4.3.3 Other

D.4.4 Other

D.5 Travel Data

D.5.1 Trip generation data (e.g., person trips by purpose, vehicle trips by purpose, transit trips by purpose, non-motorized trips, etc.) -- historical, current and projected
D.5.2 Trip distribution data (e.g., trip length distributions, trips by time-of-day, etc.) -- historical, current and projected
D.5.3 Special generator data (e.g., tourism, conventions, special events, etc.)
D.5.4 Traffic volume data (e.g., annual average daily traffic, design hourly volume, peak hour traffic percentage, directional split, peak period volume, turning movements, zone to zone modal split, external station traffic counts, etc.) -- historical, current and projected
D.5.5 VMT data (e.g., VMT mix, VMT by functional road class, VMT by time-of-day, etc.) -- historical, current and projected
D.5.6 (F) Shipper modal selection factors
D.5.6.1 Delivery times by O-D
D.5.6.2 Relative modal costs
D.5.7 Other

D.6 Travel Behavior Data

D.6.1 Mode choice data (e.g., air, rail, highway, port, transit fare matrices, parking costs, mode availability variables such as vehicle ownership and percent of houses and jobs within walking distance to transit, etc.) -- historical, current and projected
D.6.2 Route choice data (e.g., network assignment, pretrip planning, out-of-pocket and time costs, etc.)
D.6.3 User preference data (e.g., willingness to pay, rider preferences, carpooling, ridesharing, etc.) -- historical, current and projected
D.6.4 (F)Time-of-day for pickup and deliveries
D.6.5 (F)Carrier behavior data
D.6.5.1 Discriminatory pricing
D.6.5.2 Intermodal agreements
D.6.6 Other

System Performance Attributes (P)

P.1 Safety Data

P.1.1 Incident data (e.g., number, type, location, and duration of traffic incidents, etc.)
P.1.2 Accident data (e.g., number of accidents, deaths, injuries by mode)
P.1.3 Security data (number and type of security incidents by mode and service populations, etc.)
P.1.4 Medical services data (e.g., response time, number of providers, etc.)
P.1.5 Other

P.2 Performance Measures

P.2.1 Highway performance data (e.g., recurrent and non-recurrent congestion, person and vehicle miles/hours of delay, lane and vehicle miles of roadway operating at substandard level-of-service, average system speed, incident location and response, average delay per person/vehicle, etc.) -- historical, current and projected
P.2.2 Transit performance data (e.g., average system speed, on-time performance, vehicle hours per trip, etc.) -- historical, current and projected
P.2.3 Intermodal system performance data (e.g., transfer time between modes, delay along terminal access routes, etc.) -- historical, current and projected
P.2.4 Efficiency data by mode (e.g., load factors per unit of capacity, percent on-time performance, average delay time, percent service interruptions, etc.) -- historical, current and projected
P.2.5 User cost data (e.g., cost per trip and unit of travel, travel time, etc.) -- historical, current and projected
P.2.6 (F) Delivery times by O-D and mode/intermodal
P.2.7 (F) Cargo damage by mode/intermodal
P.2.8 (F) Congestion at terminals
P.2.9 (F) Shipment costs
P.2.10 Other

System Impact Attributes (I)

I.1 Air Quality Data

I.1.1 Vehicle registration data (e.g., vehicle populations by class, fuel type, vintage distributions, etc.) -- historical, current and projected
I.1.2 VMT data (e.g., VMT by functional road class and time-of-day, VMT mix by vehicle class, mileage accumulation rates by vintage, traffic counts by time-of-day, VMT forecasts, etc.) -- historical, current and projected
I.1.3 Speed data (e.g., average speed by functional road class, vehicle class, time-of-day, geographic area, etc.) -- historical, current and projected
I.1.4 Trip data (e.g., number of trips by purpose, cold versus hot starts, etc.) -- historical, current and projected
I.1.5 Impact assessment data (e.g., emissions contributions by vehicle class and pollutant, TCM effectiveness estimates--VMT reduction, etc.) -- historical, current and projected
I.1.6 Interurban emission contribution by mode (highway, rail, air, port) -- historical, current and projected
I.1.7 Other

I.2 Other Environmental Data

I.2.1 Visual and aesthetic impacts (e.g., information on interrupted views, neighborhood view of facility, simulations or drawings that scale facility to neighborhood, etc.)
I.2.2 Noise and vibration impacts (e.g., local noise criteria, etc.)
I.2.3 Ecosystems (e.g., existing wildlife or vegetation resource data, acres of wetlands affected by construction of transportation facilities, etc.)

1.2.4 Archeological and cultural impacts (e.g., inventory of national register sites, aerial photographs and periodicals, etc.)
1.2.5 Parklands (e.g., information on size, owner, and location, accessibility, function, etc.)

I.3 Land Use Data

I.3.1 Socio-economic impact (e.g., information on displacement of residents, dwellings, and businesses, conceptual design drawings, land market value data, parcel mapping, etc.)
I.3.2 Neighborhood impacts (e.g., neighborhood plans, demographic composition, socio-economic composition, etc.)
I.3.3 Other

I.4 Energy Data

I.4.1 Energy consumption impacts by mode -- historical, current and projected
I.4.2 Energy efficiency impacts by mode -- historical, current and projected
I.4.3 Energy price impacts -- historical, current and projected

I.5 Economic Growth Data

I.5.1 Local employment impacts (e.g., expected job creation of transportation projects in local area, etc.)
I.5.2 Regional employment impacts (e.g., expected job creation of transportation projects in local area, etc.)
I.5.3 (F) Access to natural resources
I.5.4 (F) Access to domestic markets
I.5.5 (F) Access to ports and foreign markets

The **Transportation Research Board** is a unit of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. The Board's mission is to promote innovation and progress in transportation by stimulating and conducting research, facilitating the dissemination of information, and encouraging the implementation of research results. The Board's varied activities annually draw on approximately 4,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation.

The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. William A. Wulf is president of the National Academy of Engineering.

The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Kenneth I. Shine is president of the Institute of Medicine.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purpose of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both the Academies and the Institute of Medicine. Dr. Bruce M. Alberts and Dr. William A. Wulf are chairman and vice chairman, respectively, of the National Research Council.

Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
U.S.DOT	United States Department of Transportation

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