MODELS OF MOBILITY
THE OUTCOMES SUPPORTED BY THE DATA WE COLLECT

A WHITE PAPER FOR THE TRB WORKSHOP ON

THE ROADWAY INFOSTRUCTURE: WHAT? WHY? AND HOW?

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Introduction

This White Paper is presented at a time when serious consideration is being given to the creation of a national program of highway and transit monitoring.[1] The paper explores the issue of purpose, posing the question, “What is it that we want to accomplish?” It addresses the ‘why.’ Others will address the ‘what,’ the ‘how’ and even the ‘how much.’ This White Paper is intended to explore *outcomes*, not mechanisms. It will contain no recommendations as to how to collect the information, nor how much to invest to build the capability to do so. Rather, the paper focuses on the purpose and use of the information which would be collected, fused, organized and analyzed in a national program of transportation *infostructure*.

The Ten Year Vision prepared by the Intelligent Transportation Society of America, in cooperation with the United States Department of Transportation, is a good example of the widened vision of the role of ITS technology in the future of the American transportation system. That document called for the creation of “An Integrated Network of Transportation Information,” presented as an example of a second generation of technology application, one in which the broader potential of the impact of the technology can be explored and envisioned.

A national program of transportation infostructure must support a wide variety of applications. The importance of incident management, weather and strategies to minimize congestion will most certainly receive well deserved attention at this conference. The intent of the author is to emphasize the breadth of the issue of the data needed to make the full transportation system work well, and provide mobility to our citizens. This White Paper has been created to focus attention on the broad range of ultimate uses of the data and information. It is particularly important during the early conceptualization of a massive program not to unnecessarily constrain its future application and relevance. At this point in the development of the concept, it is important to place the proposed program in the context of its ultimate application to a wide variety of societal goals and objectives.

The paper will review five models of information flow, and review what is revealed by each of the five attempts to describe the concepts being illustrated by these graphics. Each of the graphic models depicts the process of application of data; in each case, the model depicts the use and reuse of the data in several phases of application.

A roadway orientation or a transportation orientation

This White Paper is concerned with outcomes, with those end states that we seek to influence through the application of ITS technologies and strategies. While the conference itself will focus primarily on the roadway elements of a total transportation infostructure, it makes little sense to narrow the discussion of purpose and outcomes in this manner. A given policy goal to clean the air, to provide mobility to those in need of it, a policy to minimize wasting of energy -- all of these are societal outcomes for the transportation system as a whole. Actions and strategies designed to bring about desired social objectives will involve broad ranges of implementation. As such it makes little sense to examine a long term outcome as a roadway-outcome, a transit-outcome, or even a long distance inter-city intermodal outcome. The paper will examine the stated purpose of the application of the data, as defined in each of the case studies.

Background: Timing of the Application of Empirical Information

It can be argued that transportation planning came of age in the early 1960s, with the creation of the “3C” planning process. At the time, our goals were clear, and the primary use of empirical data was equally clear. In the first half of the 1960s, most American metropolitan areas undertook a large scale survey of origin, destination, and mode. The life of that data was a bit tortured. In a long, sometimes endless process, the results of the assignment process were carefully cross checked with ground counts, and other empirical data. The results of this ground calibration process were promptly thrown away in the creation of the dataset mandated by the law, a description of origins, destination, modes and paths for a design year set some twenty to forty years in the future.

The logic behind this data manipulation was clear: who would want to build roads and transit lines for today’s flows? The desired planning process was a system for the design year in which the extra capacity added would result in free flowing systems. In its life of application, a given empirical fact about the flow of the system was used as a way-point, a mid-step in the process. The ground counts and the time and delay studies, describing the empirical truth about the operations of the network were then inflated and transformed into an honest guess of how the world would be operating twenty to thirty years later. And then the data was applied, and decisions were supported by that honest guess about the future.

We are in the midst of a revolution in the way we look at transportation decisions, and in the way we utilize information to support those decisions. This White Paper examines the purpose of those decisions, and the use of data supporting those decisions.

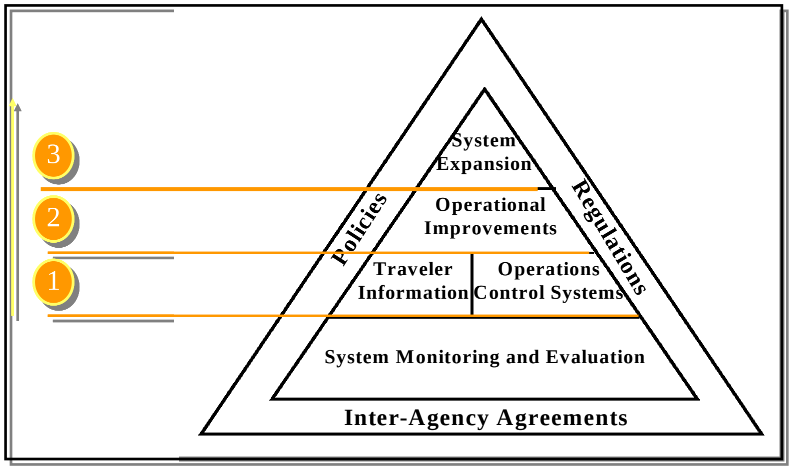


Figure 1, The "Caltrans" Data Flow Model

FOUR MODELS DESCRIBING THE APPLICATION OF SYSTEMS MONITORING DATA

Our concern at this point is to establish a relationship between the process of monitoring the operations of the system and the policies and actions the process is meant to support. Four case studies are presented and reviewed. In each case, we seek to understand the relationship between the results of the system monitoring, and the outcomes they are designed to bring about. (Later in the text, with a focus of attention on the use of "archived data," a fifth model will be examined.)

The Caltrans Model

The Caltrans model has been used extensively in the recent dialog on operations to show how the use of data primarily to serve the long term forecasting process has been reversed.[2] It shows simply and clearly the "path" of utilization of a given set of information over time. As the system is monitored, the information is processed for immediate use in two very different formats, shown on level one. It is processed for immediate use in traffic control and traffic management; the same information is processed in somewhat different form for use by the end user/traveler.

On the second level up in the diagram, that same information is now used again, but out of the context of real time application. It is used to design and establish operational improvements, which might range from the change in timing of a given signal, to the construction of modified geometry.

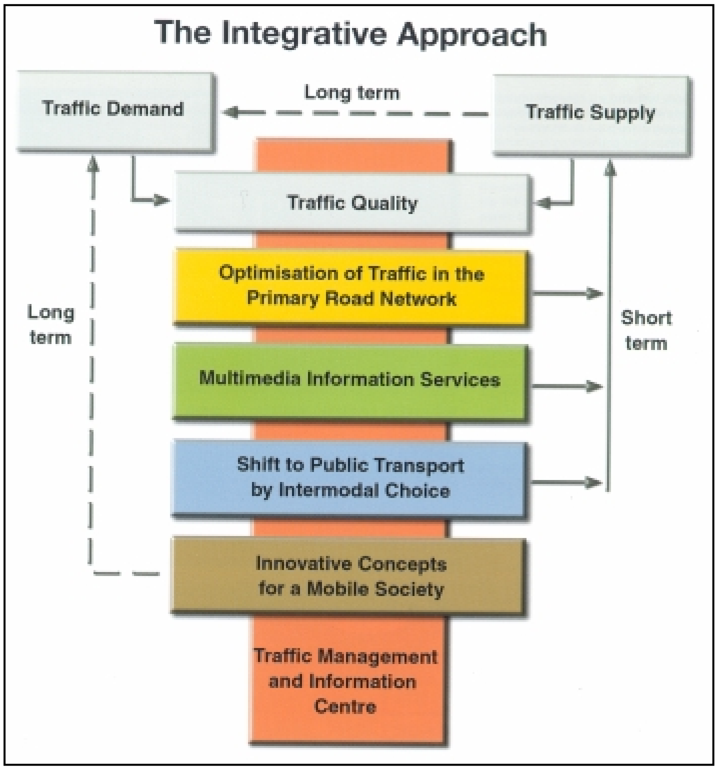


Figure 2, German Mobinet Data Flow Model. Source: BMW

Finally, at level three this same data proceeds to the top of the "triangle." The information originally used for operations and information, then used for near term alterations of the system is now applied to the longer term issue of system expansion, and additional capacity. Effectively, the application process of the data has been turned upside down from that mandated in the 3C process in the 1960s, when the data was seen primarily for its usefulness in the long term capacity addition, and less for its immediate application.

The Caltrans model is reviewed here because it shows that we should be wary of any quick summary that asks us to chose between a data collection program designed for operations *versus* a data collection for planning. In the Caltrans diagram, data created in the monitoring of the system is processed for use in the analysis of near term investments, and long term investments. The diagram is effective at depicting that it is one process, not an either/or situation. Note also how the diagram surrounds this description of data application with an outer layer emphasizing the unifying elements of multi-agency cooperation, polices and regulations.

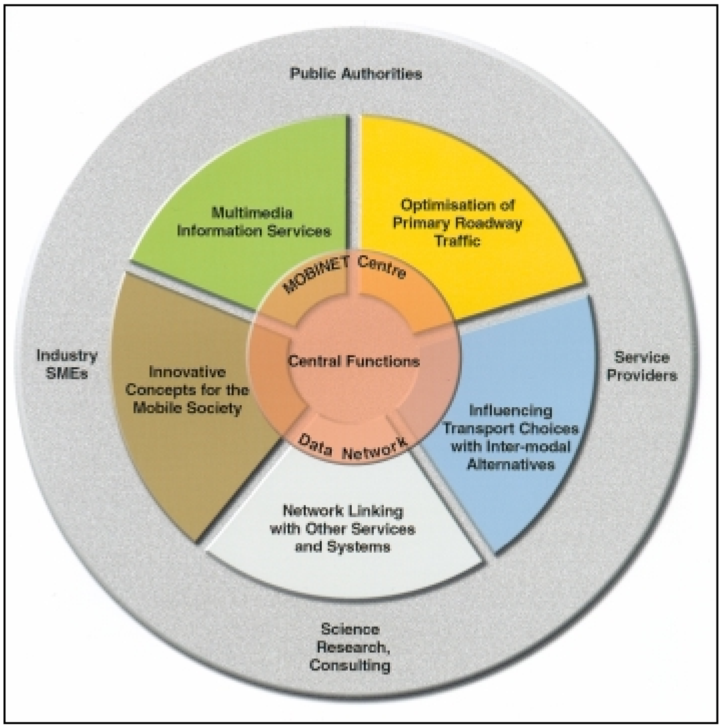


Figure 3, The German Mobinet Process Model. Source: BMW

The Mobinet Model

In Munich, Germany, a consortium information system designers worked to convey a very similar message in the creation of graphic depictions of the flow of information in their local program of transportation infostructure.[3]

The first German Mobinet diagram is presented here as Figure 2. Like the Caltrans model, it serves to emphasize that some elements of the program have their impact in the short term, while the same database is used to support strategies with longer term implications and timeframes. The "backbone" of the diagram is the program of the "Traffic Management and Information Center," roughly paralleling the functions of a National Program of Transportation Infostructure.

Superimposed over the backbone of data created in the monitoring of the system are a series of strategies. In the short term, these strategies seek to "optimize traffic," get information to the end user/traveler, and cause a shift to public transport by the application of intermodal strategies.

In the long term are a series of strategies designed to lower overall travel demand, which they call "Innovative Concepts for a Mobile Society." This category incorporates what we refer to as Transportation Demand Management, and the general category of longer term steps needed for demand reduction.

Comparison of the German Mobinet data flow diagram with the Caltrans diagram reveals both common content, and differences of expressed policy interest. Near term uses of the German data system include direct application to roadway operations, and getting information to the traveler. While the Caltrans model refers next to "operational improvements" in general, the German model specifies that these near term strategies are aimed at moving travelers to public transportation modes. And finally, both support strategies to change transportation characteristics in the long term.

A major difference between the American and the first German diagram is the emphasis in the Caltrans diagram on the role of inter-agency policies and regulations. This must have also occurred to the German team, as they created a second graphic diagram to illustrate the process of the program, as shown as Figure 3. Importantly, this refined graphic image identifies the importance of a collaborative approach between public and private, emphasizing a similar theme from that contained in the Caltrans diagram. Just as the Caltrans model "surrounds" the technical steps with the concept of interagency agreements, etc., the second Mobinet model surrounds the technical process with an outer ring illustrating the collaboration between agencies, operators, industry and researchers.

Within the center of the diagram is the common data source utilized by all of the sectors shown in the circle diagram. In the next "ring" a data network is described that is both specific to each strategy and reliant upon a common data base. Again, both the short term and long term applications are emphasized as dependent upon the data in the central data network.

TCRP Collaboration Diagram

In two recent TCRP Studies, the Mobinet ring diagram was adapted to American policies and procedures. In the ongoing TCRP Study, "A New Vision of Mobility: Guidance to Foster Collaborative, Multimodal Decision-making" [4] the Mobinet diagram was modified slightly to reflect uses of systems monitoring data currently in use in the United States. The long term changes are described as "Land Use Management" while the German category "Influencing Transport Choices with Intermodal Alternatives" has been renamed as "Mobility Provision."

Figure 4, The TCRP "Collaboration" Model

The TCRP "Collaboration" model was based on the examination of the issues actually being addressed by American transportation managers and planners. The research suggested that this kind of data needed to be applied in:

Operations and infrastructure management,
Mobility provision,
Economic and policy strategies,
Environmental strategies, and
Land use and other long term strategies.

The TCRP diagram of "Collaboration" examines the concept of outcomes somewhat more broadly than the previous two models. Modeled after the Mobinet ring and sector diagram, the set of outcomes reflects the major issues that the American transportation manager is tasked to deal with. A common information system is needed to support such well documented areas as roadway operations, and the provision of public mode services. That same information base is needed to develop economic strategies (economic development, tourism, welfare to work), environmental strategies (minimized VMT, minimized energy consumption) and longer term TDM type strategies (sustainable land use patterns, conditions supportive of walking, etc.).

The diagram is designed to show how a common source of information forms an integrated base for decision making in a wide variety of outcome areas.

The I-95 Corridor Coalition Diagrams

Recently, during the development of the Strategic Plan for the I-95 Corridor Coalition, a highly simplified model was developed to show the multiple paths that the Coalition must follow in carrying out its broad work program. [5] The work of the Coalition is highly relevant to the subject matter of this conference, because of its focus on a national program. The Coalition has been wrestling with the difference between issues of multi-state/regional importance, and the issues that are local in nature. Similar differentiation between legitimate local roles and legitimate national interests will be faced in the development of a 50 state system just as they are now being addressed in the development of a 14 state system.

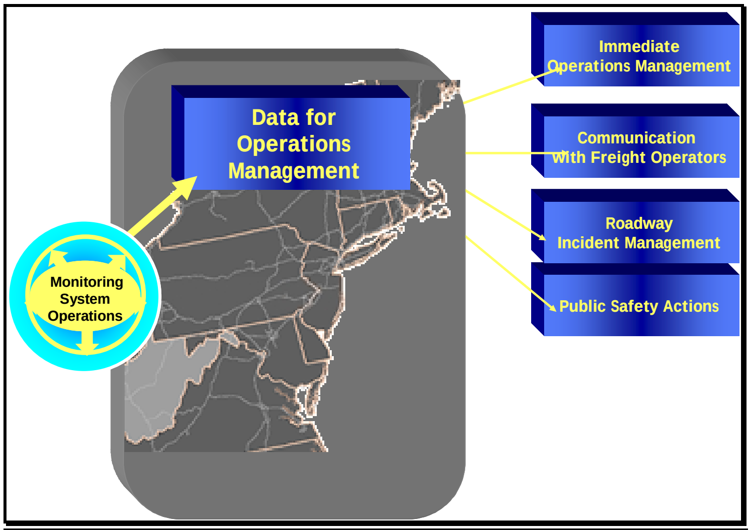
The I-95 "model" follows the data collected to monitor the operations of the system, and shows three separate "tracks" for that original, unprocessed data. Each of the three diagrams shows the relationship between that track of activity and the outcomes that are relevant to that particular action or strategy.

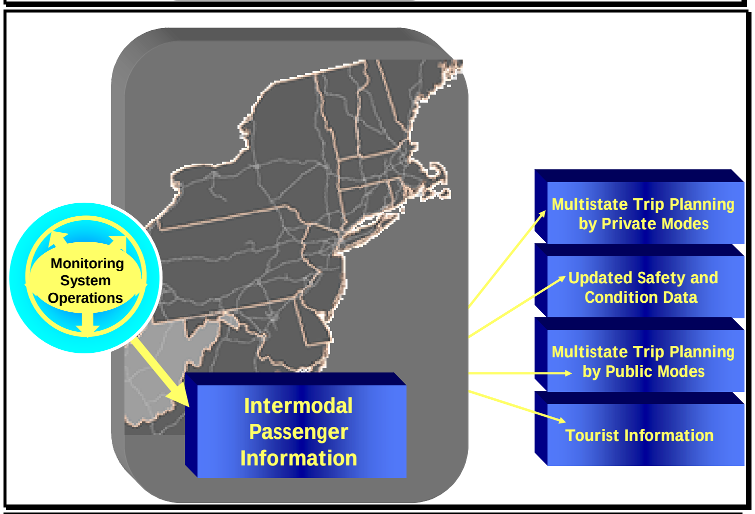
In the top diagram, data about performance and condition is sent as directly as possible to the network of operations managers. (A sudden back up of vehicles in New York State is communicated instantly to the managers in Connecticut.)

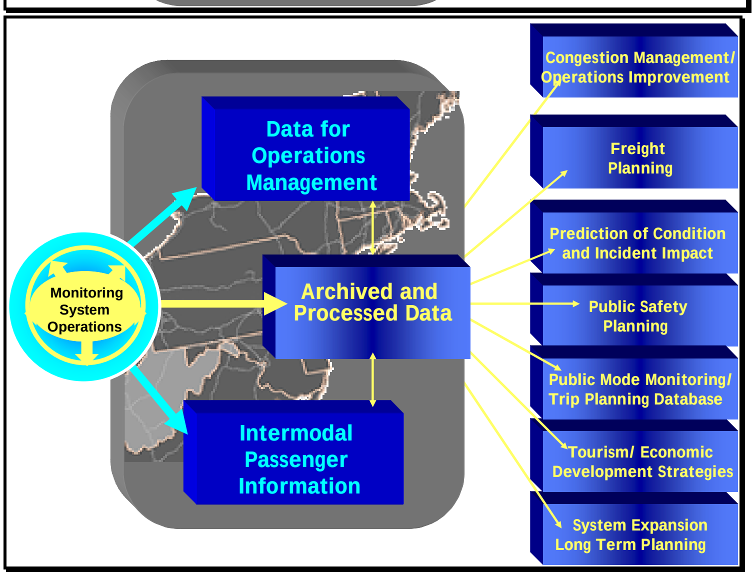
In the middle diagram, data about the performance and condition of the system is transmitted in one form or another to the end-user/traveler. (News about a northbound lane closure in Philadelphia is communicated to users in Delaware.)

In the lower diagram, the same raw information is archived and organized in a manner that will make it useful to a wide variety of applications, including the long term system expansion that once dominated the planning process. On the following page is shown the relationship of the three tracks, and the three ways that the data is processed. Each of the outcomes listed on the right hand side of the diagram represents a significant issue area being addressed by the Coalition.

Models of Mobility: The Outcomes Supported by the Data We Collect







Seven categories of outcomes for the use of the archived data are spelled out in the I-95 diagram. They are (from top to bottom)

- Operations management, both immediate and near term
- Freight management, both as the recipient of real time information and in terms of longer term planning
- Roadway incident management, in terms of immediate action, communications to the traveler, and the ability to predict flow conditions
- Public safety actions, in terms of information to the managers of public safety/security, in terms of information to the traveler, and in terms of the ability to undertake planning and simulation of emergency activities
- Information on the status of public mode services, and the ability to support multimodal long distance travel planning by public modes
- Information to support tourism and economic development, both in terms of immediate information about destinations, and accessibility and access in the longer term
- Support for long term transportation planning of both operations and capacity expansion

The Coalition is currently developing the capability to undertake network analysis of the travel flows of the 14 state region, based first on empirically observed, calibrated trip times documented for the links of the system. The analysis of the functioning of the system will first occur using stored and synthetically reconstructed flow and condition data. At a later point, it will be further populated by “real time” information.

The breadth of the applications described in the third diagram emerges as a central concern of this White Paper. The extent to which the transportation management process is dependent upon the content of the “archived,” processed data has been a major observation in the I-95 Corridor Coalition work. The seven categories represent areas where the Coalition has been involved, and are not intended to be a comprehensive list of the use of or need for archived ITS data.

Building an Information System to Serve Specific Societal Objectives

The transportation managers and planners in the 21st century cannot carry out their complex mandates without an understanding of the societal outcomes in place in the area of their work. There are areas where policies are driven by environmental mandates, and areas where they are not. There are rural areas in this country where congestion on the roadway is not an issue, and getting people to spend money at small bed-and-breakfasts is an issue. A traveler information system in Northern Virginia has the task of discouraging from using “the Beltway” at certain times. A traveler information system in Southwestern Virginia has the task of encouraging travelers into the Shenandoah Valley, and helping people to understand the variety of tourist destinations available to them. *The two systems serve different societal outcomes.*

But, at base, the demands on the Integrated Network of Transportation Information may be quite similar in either case. In the case of the congested urban area, the Integrated Network should reveal options for both path and mode. In the case of the rural tourist destination, the Integrated Network should reveal options for both path and mode. In Vermont, the state wants to encourage skiers to come to Stowe, and it heavily subsidizes a train service from New York City to Stowe. The Integrated Network of Transportation Information should reveal to the consumer at the time of trip planning the options available for the trip, including details about expected roadway conditions, and details about bus and rail alternatives to that auto trip.

A pre-requisite to a such a full system of information is the creation of base case descriptions of the expected operations of the transportation system, which must include both roadway-based and public mode operations. These must be accurate by time of day, and reflect variation by season of the year. Part of this base case description of operations is derived from calibrated, historically accurate roadway travel times; the other part of the base case description of operations is derived from published routes, schedules and other forms of public mode service description. A key to the strategy is the understanding of the simultaneous operation of both the private auto-based and the public mode-based systems seen and analyzed as *one transportation operations network.* Armed with the understanding of the expected (base case) operations of the system, the analysis capability can interpret the meaning of the real time information, particularly when it reports a deviation from the expected operation. In many cases, this information must be presented to the traveler while en-route.

The Importance of "Transportation Systems Structural and Historical Data"

What emerges from this quick review of the *purpose* for which information strategies are applied is the importance of the creation of a static description of the expected operations of the system, specific to time of day, etc. The Ten Year Vision speaks eloquently to the need for "structural and historical data," which is often the codification of information initially used for a real time purpose. Describing its program for "Transportation Systems Structural and Historical Data," the document states

> "With appropriate planning and incentives, a database of foundational information will be built. This foundation starts by organizing and integrating, from multiple sources, basic data about the transportation system: what roads, rails, transit routes, freight terminals, commercial vehicle checkpoints, toll collection facilities [exist] … This will be augmented with historical performance data… to the extent that such information can be located, gathered, translated and stored."[6]

The importance of building up an accurate description of the functioning of the network, *before* its expansion to accommodate real time information, was emphasized in the ITSA Ten Year Vision,

> "Once the basic database is built and the historical database started, the network can be expanded to incorporate real time information on what the system is doing and how it is performing across all modes… Strong links will exist between the real-time data collection system and the historical database system, with historical information augmented and refined through actual experience and real time predictions made in the context of historical experience." [7]

Consistent with this observation, it is worthwhile to note that what we often refer to as an example of "real time" information is in fact a highly sophisticated *description of the expected operation of the base case*, to which a small amount of real time information is added as needed. But the real time information has optimal impact because of its use in the context of the carefully constructed description of the expected conditions of the system. Two examples follow.

The static base case network at London Transport Bus

In London, a sensor notes that a bus is approaching an intersection. The Automatic Vehicle Location (AVL) system does *not* send a message to the signal timing system at the intersection to grant priority to the bus; rather, it checks the exact location of the bus against where that bus is supposed to be in the expected base case. Then, if the bus is behind schedule, and if the total system would benefit from that bus returning to its schedule, the message is sent to the intersection signal to grant priority or even pre-emption to the bus. At the heart of this system is *a precise description of where every bus is scheduled to be at any given minute, a comprehensive description of the expected operation of the system.* Against this application of static data, the real time information can be compared, and an operational decision made in real time. All the while, this is based on what ITSA calls the "structural and historical database," (which we call simply static data) about the operations of the system.

The static base case network at FedEx

At the base of these information systems is a solid description of, expected conditions. Mature infostructure systems are in daily operation at FedEx and UPS, just to name the biggest. When you wish to send a package from rural Vermont to a small town outside of Bangkok, or the smallest town in Alaska, the overnight parcel carrier has a database that knows *precisely, exactly* what routes and services are in the system and, conversely, what connections cannot be promised. The company then enters into a contract with the customer that the package will be delivered by 3 PM on Tuesday. Importantly, *none of this is "real time" data.* At 3 PM on Tuesday, the customer can ask who signed the receipt of acceptance of the parcel, and this is based on real time tracking. But the contract was based on very precise understanding of the expected operation of the network, which itself was based on the empirical observation about what travel times can and cannot be guaranteed in Thailand or rural Alaska.

Development of a static base case network for the National Infostructure

A national system of "foundational information" must document the expected travel times for major roadway segments, by time of day. It must include a good static description of the routes and services operating serving every bus stop. It must facilitate the integration of the itinerary trip planning systems of the long distance carriers with the itinerary trip planning systems in the major metropolitan areas, and develop descriptions of services for all the areas not covered by itinerary trip planning systems. In the words of the ITSA Ten Year Vision, the program needs to support "true multimodal trip and itinerary planning for urban, rural and intercity travel. System, agency and political boundaries should be invisible to users as they ask about their door to door trip."[8]

The opening step in the creation of a national infostructure requires the creation of the description of the expected operation of the system, specific to time of day, specific to weather condition, and planned events in the area. Only then can we meaningfully deal with variations from that expected condition set. A key to the ability to predict condition and speed is the ability to document the history of travel speeds at a particular site. Prediction, when it is fully mature, will be applied on a real time basis, based on a process of calibration from historic variation in travel time for that facility and that environment.

The Role of Archived Data Relative to Societal Outcomes of the Planning Process

Fortunately, the importance of careful processing of monitoring data for use in later transportation management functions is well understood by leaders in our profession. Of interest to this paper is the breadth of purpose, and the variety of outcomes that are supported by the application of so-called "archived" data. The process of "recycling" the data used in real time observation for use throughout the transportation management process has been labeled "Archived Data User Services" (ADUS).

The role of archived data, when supplemented by "Real Time ITS Sources" is well illustrated in the flow chart included in the "*Strategic Plan for the Development of ADUS Standards,*" reproduced here as Figure 6. [9] The diagram shows how the real time data is processed with the help of the archived data services, resulting in predicted travel condition data. That, in turn, is utilized in a variety of applications consistent with the set of outcomes discussed in this White Paper. Those outcomes listed in Figure 6 include safety, land use, and air quality as well as long term planning. Importantly, the ADUS diagram also points out the importance of this historically calibrated information within near term

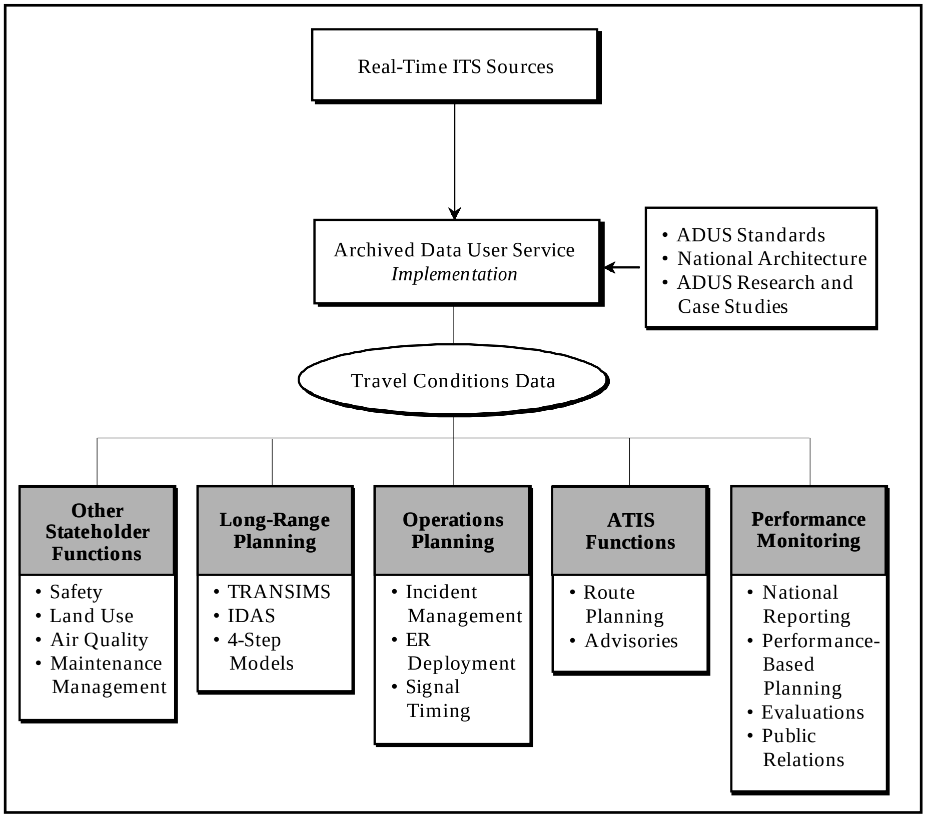


Figure 6, Data Flow Diagram from ADUS Strategic Plan. Source: Cambridge Systematics, 2000

operations management (e.g. incident management and signal timing) and in traveler information (ATIS).

Once the “foundational” description of the multimodal system is underway, the addition of real time information can complete the picture. The static description of the system allows the realistic documentation of those services which are deviating from the expected pattern of operations. In Gothenburg, Sweden, an entire city department is devoted to the design of real time passenger information to the users. When a specific bus is delayed by an incident, information is presented on the bus to show alternative routes, paths and modes for consideration by the traveler. This example shows that the information system goes far beyond reporting the incident, and predicting the delay, to include an analysis of where those particular bus passengers were going. This is based on an understanding of the static base case system on which the alternative paths are proposed. It is when the information about the deviance from the expected condition is set in the context of the historically accurate description of the full system that the full synergy between the two kinds of information can truly occur.

The Most Important Outcome? The Most Important Purpose?

At this point, it is not necessary to foresee all of the uses that will develop for the data collected and organized in an Integrated Network of Transportation Information. But, over the long term, it may evolve that the creation of a working description of the expected transportation operations of the multimodal system proves to be most important for our ability to work with others, with other disciplines and other responsibilities.

It is often worthwhile to conceptualize our work in transportation information as *one of several layers* of a multidisciplinary Geographic Information System (GIS). When there is an accident, a professional in the public safety arena works with the data and tools in his/her *layer:* how many hospital beds within 10 minutes of the accident? Are the emergency rooms consistent with the needs of the persons in the disaster? The safety or security professional then reaches into our layer and asks, given that the road is closed because of the accident, what are the alternate paths? What are the travel times to the incident scene? And what are the paths to those candidate hospitals?

Our job is to provide just one layer, the transportation layer. *But it had better be a good, and accurate layer.*

Most of the managers of transportation will not be expected to be experts in the location of hospital beds, nor the size of emergency rooms. Nor will we be expected to be experts in the flow of fluids through the water and drainage systems of our city, or the dispersal patterns of plumes and vapors. We are not asked to understand the locations of disease outbreak, nor even the location of persons needing to be connected with jobs. But each of these represents an example of a layer within a multilayer Geographic Information System. *And the managers of most of these layers will need to utilize the transportation layer at some point in carrying out their duties.*

In a time of emergency, transportation facility characteristics, capacities, and expected travel times under a variety of emergency demand assumptions will all be needed. This understanding of the operations of the system will be needed first to portray its expected, base case operating characteristics. And then, with the arrival of the real time data, the managers can begin the process of predicting the impacts of the developing situation, and of possible alternative actions and strategies.

In this White Paper, we have been concerned with the *purposes* of national and local programs for increased monitoring and data collection describing the operations of the system. We have reviewed lists of *outcomes* associated with various programs that utilize the information gained in the monitoring of the system. It is critical that the development of the a national program of transportation information place a high priority on the transformation of immediately applied information into a format that can be used in wider, longer term applications of the data.

The breadth of these applications is potentially so wide ranging that we cannot even attempt to predict all of them. But it is clear that the *content* of this information must not be driven by the sophistication of the technology that is required to prepare it. The methodical collection of static data describing travel times, by time of day, is one key transition to the needs of the rest of the information driven process. Similarly, public modes routes, schedules and fares must be systematically documented in the national program. Importantly, this data is already commonly available, but it is cursed by the formatting differences that preclude its effective integration. This White Paper concludes that the creation of this "structural and historical…database of foundational information" is the necessary precondition to the full utilization of the infostructure in influencing the kinds of outcomes discussed here.

Conclusion: The Purpose of the Program

The "purpose" of a national program of information will be determined by the needs of each of the component elements, which, when aggregated together, make up the national program. The purpose of advanced information systems in Phoenix will be fundamentally different from the purpose of systems applied in Portland, because the stated goals and the very definitions of mobility are different. But it is clear from this review of alternative approaches to the application of the data that many of the outcomes valued by society will derive optimal benefit from the new "real time" information only when it is merged with full, complete, and accurate descriptions of expected system operations. These network simulations will, by their nature, be built up from static, historical data of condition and performance. The development of these capabilities should be an immediate priority.

Shifting from the analytical tools designed to expand capacity 30 years in the future to the analytical tools that will predict the operations of the system this afternoon at 5 PM will require money, training, and, most of all, commitment. But it has to be done if our program of system monitoring is to be appropriately linked with the policy outcomes our society is committed to. It demonstrates once again the importance of a closer integration between the world of ITS technology, and that of the established planning process.

Footnotes

[1] While this paper has been created to discuss the purpose of a national program of monitoring of the highway and public mode system in general, it has benefited from the presentation by Jeff Paniati of the Joint Program Office, entitled *Meeting the Information Needs for Surface Transportation Operations: The INFOstructure,* 2002

[2] The diagram was created at Caltrans, it has been extensively interpreted by Dr. Michael Meyer as part of his on-going work for FHWA. The arrows highlighting the three layers showing the direction of data flow were added by the author.

[3] The Mobinet program is actually a collaboration between government and business leaders in Munich. The diagrams are taken from a CD ROM. That CD states that "all copyrights for "Research at BMW: Telematics" are held by BMW, A G."

[4] The diagram was originally created by the author for the TCRP Study, J-08 "*New Paradigms for Local Transportation Organizations.*"

[5] The three diagrams were created by the author for use in various management seminars held in support of the development of the Strategic Plan, 2001.

[6] ITSA, *National Intelligent Transportation System Program Plan: A Ten Year Vision,* page 47

[7] *ibid*

[8] *ibid*, page 41

[9] Cambridge Systematics, *Strategic Plan for the Development of ADUS Standards,"* 2000