Arizona Department of Transportation Information Data Warehouse Application: Evaluation of HERS/ST as a Data Source Component

Final Report 529

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16. Abstract

This report was prepared by a team of graduate students in the Management Information Systems Department at the University of Arizona. The purpose of this project was to:

- Determine if the Highway Economic Requirements System (HERS) analysis program is suitable for use by the Arizona Department of Transportation;
- If not, determine if it could be made suitable with some manageable modifications; and
- If no manageable modifications seem reasonably workable, recommend a path the Arizona Department of Transportation should take for achieving its asset management objectives.

The team concluded that:

- The Highway Economic Requirements System, even when modified for the Arizona Department of Transportation environment, will not meet Transportation Infrastructure Asset Management requirements and is not a product on which to base an On-Line Analytical Processing (OLAP) System from either a user or an organizational viewpoint.
- A model framework for an analysis that can be a start for achieving Arizona Department of Transportation asset evaluation needs is the Transportation Economic and Land Use System (TELUS).

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METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	2.54	centimeters	cm
ft	feet	0.3048	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
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mi^2	square miles	2.59	kilometers squared	km^2
ac	acres	0.395	hectares	ha
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oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		VOLUME		
fl oz	fluid ounces	29.57	millimeters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0328	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

Note: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

These factors conform to the requirement of FHWA Order 5190.1A

*SI is the symbol for the International System of Measurements

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
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yd	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
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		MASS (weight)		
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kg	kilograms	2.205	pounds	lb
Mg	megagrams (1000 kg)	1.103	short tons	T
		VOLUME		
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L	liters	0.264	gallons	gal
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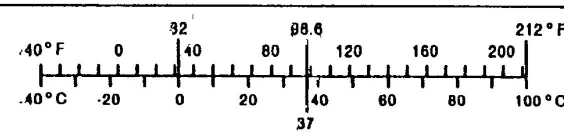
m^3	meters cubed	1.308	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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EXECUTIVE SUMMARY

The Arizona Department of Transportation (ADOT) is in the process of implementing an Asset Information Data Warehouse. The Arizona Department of Transportation invests hundreds of millions of dollars annually on the construction, enhancement, rehabilitation, and maintenance of multi-billion dollar assets for public use. The Arizona Department of Transportation wishes to effectively leverage information, in addition to engineering data, and apply it towards making better investment decisions. The Asset Information Data Warehouse (AIDW) will be used as a decision support system for Arizona Department of Transportation projects. Ways in which the Asset Information Data Warehouse information will be used are needed to effectively prioritize, propose, and provide performance feedback for Arizona Department of Transportation programs.

This report was prepared by a team of graduate students in the Management Information Systems Department at the University of Arizona. The purpose of this project was to:

- Determine if the Highway Economic Requirements System (HERS) analysis program is suitable for use by the Arizona Department of Transportation for establishing priorities and managing assets;
- If not, determine if it could be made suitable with some manageable modifications; and
- If no manageable modifications seem reasonably workable, recommend a path the Arizona Department of Transportation should take for achieving its asset management objectives given the internal data system available and the data warehouse under development.

The team gathered information from the Arizona Department of Transportation management and other users of information. Plans and the existing status of Asset Information Data Warehouse, the legacy databases, and the other databases within the Arizona Department of Transportation to be used were assessed to better understand the body of data available and the specific goals of Transportation Infrastructure Asset Management (TIAM). The Highway Economic Requirements System computer program was evaluated (Section 4) and operated (Appendix A) to determine its methodology and applicability for meeting Transportation Infrastructure Asset Management needs as well as prepare operating instructions. Searches were made to identify other analysis packages that could meet Arizona Department of Transportation requirements.

The team concluded that:

- The Highway Economic Requirements System, even when modified for the Arizona Department of Transportation environment, will not meet Transportation Infrastructure Asset Management requirements for managing all of the Arizona Department of Transportation assets (highways, bridges, aviation, transit, other) and is not a product on which to base an On-Line Analytical Processing (OLAP) System from either a user or an organizational viewpoint.

- A model framework for an analysis package exists that can be a start for achieving Arizona Department of Transportation asset evaluation needs. This package is the Transportation Economic and Land Use System (TELUS) and was developed by the Institute for Transportation, New Jersey Institute of Technology, in conjunction with the Center for Urban Policy Research at Rutgers University. The Transportation Economic and Land Use System is available free to state Departments of Transportation.

The team recommends that the Arizona Department of Transportation develop a System Requirements Document for the On-Line Application Processing to be used with the Asset Information Data Warehouse and also investigate the Transportation Economic and Land Use System model framework further with the goal of incorporating it, or a functional equivalent yet to be identified, into the Asset Information Data Warehouse system for use and subsequent enhancement by Transportation Infrastructure Asset Management for managing all Arizona Department of Transportation assets.

The Team also recommends an approach that makes the Transportation Infrastructure Asset Management, On-Line Analytical Processing, and Asset Information Data Warehouse an integrated methodology in the Arizona Department of Transportation planning and budgeting process.

1. BUSINESS AND BUSINESS AREA ANALYSIS

The mission of the Arizona Department of Transportation is "to provide a safe and efficient transportation system, together with the means of revenue collection and licensing for Arizona." Specifically, the Arizona Department of Transportation develops and operates the transportation infrastructure; develops and employs a measurement system that provides information for securing and allocating resources and improving performance; and allocates resources according to mandates, planned priorities, customer requirements, and return-on-investment so as to improve the movement of people and products throughout Arizona. The Arizona Department of Transportation reports to the governor of Arizona.

The current Five-Year Transportation Facilities Program for fiscal years 2002-2006 shows that through 2006, the Arizona Department of Transportation plans on spending approximately $3.9 billion. Of that, about $700 million is planned just for preserving the current assets. There are six major categories of preservation and 22 sub-categories. Developing spending plans require examining data from districts, municipal governments, public groups, and others who request projects. Matching requests with a funding source with priorities that will provide the maximum benefit to the public is just one of the reasons that decision support systems are needed.

Benefits from Arizona Department of Transportation projects come in the form of improved transportation system performance, reduced travel time, increased safety, job creation, and the economic impacts associated with improved transportation system performance. This presents management, political, environmental, and legal challenges. Funding and financing of Arizona Department of Transportation projects comes from state revenues and federal government funds. Debt supported by tax revenues is also used. Federal funding, for instance, may come from over twenty separate sources earmarked for specific spending categories or projects. As a result, projects must be tracked by funding source, and analysis for budgeting must recognize the nature of this situation. To manage this and to respond to the dynamic nature of the budgeting process, Transportation Infrastructure Asset Management needs executive decision support tools for analyzing, comparing, and establishing priorities. This need applies to all assets under the jurisdiction of the Arizona Department of Transportation.

A team of graduate students in the Management Information Systems Department undertook as a class project Arizona Department of Transportation Project #529: *Arizona Department of Transportation Information Data Warehouse Application*. The effort, stated in the Arizona Department of Transportation Solicitation was "…to research and develop a plan to utilize the Asset Information Data Warehouse as the analytical engine for the effective management of its infrastructure assets (Roadways, Bridges, and Rights-of-Way)." The Arizona Department of Transportation started development of the Asset Information Data Warehouse at the end of year 2000. The Asset Information Data Warehouse will be used as a decision support system (possibly in conjunction with existing supplementary software) for Transportation Infrastructure Asset Management. However, ways in which the Asset Information Data Warehouse information and other information available to the Arizona Department of Transportation will be used are needed to effectively prioritize, propose, and provide performance feedback for Arizona Department of Transportation programs.

2. CURRENT ADOT ASSET PRIORITY PLANNING SYSTEM (AS-IS)

The Transportation Planning Division within the Arizona Department of Transportation is responsible for priority planning. These responsibilities include priority programming, local government coordination, transportation safety and other related functions.

Descriptive information that follows is taken largely from the Transportation Planning Division web site at http://map.azfms.com/index.html. Other sources are referenced where appropriate. Items in **bold** are observations by the Team.

2.1 Priority Planning System Description

Planning Criteria

The "Priority Programming Law" in Arizona Revised Statutes establishes guidelines for Arizona Department of Transportation Priority Programming. [1] The State Transportation Board uses this in prioritizing road improvements and projects. The types of criteria considered in preparing the program include:

- Safety factors
- User benefits
- Continuity of improvements
- Social Factors
- Land use
- Aesthetic factors
- Conservation factors
- Life expectancy
- Recreational factors
- Availability of state and federal funds
- Other relevant criteria

The Arizona Department of Transportation desires to incorporate these criteria in evaluating asset projects on a cost/benefit ratio basis in order to develop priority recommendations based on data and analysis that will reside in Asset Information Data Warehouse.

Arizona Department of Transportation Priority Programming Process Guiding Policies

The statutory power to prioritize individual airport and highway projects is placed on the State Transportation Board. This board is a seven-member panel appointed by the governor. A Priority Planning Advisory Committee appointed by the Arizona Department of Transportation director assists the Transportation Board in setting priorities. They are guided by a number of policies that are established by the Board. The current policies address the following commitments:

- To the state highway system
- To take full advantage of federal-aid
- To value engineering
- Program categories
- Criteria for prioritizing projects
- Joint sponsorship criteria
- Interstate funding
- Controlled access systems
- Transportation systems management
- Non-interstate system rest areas
- Non-interstate system landscaping
- Interstate system rest areas

Board policies are reviewed periodically and updated as needed to meet ever-changing transportation needs.

Identification of Highway Projects

The highway construction program takes input from citizens, local governments, planning organizations, chambers of commerce, the business community and Arizona Department of Transportation professionals. The Arizona Department of Transportation planners and engineers use a number of technical measures to identify highway needs. These measures include the Arizona Department of Transportation pavement management system, accident studies, route corridor studies and the State Highway Plan. Databases now exist and are to be incorporated into the Asset Information Data Warehouse.

Prioritizing Highway Projects

The current main criterion used by the Arizona Department of Transportation to evaluate projects on existing highways is a technical measure called the sufficiency rating system. This system is an objective tool that incorporates a number of roadway characteristics, including pavement conditions, accidents and traffic volumes. Other criteria are also used to prioritize projects, such as: the significance of the route, route continuity, cost effectiveness measured by the project cost per motorist served, and recommendations of experts in the field (district engineers). Candidate projects are ranked based on the above criteria. The highest ranked projects are then considered for inclusion in the construction program to the extent that funding is available. Some data to develop measures for criteria exist in the current Arizona Department of Transportation databases. However, these data may not always be complete or comprehensive.

The Arizona Department of Transportation's efforts to construct Arizona's transportation facilities are focused on the Five-Year Transportation Facilities Construction Program. The program is updated annually and must be adopted by the State Transportation Board and submitted to the Governor by June 30th of each year.

Arizona Department of Transportation Interim Programming Process

The Arizona Department of Transportation Interim Programming Process defines statewide priorities and recommends a final performance-based programming process [2]. Performance-based programming links to objectives such as:

- How well is the system performing
- Implications of policies, plans, and programs
- Identification of opportunities for improvement
- System performance over time

Performance-based project selections are also linked to desired outcomes such as congestion/delay reduction, safety, and preservation. Geographic balance also is addressed within a Performance-Based Framework.

Proposed programming guidelines for Year 5 Major project eligibility and selection criteria are:

- Performance objective
- Crash reduction
- Crash prevention (hazard elimination)
- Delay reduction
- Accessibility and connectivity
- Priority Locations
- High accident or hazardous locations
- Identified corridors of statewide concern: completion of gaps
- Priority Project Types: relatively low-cost ($2-5 million) projects that address a safety or delay problem in highly cost-effective manner
- Climbing lane
- Passing lane
- Traffic interchange improvement
- Shoulder widening
- Other Eligible projects
- New general purpose lane
- Realignment

- Bridge construction
- Bridge widening

2.2 Existing Information Systems at the Arizona Department of Transportation

2.2.1 Existing Arizona Department of Transportation databases

The databases within the Arizona Department of Transportation that are used in managing individual groups of assets are:

- Maintenance Management Systems (MMS)
- Bridge Management Systems (ABISS)
- Pavement Management Systems (PMS)
- Right of Way Information System
- Accident Location and Investigation Surveillance System (ALISS)
- Construction Management
- Advantage Financial Systems
- Primavera Scheduling System
- Highway Performance Monitoring System (HPMS)

These databases do not directly feed the priority planning process, but the data they contain, and information they can generate, is used by the Transportation Planning Division. They will be directly integrated into the Asset Information Data Warehouse and that process is now underway. The Transportation Planning Division also has a database used in the priority planning process. It is called the Transportation Planning Division-Priority Programming System Data Warehouse. It is maintained on a SQL server, but is easily accessed by authorized users directly from their PCs using Microsoft Access. **This usability is a necessary requirement for any On-Line Analytical Processing System that will be used with the Asset Information Data Warehouse.**

As an example, the following are some of the data fields used in the Highway Performance Monitoring System database: [3]

- Route Number
- Beginning Milepost
- Location
- Section Length
- Number of Through Lanes
- Terrain Type
- Percent of Section Length with at Least 1500 Feet Passing Sight Distance
- Percent Average Daily Combination Commercial Vehicles

This data will be incorporated into the Asset Information Data Warehouse and will become a shared resource. Ownership of this data, and data from other existing databases, should remain with the organizations now having responsibility.

2.2.2 <u>Data / Information at the Arizona Department of Transportation, Current Situation</u>

The Team verified previous Arizona Department of Transportation conclusions that the data situation within the Arizona Department of Transportation may be summarized as follows [4]:

- Requires extensive technical expertise to retrieve and decipher
- Requires re-formatting / re-programming
- Lacks chart / graph / geographical display capabilities
- Does not lend itself to trending and statistical analysis
- Can't be asked for using business terms
- Is usually not identified, catalogued, documented and published; therefore, lacks awareness from potential users
- Is incompatible from system to system and functional area to functional area
- Is not integrated and readily accessible
- Is difficult to obtain quickly, particularly across systems
- Is in many cases inconsistent, inaccurate, and unreliable, leading to credibility problems

An Example: Traffic Data [4]

Traffic data are a crucial component needed for almost all key Arizona Department of Transportation decisions and activities: Planning and Programming, Advance Engineering, Pavement Design and Management, Bridge Design and Management, Safety Management, Traffic Operations, Maintenance Management, etc. In addition, special needs such as corridor studies, Small Area Transportation Studies (SATS), legislative programs, the Governor's Vision 21 Transportation Task Force, etc. all require traffic data in some depth. Analysis has shown that there are only a certain number of traffic data elements used by a good majority of these decisions and activities. They are:

<u>Volume</u>: Average Annual Daily Traffic (AADT), Design Hourly Volume (DHV), Peak-hour Traffic Percentage (K factor), Directional Split (D factor), Peak-hour Volume Turning Movement, Vehicle Miles of Travel (VMT), and Hourly Approach Volume.

<u>Vehicle Classification</u>: Average Daily Truck Traffic (ADTT), Percentage Trucks in Peak, and Percentage of Vehicle Class.

<u>Truck Weights:</u> Equivalent Single Axle Loads (ESALs).

<u>Speed and accident data</u>.

Currently traffic data is collected by the Transportation Planning Division Data Team for Highway Performance Monitoring System reporting, the Arizona Transportation Research Center (ATRC) for the Long Term Pavement Performance Project (LTPP), Advance Engineering Section for Design Concept Reports (DCRs), the Traffic Operations Center (TOC) using the Freeway Management System (FMS), and other agencies within and outside of the Arizona Department of Transportation throughout Arizona for special needs. Different and inconsistent methodologies may be used to collect traffic data. A lot of it ends up being used for the special needs and then discarded.

2.3 Asset Information Data Warehouse

2.3.1 Description

The Arizona Department of Transportation is currently implementing an Asset Information Data Warehouse that will contain consistent and pertinent information about Arizona Department of Transportation assets. The Asset Information Data Warehouse will serve as the tool for "enterprise-level" reporting and analysis and support existing and new initiatives aimed at satisfying the Arizona Department of Transportation's Vision and Mission statements.

The Asset Information Data Warehouse will be populated (a process which is now underway) from the operational management systems such as Maintenance Management System (MMS), Traffic, Engineering & Construction, Pavement Management, Bridge Management, Accident Location Information, and Advantage. The Asset Information Data Warehouse will consist of an analytical system and a separate database to provide executive information and decision support. The analytical engine and requirements have not yet been identified. Arizona Department of Transportation personnel stressed that the Highway Economic Requirements System was being considered as a separate analytical tool to support the Transportation Infrastructure Asset Management System.

The Asset Information Data Warehouse will be used to answer the following types of business questions: [4]

- How many total miles of Roadway is owned by the State of Arizona? What's the breakdown by Rural, Urban, and other sub-criteria, according to Arizona adapted Federal Highway Administration (FHWA) functional classifications?
- What did it cost to build the current Arizona Department of Transportation network of infrastructure assets? What's the breakdown by funding sources? What does it cost to maintain and enhance them on an ongoing basis? What are their replacement values?
- What are the goals of asset management, at all levels, and are we meeting them? What are the areas that need improvement and why?
- What are the levels of service committed to our customers, the public, and are we meeting them? What are the areas that need improvement and why?
- If funding were to be allocated a certain way, how would levels of service be improved ("what-if" analysis)? What kind of funding is required to bring asset conditions to the desired levels of service?

- What is the cost-component make up in constructing and maintaining Arizona Department of Transportation infrastructure assets (e.g., pavement, the Freeway Management System, rest areas, etc.)? Are there areas of cost that seem excessive and need further examination? Are there cost components that help explain why average cost per mile differs from area to area, asset to asset?
- Why were there multiple construction projects and maintenance activities on the same part of an asset within a given quarter? Can they be coordinated more efficiently and effectively?
- Is there a correlation between construction or maintenance projects and traffic accidents?
- What was the freeway closure situation in the past fiscal year?

The answers to these types of business questions require extensive effort currently. The Asset Information Data Warehouse will reduce the time to provide answers, and the answers provided will provide for recommendations supported by data.

2.3.2 Asset Information Data Warehouse Capabilities

The Asset Information Data Warehouse produces “drill down” capabilities, at a “click of a button”. Drill down capabilities are a cornerstone of any data warehouse, along with easy-to-use, graphical user query and analytical tools.

In general, Arizona Department of Transportation asset costs currently are aggregated into lump sums.

With the Asset Information Data Warehouse, these costs can be drilled down to the first level, by District.

- Second-level drill down identifies the Federal Highway Administration functional classification, or Rural, Urban, and sub-classifications (Rural Principal Arterial Highways, Rural Minor Arterial Roads, Rural Collector System, Rural Major Collector Roads, Rural Minor Collector Roads, Rural Local Roads, Urban Principal Arterials, Urban Minor Arterials, Urban Collectors, and Urban Local Streets, Freeway & Expressway, Arterial, Collector, and Local).
- Third-level drill down identifies the individual assets (Bridges, Right-of-Way, and Roadway).
- Fourth-level drill down represents the individual asset components (Drainage, Guardrails, Landscaping, Lighting, Signage, Signals, the Traffic Operations Center, Rest Areas, etc.).

The same drill down concept applies to other asset area information that will be available in the Asset Information Data Warehouse, such as replacement costs, traffic and accident information, project activities, closures, funding information, asset management goals, assessments and measures.

Appendix C lists representative data that the Asset Information Data Warehouse will contain.

3. PROPOSED ASSET MANAGEMENT PROCESS (TO-BE)

3.1 Objectives

The Team concurs with the approach that the Arizona Department of Transportation is using for the Asset Information Data Warehouse. The database portion of the Asset Information Data Warehouse appears to be well defined, and data from current existing legacy systems are being loaded. The analytical engine, its requirements, and how it will interface have not been clearly established at this time. The team has developed an approach to On-Line Analytical Processing that is within the framework of the priority planning process as shown in Figure 3-1. This "TO BE" diagram suggests an integrated framework that combines existing processes with a decision support capability to be provided by On-Line Analytical Processing.

The approach follows the current planning process steps. It includes the data warehouse and an On-Line Analytical Processing system using the Transportation Economic and Land Use System type or similar analysis and other knowledge discovery processes that may be identified later. The Team envisions achieving the objectives expressed by Arizona Department of Transportation personnel by combining the existing priority planning process with the support of analytical tools using data contained in the Asset Information Data Warehouse. Discussions with Arizona Department of Transportation personnel established a desire to consider the Highway Economic Requirements System for analysis and the Asset Information Data Warehouse as a separate supporting tool. Our approach combines the analytical tool with the Asset Information Data Warehouse and blends it with the priority planning and Transportation Infrastructure Asset Management approaches.

The major, first generation On-Line Analytical Processing system "TO BE" requirements of a system to support Transportation Infrastructure Asset Management are:

- Provide economic comparisons of dissimilar asset projects (e.g., highway vs. light rail transit)
- Provide project ranking based on economic benefits (project cost/benefit ratios)
- Present a user friendly (Windows environment) interface
- Provide highway performance given expected funding levels
- Determine funding levels given a desired highway performance level
- Estimate job creation and economic flow through benefits
- Determine project relationships and impacts
- Determine the Arizona Department of Transportation capital investment required
- Estimate environmental compliance costs so that the total costs of projects can be identified
- Estimate land use projections to support planning and implementation
- Utilize geographic information systems (GIS) to provide visualization of asset analysis
- Utilize a single data source (the Asset Information Data Warehouse) for all analysis

The system will be able to compare the different asset areas to allow Transportation Infrastructure Asset Management to make recommendations about utilizing funding for bridges vs. pavement, or light rail vs. new highway to address commuter transportation.

The On-Line Analytical Processing system must be easy to use. This will aid in user adoption of On-Line Analytical Processing. Command line processing is becoming obsolete for modern business analysis, and therefore the system should present a Windows type environment.

Highway performance based on funding available or funding required to obtain a level of highway performance is a basic requirement. Having a graphics capability plus a geographical information system capability along with being able to determine creation of jobs in a community will provide better information for making decisions. It will also aid in more quickly assessing the impact of those decisions.

The other requirements support and enhance the critical information required from the system--cost/benefit ratios and funding levels vs. performance.

The State Transportation Board will make final decisions in the priority planning process, but they will have the best available quantifiable information when making the decision. This information will be based on a single source of Arizona Department of Transportation data. They will be able to provide responses, supported by analysis, to stakeholder concerns about project costs, the basis for choosing projects, the effect of projects on jobs, and the cost of environmental compliance. Although such information may not be available in the near term, our approach establishes a foundation for guiding Arizona Department of Transportation planning to achieve the goal of improving decision support methodology.

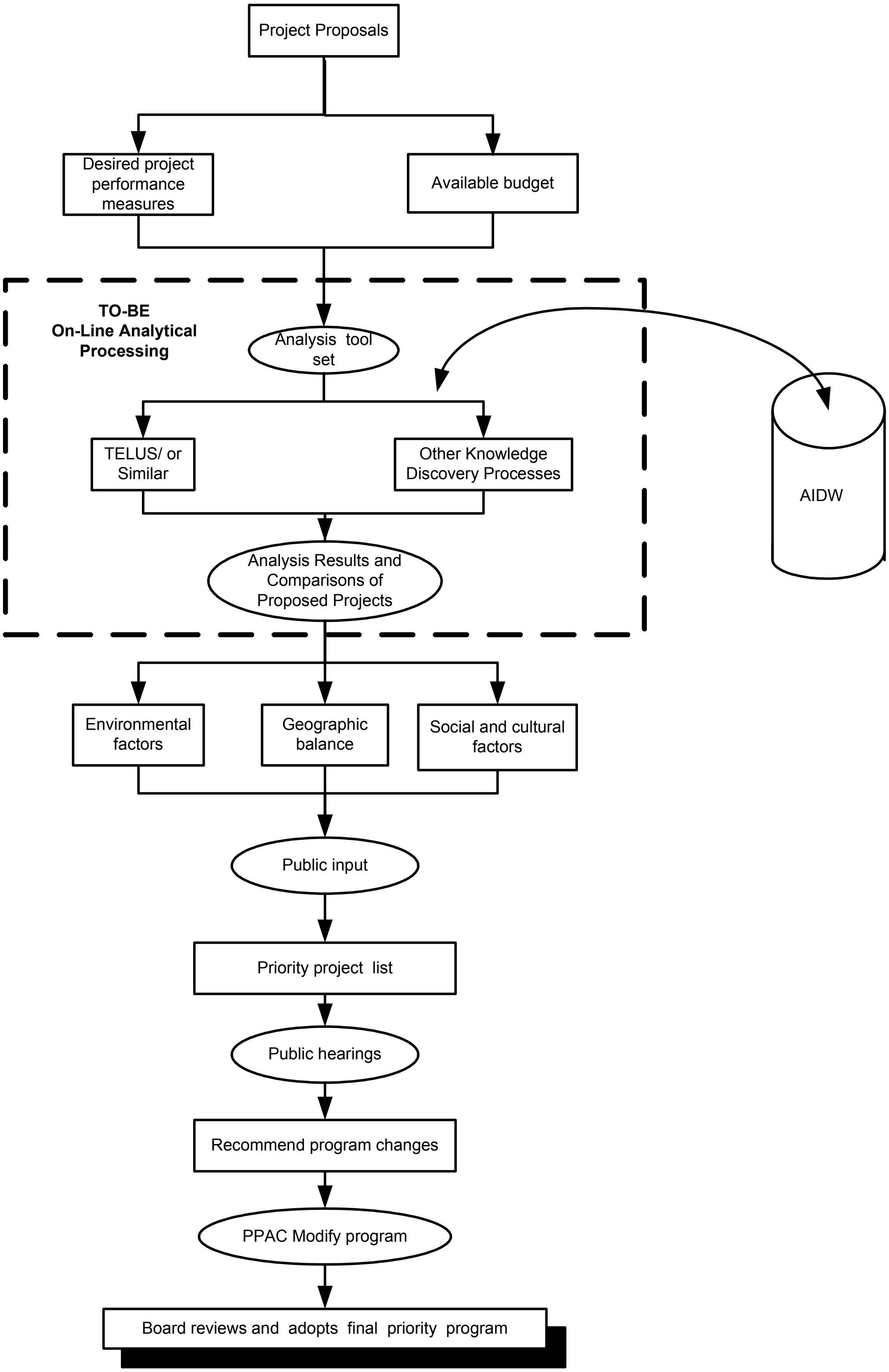


Figure 3-1 Transportation Infrastructure Asset Management Recommended TO-BE Process

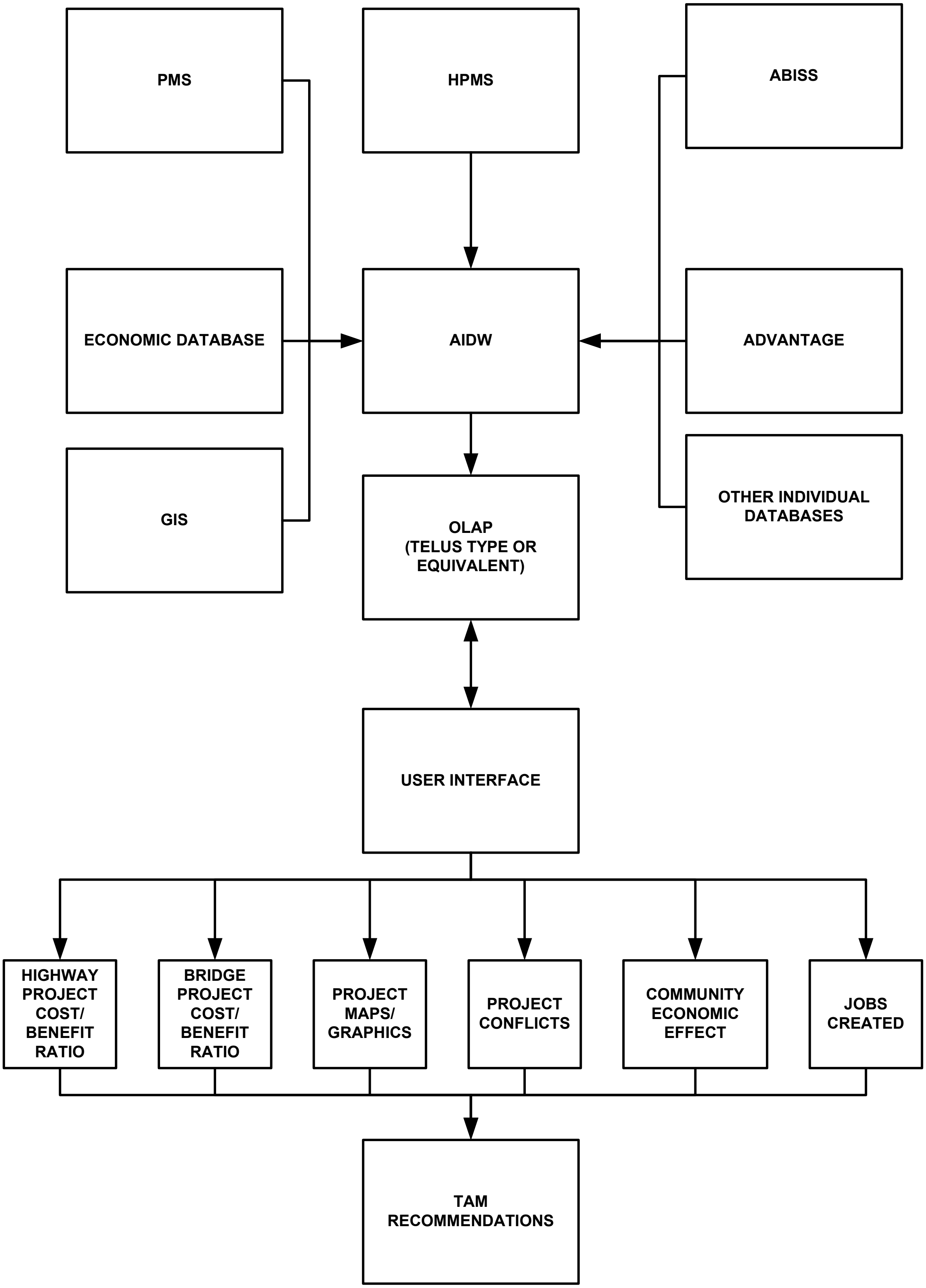


Figure 3-2 Representative Data Flow Concept

3.2 Data Selection

As discussed previously, the Asset Information Data Warehouse will receive data from the Pavement Management System (PMS), the Highway Performance Monitoring System (HPMS), the Traffic System, the Bridge System, and the Safety System. The On-Line Analytical Processing system will interface directly with these databases and select the data required to perform the chosen function. For instance, when comparing bridge and highway projects, On-Line Analytical Processing may request data on highway conditions from the Pavement Management System, bridge data from ABISS, job creation data from an economic database to be defined, project cost data from Advantage, and geo-spatial data from the geographical information system. It would then quantify the highway and bridge conditions, develop estimated costs, balance to reflect the available funding, compute job creation potential, determine the economic effect throughout the community, and calculate the cost/benefit ratio of the two projects. Using the geographical information system functionality and project relationship functionality, On-Line Analytical Processing would determine if any conflicts exist and if they did, the conflicts would be plotted. Figure 3-2 provides a representative concept.

3.3 Data Transformation/Mining

The next step in this proposed Transportation Infrastructure Asset Management system is to convert the data from the combined database into reports, tables, and graphics, as required. Because of the impact of the decisions made by the Arizona Department of Transportation, graphics, provided quickly, will help the Arizona Department of Transportation focus on key issues. This effect cannot be obtained with tables and numbers. This On-Line Analytical Processing tool therefore must be user-friendly and graphics oriented so that Arizona Department of Transportation professionals with general knowledge of Windows applications will be able to easily operate it. This system will not only extract from the common database either weekly or monthly and generate, on request, a standard report detailing projects, costs, and priorities, but it will also have *ad hoc* querying capabilities. This will allow Transportation Infrastructure Asset Management to provide the human input into developing what-if scenarios so that alternate approaches to maximizing benefits to the public can be developed. Another feature that the On-Line Analytical Processing system should have is the ability to provide alerts and run priority reports about projects that are identified as having potentially hazardous conditions when the data is received into the collective database.

4. DESIGN ALTERNATIVES

4.1. Highway Economic Requirements System/State Model Analysis Package

This material is taken largely from The Highway Economic Requirements System/State Model overview report [5]. Several specific items are noted with references. Observations by the team are in **bold**.

4.1.1 Introduction

The Highway Economic Requirements System was developed in 1989 to provide the Federal Highway Administration (FHWA) with a tool to estimate the "long-term capital spending necessary to achieve specified levels of future highway performance." The Highway Economic Requirements System is used to develop a report that the Federal Highway Administration must make biennially to Congress called "The Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance" (C&P). This report is used by Congress to determine the amount of funding the Federal Highway Administration receives each year.

The Highway Economic Requirements System uses a combination of systems engineering and economics. Systems engineering is used to determine the relationships between traffic volumes, road capacity, pavement deterioration, vehicle speeds and crashes, travel time, road alignment (curves and grades), and other highway attributes. Economics is used to take engineering calculations and produce a relevant measure of benefits vs. costs, such as travel-time savings and pollution reduction. The Highway Economic Requirements System is based on data provided from the Highway Performance Monitoring System database, which was developed in the 1970s to track highway construction and maintenance effectiveness in a consistent format throughout the nation. The Highway Performance Monitoring System database contains information on over 100,000 highway sections sampled to represent the national highway system.

The Highway Economic Requirements System estimates the amount of capital investment in the national highway system that would be justified based on benefit-cost analysis. It does this by taking a representative sample of highway sections, designing alternative improvements for each section, selecting the best improvement (if any), and extrapolating the results to the national highway network. Benefits can be grouped into: reduction in user costs, reduction in Department of Transportation (DOT) costs, and externalities over the life of the improvement. Costs are calculated as the initial capital costs to implement the improvement.

The Highway Economic Requirements System can be used to answer three basic questions: What is the national highway investment required to implement all improvements whose benefits exceed their costs? What is the national highway investment required to achieve a specified user cost level? What is the user cost level for a specified amount of investment? **The Highway Economic Requirements System, even when applied at the state level, will not compare the benefits of an investment in highways to the benefits of investments in other state assets such as light rail system projects. Thus, it will not meet the Arizona Department of**

Transportation's asset management requirements to be able to make economic comparisons between unlike assets.

The Highway Economic Requirements System was not intended as a highway project evaluation tool. The reason for this is that the system's knowledge of the conditions and characteristics of a given section are far from complete, so the estimated benefits and costs of improvements may be significantly inaccurate. Instead, the Highway Economic Requirements System is designed to broaden the information available to decision makers engaged in developing highway programs and policies. In fact the Highway Economic Requirements System/State Model Overview Report states:

"It is very important that the user of the Highway Economic Requirements System model not treat it as an inscrutable "black box." The Highway Economic Requirements System cannot make decisions based on information that it lacks, or on relationships that are not in the model. The user is expected to be knowledgeable about highway construction, traffic engineering, and benefit-cost analysis, and to understand how the Highway Economic Requirements System derives its results. This understanding allows the user to provide sound input data and parameters, to interpret the results with insight, and to modify the output to account for the Highway Economic Requirements System limitations."[5]

The Highway Economic Requirements System was designed with several limitations inherent in the system, which makes it very important that the Highway Economic Requirements System user view it as one of a group of analysis tools and not the only input to decision-making. These limitations are described in more detail in Table 4-1.

Table 4-1: Limitations Inherent in the Highway Economic Requirements System

- Only highways are considered explicitly (other transportation resources such as bridges and transit are considered indirectly through the discount rate)
- At the national level, the analysis provides recommended investments by type of improvement and functional class, not by individual project or by state.
- New construction is not considered.
- Initial improvement costs include typical expenditures, but do not take into effect other costs such as the cost of delaying the improvement implementation.
- No interdependencies among highway sections are addressed. For instance, the Highway Economic Requirements System does not consider how construction or maintenance in one highway section will affect conditions in another highway in the same region.
- Direct user charges are omitted (ex. fuel taxes and tolls)

In November 2000, Cambridge Systematics, Inc, developed a modified version of the Highway Economic Requirements System for state-level DOTs. The state-level system was funded by the FHWA and is called the Highway Economic Requirements System/State Model. The initial version of the Highway Economic Requirements System/State Model is built around the framework of the Highway Economic Requirements System, incorporating several modifications that the Indiana and Oregon Departments of Transportation had independently built into the Highway Economic Requirements System to implement it at the state level.

The Highway Economic Requirements System/State Model is still in it's pilot-program stage, but it has been designed to assist state DOTs with the following:

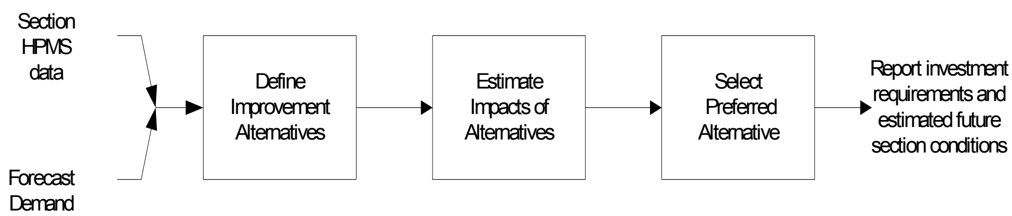
- To screen candidate highway projects for further study, refining specific quantitative measures while using the benefit-cost framework offered by the system.
- To apply a consistent objective standard to a variety of highway projects proposed by the different agencies for different purposes, with differing levels and styles of supporting documentation.
- To suggest funding priorities, such as among functional classes, geographic areas, or types of improvements depending on the highway projects selected for evaluation.

4.1.2 The Highway Economic Requirements System/State Model System Logic

The Highway Economic Requirements System/State Model identifies and evaluates possible improvements on individual sections of highways. It performs this evaluation on each section of highway in its input database file for a single funding period. It then repeats the process for the next funding period. After all the funding periods for the overall analysis period have been completed, the results are tabulated and printed to several output files.

Highway improvements evaluated by the Highway Economic Requirements System/State Model can be broken down into various combinations of three improvement types: pavement, widening, and alignment. The process for improvement evaluation begins by analyzing a section's Highway Performance Monitoring System data, calculating forecast demand, and determining if any deficiencies exist. If a deficiency exists, a list of possible improvements is generated. Impacts of each alternative are estimated, and then the differences are compared to the initial section conditions to give estimates of incremental benefits and costs. Benefit-cost criteria are applied to select the best set of section improvements for implementation, given funding constraints or performance objectives indicated by the user. This process can be seen in Figure 4-1.

Figure 4-1 - Improvement Evaluation and Selection

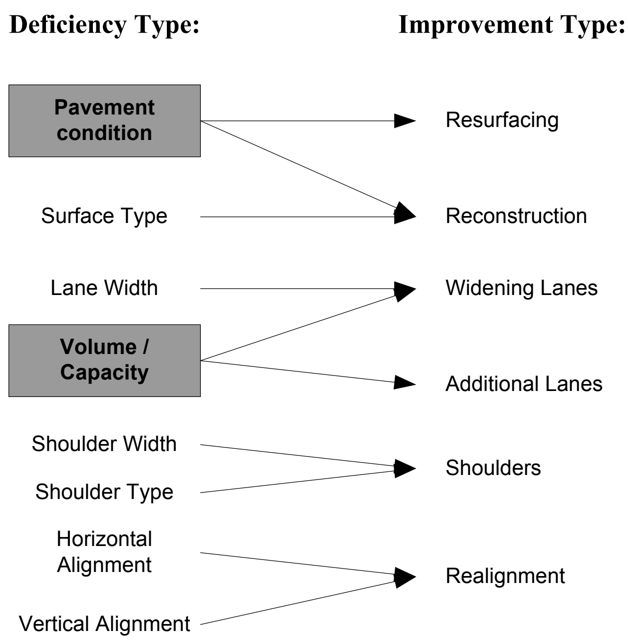


4.1.3 <u>How the Highway Economic Requirements System Determines Improvement Alternatives</u>

The Highway Economic Requirements System/State Model starts the improvement selection process by using the section Highway Performance Monitoring System data and a deficiency level specification file (DLTBLS.DAT) to search for conditions that indicate deficiencies. The Highway Economic Requirements System/State Model not only considers present conditions, it also extrapolates future conditions to determine possible candidates for future deficiencies. Each section is analyzed to determine if deficiencies exist at the midpoint of a funding period. This means that some conditions or performance are bad enough that an improvement might be considered to correct these conditions. The Highway Economic Requirements System/State Model considers deficiencies of the following eight types: pavement condition, surface type, lane width, volume/capacity, shoulder width, shoulder type, horizontal alignment, or vertical alignment. If a section exhibits none of these deficiencies for a particular funding period, no improvements are suggested. In fact, the Highway Economic Requirements System/State Model is specifically designed so only two types of deficiencies will trigger the consideration of an improvement: pavement conditions or volume per capacity deficiencies. (It is assumed by the system that these are the two major types of deficiencies that would initiate a highway improvement project, and any of the other types of deficiencies would be corrected within the scope of that improvement.) The thresholds for determining if a section is deficient in any of these areas are known as deficiency criteria and can be set in the DLTBLS.DAT file by the Highway Economic Requirements System/State Model user.

The types of deficiencies in a highway section determine the potential improvement types that the Highway Economic Requirements System/State Model will evaluate. The relationship between deficiency types and improvement types can be seen in Figure 4-2 [5].

Figure 4-2 - Deficiency Types matched to correcting Improvement Types



The Highway Economic Requirements System/State Model allows users to add "superfields" to the Highway Performance Monitoring System section data that will identify a specific improvement that will occur on the section and the date when the improvement will occur. If entered, these "superfield" improvements will override any calculated deficiencies and suggested improvements that the Highway Economic Requirements System/State Model may generate.

4.1.4 Estimating Impacts

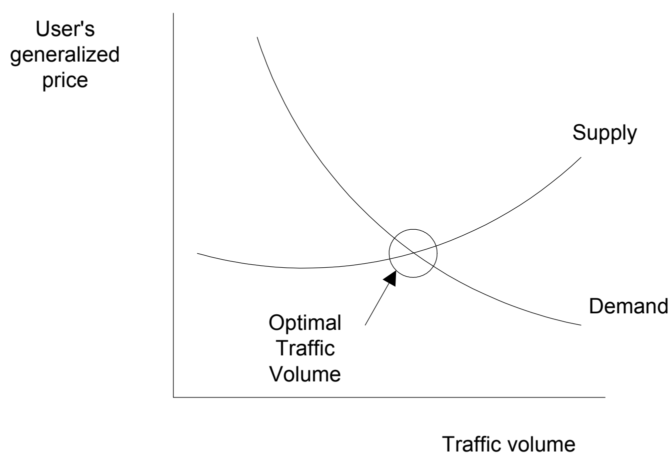
After a list of improvements has been generated for a specific period, the impact of these improvements on traffic volume and pavement conditions must be evaluated. For each funding period within the overall analysis period, changes are made to the input records to simulate the actual changes that will occur to the highway section over time. The two main parameters that are changed for each funding period are the Annual Average Daily Traffic (AADT) and the pavement condition (expressed by the Present Serviceability Rating (PSR). The Volume/Capacity ratio is also recalculated based on the adjusted Annual Average Daily Traffic.

Annual Average Daily Traffic is provided in the Highway Performance Monitoring System data file for both the current year and a specified future year. The Highway Economic Requirements System/State Model uses these two Annual Average Daily Traffic figures and the time distance between them to calculate an annual growth factor for the Annual Average Daily Traffic of the highway section. The Highway Economic Requirements System/State Model does not use any other methods to calculate future traffic volumes or travel demands. This requires that the state perform any analyses needed to determine the effects of economic growth, land development and use, demographics, alternative routes, and other factors, to ensure that the future Annual Average Daily Traffic value entered into a highway section's Highway Performance Monitoring System data file is accurate. **The only forecasting that the Highway Economic Requirements System/State Model can do is to determine the effect of improvements on traffic volume.**

One of the major factors that the impact analysis must take into account is the effect of pavement conditions and traffic volume on the overall condition of a section of highway. Trucks, weather, and time affect pavement condition and lifetime. Pavement conditions affect speed and maintenance. Traffic volume affects speed, crashes, and emissions. Capacity, terrain, and vehicle type affect speed. Geometric design (alignment) and traffic volume affect crashes. Speed and pavement affect vehicle operating costs.

The Highway Economic Requirements System/State Model evaluates the relationship between traffic volume and a user's "generalized price" to represent how much traffic volumes change as a result of highway conditions. This relationship is shown in a "supply and demand" graph (Figure 4-3) to determine the optimal level of traffic volume for that section. The user's "generalized price" is a measure of the vehicle costs for the user to travel that section of highway, including travel time, operating costs, and safety costs. The Highway Economic Requirements System/State Model does not take into account any additional fees to the user such as tolls or fuel taxes. The Highway Economic Requirements System/State Model uses the section's Annual Average Daily Traffic to create a constant-elasticity demand curve, and uses the generalized price to generate a supply curve. The demand curve represents a relationship between volume and generalized price, in which a higher price implies a lower volume. The supply curve is a relationship between volume and unit cost to the user (the price) of travel, in which higher volume results in higher price, due to congestion. The point where the two curves intersect is the optimal traffic volume for that section.

Figure 4-3 - Traffic Volume Supply and Demand



4.1.5 Improvement Evaluation

Once the forecast impact of improvements is evaluated, the Highway Economic Requirements System/State Model uses benefit-cost analysis to compare the cost of implementing an improvement to the benefits expected over the life of the improvement. When evaluating a highway section for improvement, the Highway Economic Requirements System/State Model determines which option from the list of possible improvements would be the best to implement. Improvements are selected on the basis of the ratio of the net present value of each improvement's incremental benefits to the present value of its incremental costs. Potential improvements are sequentially compared until the optimal improvement is identified. The objective is to maximize total net benefits, even if funding or performance is constrained. For alternative improvements on the same section, the one with the highest net benefits is selected. If there are funding constraints, however, a lesser improvement with a higher benefit-cost ratio (BCR) may be selected in order to also implement an improvement on another section. This procedure uses an analysis method known as incremental benefit-cost ratios (Biers). If the Highway Economic Requirements System/State Model user has requested that only the improvements that achieve some minimum benefit-cost ratio be implemented, then the best improvement for each section having a cost beneficial alternative is selected for implementation. If no minimum benefit-cost ratio is indicated, the highest benefit-cost ratio improvements are selected in sequence until all available funds are exhausted or a user specified level of highway system performance is reached.

4.1.6 The Highway Economic Requirements System/State Model Operation

The Highway Economic Requirements System/State Model application consists of two programs: the Highway Economic Requirements System/State Model preprocessor (HSTPP) and the main program (Highway Economic Requirements System/State Model). In addition to these two programs, the Highway Economic Requirements System/State Model requires several other files to control program operation, furnish parameters for program calculations, and provide highway section data for input. The functions of all Highway Economic Requirements System/State Model support files are listed in Table 4-2.

Table 4-2 – Highway Economic Requirements System/State Model System Files

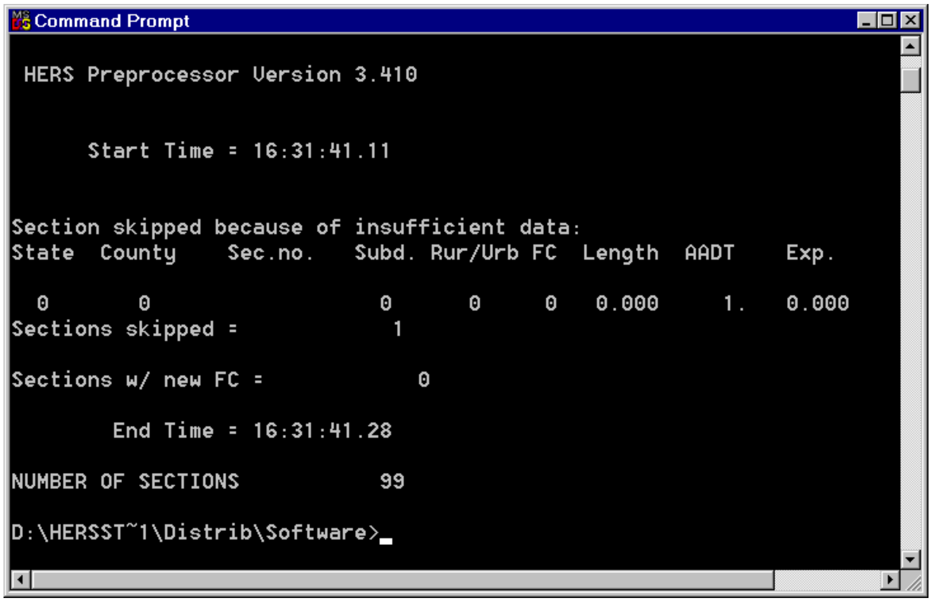
HSTPP	The Highway Economic Requirements System/State Model Preprocessor program. Converts HPMS input data into binary format for use by the Highway Economic Requirements System/State Model main program.
HERS/ST	The main program. Performs benefit-cost analysis on input data and produces a set of output files indicating highway system conditions and recommended changes before, during and after the analysis period
HPMS Data File	Contains an ASCII description of a set of highway sections for some base year. There is one record per highway section, in fixed-field un-delimited format.
PPSPEC.DAT File	The Preprocessor control file. Provides user modifiable control parameters for running the Highway Economic Requirements System/State Model Preprocessor program.
DLTBLS.DAT	File containing design standards, deficiency levels, etc. for highway sections by functional system, terrain, and traffic level.
PARAMS.DAT	File containing price indices, efficiency adjustment factors, state cost factors, and parameters for speed calculations, pavement deterioration, safety values, and other miscellaneous functions.
.HRS and .DST files	Files outputted by the Highway Economic Requirements System/State Model Preprocessor program. The .HRS file is the binary input file for the Highway Economic Requirements System/State Model main program. The .DST file is a distribution file containing data common for all sections of the binary file. Both files are also produced as output from the main program for use as input to future runs of the Highway Economic Requirements System/State Model application.
EILFIN.BIN	File that contains information about user-requested improvements to individual sections that are obtained from the input data file. Also produced as output from the main program for use in future program runs.
RUNSPEC.DAT	The main program control file. Provides user modifiable control parameters for running the Highway Economic Requirements System/State Model program.
IMPRCOST.DAT	File containing specifications of the costs of highway improvements considered by the Highway Economic Requirements System/State Model.

EMICOST.DAT	File containing factors used to determine the cost of damages due to vehicle emissions.
.OUT	Output files containing extensive data in tabular format suitable for printing. (Many of which are optional and can be set in RUNSPEC.DAT)
.SS1	Comma-delimited output file describing system conditions at the beginning of the run and after each funding period.
.SS2	Comma-delimited output file describing total initial cost of improvements and average BCR of selected improvements.

The Highway Economic Requirements System/State Model is run from a command line interface as a DOS application. Before beginning a program run, Highway Performance Monitoring System data must be collated, placed into an input file, and modified if necessary. (For example, superfields may need to be added to certain sections to account for highway improvement projects already scheduled.) The Highway Economic Requirements System/State Model Preprocessor control file, PPSPEC.DAT must be edited (with a text editor, not a word processor) to ensure all run parameters (ex. input data's file name) are correct. The system user can also make changes to program parameters such as deficiency levels and improvement costs before running the program.

Once all input parameters are prepared, the Highway Economic Requirements System/State Model Preprocessor program is run, producing three intermediate level files: a Highway Economic Requirements System input file, a distribution file, and a user-defined improvements file (e.g. data from sections' superfields). An example screen displaying the Highway Economic Requirements System/State Model Preprocessor's output is shown in Figure 4-4.

Figure 4-4 Sample Highway Economic Requirements System/State Model Processor Screen



After the Preprocessor generates the intermediate (binary) files, the Highway Economic Requirements System/State Model main program is then run to analyze the section data and produce a suggested list of improvements. Just as with the Preprocessor, the main program uses several external parameter files that may be modified by the user before program execution. The Highway Economic Requirements System/State Model main program control file, RUNSPEC.DAT, can be modified by a text editor or by a graphical-interface program called RunPrep. RUNPREP.DAT controls the program flow and should be modified by the user to determine funding and analysis period lengths, program objectives (constrained by funds or performance vs. minimum benefit-cost ratio), program output options, and other important specifications.

The Highway Economic Requirements System/State Model main program outputs several default and optional files (as determined by the user in RUNPREP.DAT). The primary output of the Highway Economic Requirements System/State Model is a set of tables describing:

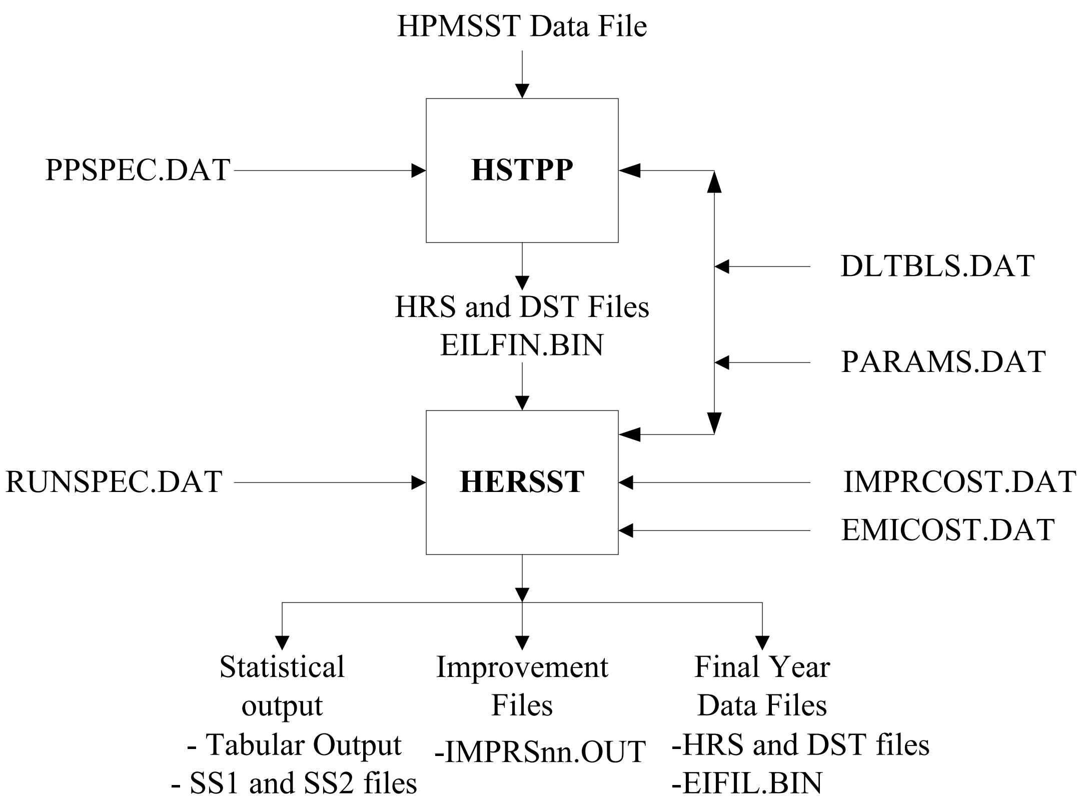
- The state of the highway system at the start of the program run and at the end of each Funding Period.
- The changes occurring during each Funding Period.
- The changes occurring during the overall analysis period.
- The benefits and costs of the improvements simulated during each Funding Period.

- The benefits and costs of the improvements during the overall analysis period.

Optional output pages can be produced presenting various statistics for sections improved during the period by highway functional system, by the type of improvement, and by benefit-cost ratio range.

The data and control flow diagrams for the Highway Economic Requirements System/State Model application are shown in Figure 4-5 [5].

Figure 4-5 HERS/ST SYSTEM ORGANIZATION



4.1.7 The Highway Economic Requirements System/State Model Advantages and Disadvantages

- *Advantages*

The Highway Economic Requirements System/State Model uses a very computationally intensive approach to predict future highway system needs and conditions. This approach is founded in basic traffic engineering and economic practices, and provides a consistent, methodical, and mathematically-accurate process for suggesting highway improvements.

The input data for the Highway Economic Requirements System/State Model program is already in a nationally accepted format (Highway Performance Monitoring System), requiring no modification for use in the program (with the exception of user-defined improvements added to the section superfields).

- *Disadvantages*

The DOS user interface for the Highway Economic Requirements System/State Model is very cumbersome and will require special training for most anticipated users unless they are already proficient with DOS.

Editing of input and parameter files must be done in text editors instead of word processors (to ensure no hidden text-formatting characters are added to the files.) All modifications to these files must exactly conform to the file format; misplacement of a single character in an input file can cause the whole program to crash.

Errors generated during program operation are very cryptic, making it difficult for normal users to troubleshoot and correct operational problems.

Output statistics are displayed in a non-graphical, tabular format. This requires the system user to closely analyze the data to understand the results generated by the program instead of allowing the user to quickly grasp the results by using graphical representations such as charts or graphs.

The Highway Economic Requirements System/State Model operates in a command-line operating system, instead of a Windows-based system that is more familiar to users.

The Highway Economic Requirements System/State Model does not provide analysis of Arizona Department of Transportation assets besides highways. If an Arizona Department of Transportation asset manager were using the Highway Economic Requirements System/State Model as one of an array of research tools to evaluate highway projects, the Highway Economic Requirements System/State Model might be useful. However, if an asset manager is trying to determine future needs, comparisons, and budget allocations of multiple modes of travel, the Highway Economic Requirements System/State Model does not have the capability to evaluate these types of analysis. In addition, the engineering and economic knowledge that the Highway Economic Requirements System/State Model contains within its algorithms is hard-coded into the framework of the program and the format of its input files, making modification of the program very complex and time-consuming.

4.2 Design Alternatives

A search was conducted to find other software that would fulfill the Arizona Department of Transportation's needs. We could not locate a package that had the capability to analyze all the Arizona Department of Transportation assets (highway, bridge, and transit) concurrently and compare them with a cost/benefit ratio. The only package located that offered part of that needed was from TELUS-National. The Transportation Planning Division had evaluated the Transportation Economic and Land Use System and deemed it too powerful for their needs.

Because the system that they were using was meeting their requirements, the Transportation Economic and Land Use System was not pursued. Transportation Planning has a database system, operating in Microsoft Access. This database is used for generating the Current Five Year Transportation Facilities Construction Program.

Information that follows is taken largely from TELUS-National web site at http://www.telus-national.org. It is discussed in terms of a model framework for an On-Line Analytical Processing system. Items in **bold** are observations by the Team.

The Transportation Economic and Land Use System is a computerized information-management and decision-support system designed specifically for metropolitan planning organizations (MPOs) and state departments of transportation (SDOTs) to help these agencies meet the transportation planning and programming requirements of the Transportation Equity Act for the 21st Century (TEA-21). The Institute for Transportation, New Jersey Institute of Technology developed the Transportation Economic and Land Use System in conjunction with the Center for Urban Policy Research at Rutgers University. **The Team feels that the framework provides a starting point to achieve the needs of Transportation Infrastructure Asset Management.**

Its primary use is to help states and metropolitan organizations decide what projects to include in their Transportation Improvement Programs (TIPs). These decisions are based upon a variety of factors, including travel demand, need for facility maintenance and repair, land-use changes, economic growth, environmental needs, and other factors. State Departments of Transportation and Metropolitan Planning Organizations also must be able track these projects as they pass through various stages toward actual construction, such stages including facility planning, engineering, and design; right-of-way acquisition; advertising; bid review; construction scheduling; and related phases of work. These stages usually occur over several years, and the projects are constantly being modified as they pass through the stages. The major Transportation Economic and Land Use System components are automated Transportation Improvement Program components. The mapping component, economic component, and land use component are described in the following paragraphs.

Automated Transportation Improvement Program Components -- a large database containing information such as project number, description, location, cost, schedule, functional class, etc. about all the projects. This component includes five modules to score projects, identify conflicts among projects, customize features and establish access levels to the system, track projects, and compare planning objectives. **The ability to score projects and identify conflicts/relationships is a major benefit of the Transportation Economic and Land Use System.**

Mapping Component -- a Geographic Information System (GIS) that allows for both the production of maps reflecting the geographical context of projects and the selection of projects for viewing or analysis. **This will provide the major link with the existing Arizona Department of Transportation databases.**

Economic Component -- an input-output model that uses the dollar investment being made in a single project, or a group of projects, to estimate the number of construction jobs that will be created and multiplier effects of the investment on community income levels, the gross regional product, and local and state tax revenues. With output from a travel-demand forecasting model, another module in this component will estimate the dollar value of travel time saved as a result of changes in the transportation network. **The Team feels that the Economic Component is another key feature that will provide the Arizona Department of Transportation with the capability to compare asset investments.**

Land-Use Component – (planned) a land-use model that will project the location of new residential and nonresidential development based upon changes in the transportation system.

the Transportation Economic and Land Use System is copyrighted, but it is free to any Metropolitan Planning Organization and State Department of Transportation wishing to install and use it. The economic and land-use models will require extensive data collection and manipulation. Much of this data used by the Transportation Economic and Land Use System appears to be in the existing Arizona Department of Transportation databases.

TELUS-National states on their web site that they anticipate developing several versions of the system over the next four years. Maintenance of the Transportation Economic and Land Use System beyond 2004 when FHWA funding expires is an issue. **The Team feels, however, that the existing system serves as a framework model for meeting the Arizona Department of Transportation's long term needs, and that it should receive serious consideration for incorporation into the Asset Information Data Warehouse.**

The team analyzed the needs expressed by the Arizona Department of Transportation along with the material describing the Asset Information Data Warehouse plans. The specific need expressed by Transportation Infrastructure Asset Management is to have a tool that will:

1. Provide information similar to that anticipated from the Highway Economic Requirements System but in a user-friendly manner—specifically through a Windows interface.
2. Utilize to the maximum possible extent the data that exists throughout the Arizona Department of Transportation databases.
3. Provide a method for comparing different Arizona Department of Transportation assets for investment to allow the Transportation Infrastructure Asset Management program to make recommendations regarding assets that will provide the greatest benefits.

The following discussion describes in general terms the data that will be entered into the Transportation Economic and Land Use System during initial configuration. This will allow the Arizona Department of Transportation reader to relate data requirements to data in existing Arizona Department of Transportation databases.

A Data Input Module is used to enter descriptive, cost, and status data in text boxes and drop-down boxes. Descriptive data is for information about the project such as project ID, agency, and contacts. Multiple projects and identification can be entered. The Descriptive Fields contain information about the project such as categories, classes, description, and other. There are also Location Fields that will contain data about the specific highway routes, termini, counties, and districts.

The Transportation Economic and Land Use System **utilizes the same information on roadways that the Highway Economic Requirements System/State Model uses.** This is primarily information that the Arizona Department of Transportation currently collects and uses. Representative Roadway data is new construction, reconstruction, interchanges, widening, restoration and rehabilitation, safety features, traffic management, and environmental/scenic.

There are also classifications screens for Bridges (right-of-way, engineering construction, new, replacement and rehabilitation). The **Transportation Economic and Land Use System includes bridges for analysis in its model. The Highway Economic Requirements System/State Model does not.**

The Transportation Economic and Land Use System also uses information regarding non-motorized travel such as pedestrian and walkways and sidewalks. Travel Maintenance and Service Facility data such as rest areas, weigh stations, maintenance sites and administration facilities is also used by the Transportation Economic and Land Use System. In addition, the Transportation Economic and Land Use System also uses data on intermodal facilities and high occupancy vehicle (HOV) lanes.

Transit project analysis is also provided by the Transportation Economic and Land Use System. This is not provided by the Highway Economic Requirements System/State Model. The Transportation Economic and Land Use System uses commuter rail, light rail, bus, ferryboats, demand response, and heavy rail data. Structures associated with transit are also included.

In summary, the Transportation Economic and Land Use System uses data and provides information on highways and other assets that the Arizona Department of Transportation is seeking.

The tracking module of the Transportation Economic and Land Use System uses information concerning the funding allocated for the project. Information that will be entered during configuration includes how the funds are to be used, when the funds are expected to be disbursed, and the source of those funds.

For instance, the following fields are filled in during system loading.

Table 4-3: Data Fields	
Field	**Data**
Planned	The planned start and end year and fiscal quarters. Numerical
Actual	The actual start and end year and fiscal quarters.
Phase	The Phase of work describing the particular activity, including Construction (CON), Engineering (ENG), Right of Way (ROW), Maintenance (MAINT)
Funding Type	Federal or Non-federal sources
Funding Source	Customized breakdown of the Funding Type
Allocated Amount	The amount, to the closest dollar, of the expenditure allocated on the phase of work
Committed Amount	The amount of the expenditure that has been committed

The status section prompts the user for descriptive, narrative information about the status and scheduling of the project. For instance, from this screen, project information can be entered about:

- Community
- Environment
- Design
- Right of Way
- Each of these issues can be classified as routine, serious, or critical

A scoring module provides the needed feature and flexibility for the Arizona Department of Transportation.

In most scoring systems, projects are scored on the basis of a set of criteria. The TEA-21 legislation provides guidance by identifying seven objectives that should be considered. Under TEA-21, projects should be assessed in terms of how they:

- Support the economic vitality of the metropolitan area especially by enabling global competitiveness, productivity, and efficiency
- Increase the safety and security of the transportation system for motorized and non-motorized uses
- Increase the accessibility and mobility options to people and freight
- Protect and enhance the environment, promote energy conservation, and improve quality of life
- Enhance the integration and connectivity of the transportation system across and between modes for people and freight
- Promote efficient system management and operation
- Emphasize the preservation of the existing transportation system

The Transportation Economic and Land Use System Project Scoring Module incorporates these seven TEA-21 objectives as Categories under which a number of factors, or criteria, are identified. The Transportation Economic and Land Use System provides assisted scoring and external scoring. External scoring is for organizations that already have well developed scoring processes that they wish to continue using.

The Transportation Economic and Land Use System assisted scoring allows projects to be scored using a pre-programmed set of categories reflecting the seven TEA-21 planning objectives. This default set of categories includes factors, or criteria, that can be modified to meet the needs of individual organizations. Those that do not currently have a scoring system, or would like to revise their present scoring system, should select this option.

External scoring allows users to enter project-scoring information into the Transportation Economic and Land Use System database from their own existing scoring system. The existing system, whether paper- or computer-based, remains separate and is not connected to the Transportation Economic and Land Use System system.

The Transportation Economic and Land Use System provides users with the capability of identifying and reviewing potential relationships among transportation projects. Potential interrelationships can be identified for existing projects and projects under consideration once entered into the database.

Transportation projects can be related in several ways:

- Commonalities, in terms of locations, mode, funding source, and project purpose.
- "Disturbance" interrelationships, which indicate that two or more projects could potentially interfere with one another. For example, a delay or stoppage of one project could trigger delays in other transportation projects.
- "Planning" interrelationships, whereby an existing project and a planned project are related. These projects could be related in terms of commonalities or a disturbance relationship.
- "Functional" interrelationships, where projects can potentially reinforce or detract from each other in terms of allowing an entire route to be more efficient. These projects can be in the same corridor, on the same route or rail-line, and involve the same mode.

This capability also is a key feature for satisfying the Arizona Department of Transportation's needs. The existing method available for searching for interrelationships is the automated search. The current version of the Transportation Economic and Land Use System only permits an automated search. A Geographical Information System proximity search and a user-defined search are planned. The Geographical Information System search will query information stored on each project to within a specified distance radius to identify potentially interrelated projects. The user-defined search will allow the user to develop a customized set of linked queries to search for potential interrelationships.

Most data required during configuration can be imported directly into the Transportation Economic and Land Use System Transportation Improvement Program database. This is done through Microsoft Access software. The Team did not investigate in detail all of the data structures of the Arizona Department of Transportation compared to that required for the Transportation Economic and Land Use System; however, it appears from an examination of the Transportation Economic and Land Use System User Manual that compiling the data is a straightforward task. Utilization of data from legacy databases is a task that should be thoroughly analyzed before it is undertaken irrespective of the system being implemented.

- Summary

In summary, while the Highway Economic Requirements System/State Model can offer a powerful functionality, the use of this software should only be undertaken by organizations that have currently qualified users (training is a costly undertaking) and qualified software specialists to maintain the system. Since today's business analytical software primarily uses a Windows based user interface, command line and menu driven systems, are becoming obsolete.

5. SOLUTION ASSESSMENTS AND JUSTIFICATION

5.1 Comparison of Alternatives

The Highway Economic Requirements System and the Transportation Economic and Land Use System are compared in Table 5-1 using requirements (Section 3.1) that must be achieved to meet the expressed Arizona Department of Transportation objectives. The Team does not recommend the Transportation Economic and Land Use System specifically, but uses it as an example of a framework model of the functionality and user interface that must be incorporated in any On-Line Analytical Processing package that will be used for evaluating and managing Arizona Department of Transportation assets.

Table 5-1 Highway Economic Requirements System and the Transportation Economic and Land Use System Framework Model Compared

Requirement	Highway Economic Requirements System	TELUS Model
Comparison of Unrelated Asset Types	No; highways only	Yes; bridges now, others later
Project Ranking	Implied	Yes
User Friendly	No	Yes
Cost/Benefits	Yes	Yes
Highway system conditions and recommended changes	Yes	Yes
Job Creation	No	Yes
Project Relationships	No	Yes
Arizona Department of Transportation Capital Investment Required	Yes; if AZ data included	Yes; if AZ data included
Consider Environmental Compliance Costs	No	Unknown
Land Use Projections	No	Yes
Built in GIS	No	Yes

As the assessment in the charts shows, the Transportation Economic and Land Use System model offers the analytical capability for multiple asset categories, the highway functionality of the Highway Economic Requirements System, and ease of use, graphics orientation, and economic/environmental compliance considerations.

Like the Highway Economic Requirements System, it is offered free to state transportation departments. It is supported and funded by the Federal Highway Administration and therefore if implemented, technical support would probably be available.

While the Highway Economic Requirements System also receives Federal Highway Administration support, the DOS operating system requirement makes the Highway Economic Requirements System much harder to maintain. Individuals with DOS expertise are available, but in fewer numbers. In addition, current business applications are not being developed using DOS, and therefore it is becoming obsolete. Attempts to add features to the Highway Economic Requirements System, such as graphics or a user-friendly interface would create an inefficient and cumbersome interface just as earlier transitions of DOS applications to Windows imitators did.

Because basic functionality exists, and is proven in the Transportation Economic and Land Use System, the model could be used as a building block for On-Line Analytical Processing if the Arizona Department of Transportation, after evaluation, feels that it meets its needs. Currently, the Transportation Economic and Land Use System version 2.1 is available. An approach would be to generate a full On-Line Analytical Processing System Requirements Document and in parallel have potential users evaluate the Transportation Economic and Land Use System with current Arizona Department of Transportation data. This could reduce the time to initial implementation. In addition, while evaluating the Transportation Economic and Land Use System, the Arizona Department of Transportation can be investigating other On-Line Analytical Processing packages.

5.2. Highway Economic Requirements System Operation

The Team tested the Highway Economic Requirements System using data provided by the Arizona Department of Transportation. Representative output is contained in Appendix B. The conclusion was that the Highway Economic Requirements System could be made to run, but to understand the details of operating the program and read through the extensive output (58 pages) to find the key executive information was not an effective method for providing executive support.

5.3. Oregon and Indiana Assessment of the HERS/ST Model

- *Oregon*

On their website (http://www.odot.state.or.us/tddtpau/HwyNeeds.html) the Oregon Department of Transportation states that the Highway Economic Requirements System is used for modeling needs.

In discussions with Oregon Department of Transportation personnel, they stated that the Highway Economic Requirements System is used for specific decision planning projects rather than for general decision support. They have modified the Highway Economic Requirements System to include text file outputs with improvement locations that can easily be used with geographical information systems for further analysis. They only use it for its intended use for highways and have no plans to extend that capability to bridges. They do not consider environmental compliance related costs in their models. They also were not aware of the Transportation Economic and Land Use System.

- *Indiana*

Much of the material in this section was obtained from a report supplied by Steve Smith, Indiana Department of Transportation (INDOT). This report, *Highway Economic Requirements System for Indiana: Statewide Planning Applications- Draft*, Steve Smith, Indiana Department of Transportation, Dean Munn, Bernardin, Lockmueller & Associates, Inc., provides detailed information about the Indiana Department of Transportation's experiences.

In a discussion and subsequent email exchanges with Mr. Smith, the major points brought out were that: the Highway Economic Requirements System improvement needs were used as one element in the overall process of determining statewide proposed highway improvements; and the Indiana Department of Transportation intends to continue developing the Highway Economic Requirements System program to use in its statewide planning process.

Their plans for future use include better integration with the statewide travel demand model and more use of automated routines.

Currently, analysis using only the basic mode has been run. This mode provides for the evaluation of costs and benefits of potential improvements. Other modes will be implemented later. They are Project Override, which allows for segment specific projects to override the improvement selection logic, and the Travel Model mode, which allows the user the ability to modify traffic volumes on all affected roadway segments.

Indiana modified the Highway Economic Requirements System to reflect their specific needs. The Highway Economic Requirements System Improvement Needs model is a modification of the national Highway Economic Requirements System Version 3.097 and is written in Fortran running under DOS. Highway Economic Requirements System Improvement Needs creates a database for specific statewide application to Indiana's highway system needs analysis. The major modifications for Highway Economic Requirements System Improvement Needs are focusing on the analysis of added travel lanes projects that add capacity to the highway system. The Highway Economic Requirements System Improvement Needs analysis uses the Indiana Department of Transportation's corporate highway database, the road inventory system, to provide the core data for the state jurisdictional highway system. This is supplemented with Highway Performance Monitoring System based default data items to provide total system coverage. The Highway Economic Requirements System Improvement Needs analysis uses the traffic forecasts from the Indiana statewide travel demand model and geographic information system capabilities for statewide mapping and display. Highway Economic Requirements System Improvement Needs was used in the development of the project specific Indiana Department of Transportation's 2000 to 2025 statewide Transportation Plan.

Other modifications were also made. The Highway Economic Requirements System capabilities for the identification of alignment deficiencies (horizontal and vertical curvature) were dropped for initial applications due to problems in the data collection and data analysis procedures associated with curvature data.

One of the major enhancements of the Highway Economic Requirements System Improvement Needs is the linking of the models project specific output with the TransCAD (computer assisted drafting) based GIS. This linkage allows the model recommended improvement output to be plotted geographically and captured as a layer for other GIS planning applications. The Highway Economic Requirements System Improvement Needs output provides for:

- Linear referencing information—unique route identifier with beginning and ending log miles
- Deficiencies including Initial Volume/Capacity Ratio and geometric characteristics
- Improvement Type (number of Added Travel Lanes and ending number of lanes)
- Added capacity, future AADT and ending Volume/Capacity Ratio
- Improvement Cost and additional ROW requirements
- Benefit/Cost Ratio (and user benefits by category)

6. RECOMMENDED IMPLEMENTATION PLAN

The Team makes the following recommendations:

1. The Arizona Department of Transportation should prepare and issue an Asset Information Data Warehouse System Requirements Document (SRD) defining the functionality, performance, interfaces, design constraints, and acceptance criteria. All potential using organizations should concur with the requirements for it to be issued as a formal document.
2. The requirements related to the databases to be used by the Asset Information Data Warehouse, the On-Line Analytical Processing goals/requirements, and the user interface should be clearly delineated in the System Requirements Document. This document should emphasize the integrated approach to Transportation Infrastructure Asset Management in that On-Line Analytical Processing is an integral part of the process and that the goal is to provide economic assessment of unlike assets.
3. The Arizona Department of Transportation should not consider implementing the Highway Economic Requirements System/State Model.
4. The Arizona Department of Transportation should investigate the Transportation Economic and Land Use System and software similar to it that may offer the functionality required by Transportation Infrastructure Asset Management and stated in Section 3.1.
5. For long range planning, Arizona Department of Transportation formal procedures should incorporate the requirement that all projects be subject to the recommended integrated Asset Information Data Warehouse On-Line Analytical Processing analysis during the planning and budgeting process (previously shown in Section 3 and repeated here as Figure 6-1). We refer to this as the Transportation Infrastructure Asset Management program "TO-BE" Process.

The Team concurs in the approach the Arizona Department of Transportation is using for Asset Information Data Warehouse. However, it was not clear to the Team that:

- There exists an Asset Information Data Warehouse System Requirements Document that defines functionality, performance, interfaces, design constraints, and acceptance criteria particularly with respect to On-Line Analytical Processing or the user interface. The team requested this document, but one was never supplied. If one exists, it should be reviewed for On-Line Analytical Processing functionality.
- The Highway Economic Requirements System is being considered as integral to the Asset Information Data Warehouse as a decision support tool. As a result, our recommended TO-BE approach integrates a framework for an analytical tool that will provide an economic analysis of unlike assets. This is a task that cannot be accomplished by the Highway Economic Requirements System/State Model.

If a System Requirements Document does not exist, it should be generated and include the requirement that it provide the capability to evaluate the cost benefit ratios to compare projects in one asset area (highways for instance) against another asset area (light rail).

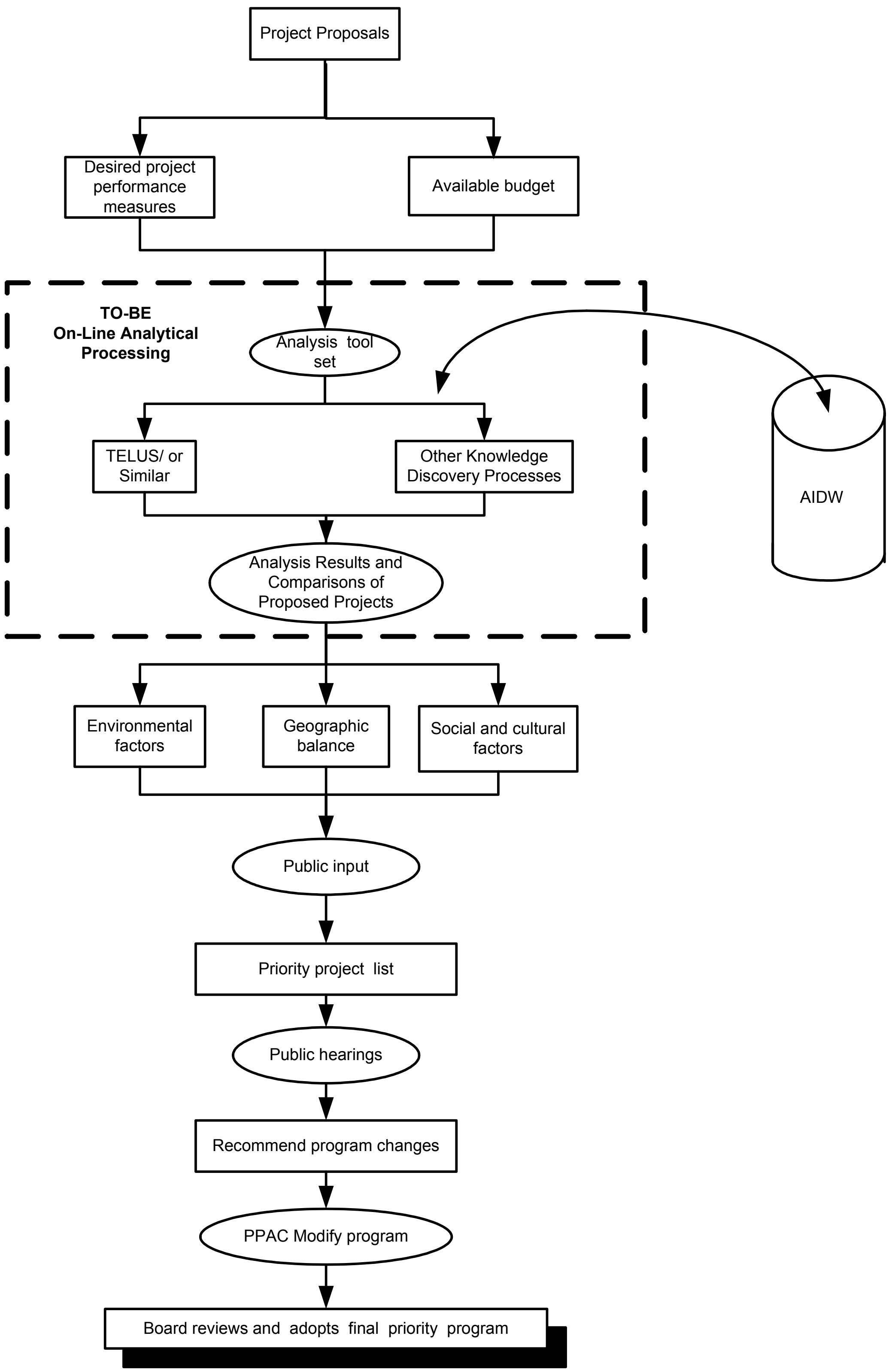


Figure 6-1 Transportation Infrastructure Asset Management Recommended TO-BE Process

The Team also recommends that the Arizona Department of Transportation not consider implementing the Highway Economic Requirements System/State Model because of the extensive training and maintenance that will be required for an essentially obsolete interface and programming language (FORTRAN) for solving modern day business problems. In addition, it does not have the functionality required for evaluating projects other than highways. Incorporation of the required functionality into the existing code could be prohibitively costly and time consuming.

We recommend thoroughly investigating software similar to the Transportation Economic and Land Use System. The Team does *not* recommend the Transportation Economic and Land Use System specifically, but uses it as framework model of the functionality and user interface that must be incorporated in any On-Line Analytical Processing package that will be used for evaluating and managing Arizona Department of Transportation assets. The Transportation Economic and Land Use System software could be used to do trade-off analysis. It would use essentially the same input data used by the Highway Economic Requirements System/State Model.

Utilization of On-Line Analytical Processing analysis for projects in the planning process is a long-range goal, but the effort to establish that requirement should start now because it will affect the System Requirements Document content of the functions and interfaces. Particularly, the Asset Information Data Warehouse should support efficient queries and collect data pertinent to the enterprise-wide decision making processes, rather than simply manage inventory and every piece of data collected by the Arizona Department of Transportation. The Asset Information Data Warehouse must be a centralized and shared database, and the collection and management of operational data must belong to and be "owned" by functional organizations. Sharing data will be the key to a successful Transportation Infrastructure Asset Management system.

Transportation Infrastructure Asset Management will be one of the important applications of the Asset Information Data Warehouse. Information developed using On-Line Analytical Processing can be used more effectively to prioritize and propose programs and provide performance feedback. Data needed by analysis tools such as the Transportation Economic and Land Use System should be stored in the Asset Information Data Warehouse, but it should be owned by the functional organizations.

Further, the Asset Information Data Warehouse should be an end-customer query and analytical tool set. The Asset Information Data Warehouse should have an integrated set of tools to allow users to easily find, access, navigate and analyze information for business use. For example, there should be graphical information system capabilities to allow data users to find data using maps along with a set of integrated productivity tools, such as Excel, Access, Visio, Word, and Internet, Intranet, and email mechanisms that allow data sharing and communication.

While these considerations may currently be a part of Arizona Department of Transportation planning, documentation, other than that contained in Asset Information Data Warehouse presentations, did not support this assumption.

REFERENCES

1. Transportation Planning Division, Arizona Department of Transportation, 206 S. 17th Ave., Phoenix, AZ 85007, Web Site http://map.azfms.com/index.html, 4/30/02

2. *Arizona Department of Transportation Interim Programming Process*. Transportation Board Study Session. Presented by Frances D. Harrison. Cambridge Systematics, Inc. Oct. 3, 2001

3. *Passing Lanes Climbing Lanes Preliminary Report*. Prepared by Lima & Associates for the Arizona Department of Transportation. January 2000.

4. *Arizona Department of Transportation Information Resource Management White Paper*, Doanh Bui. ITG Project Management, 206 S. 17th Ave, Room 119, Phoenix, AZ 850079/06/2001.

5. *The Highway Economic Requirements System/State Model Overview Report*. Federal Highway Administration. March 2001

Other Sources Related to the Highway Economic Requirements System/State Model

www.tfhrc.gov/focus/dec99/software.htm A brief introduction to the Highway Economic Requirements System/State Model software. Turner-Fairbanks Highway Research Center web site of the US Department of Transportation Federal Highway Administration; site active 4/30/02.

www.fhwa.dot.gov/infrastructure/asstmgmt/hersindex.htm Official website of US Department of Transportation, you can download the Highway Economic Requirements System/State Model software, the Highway Economic Requirements System/State Model application, and the Highway Economic Requirements System/State Model test data here. Turner-Fairbanks Highway Research Center web site of the US Department of Transportation Federal Highway Administration; site active 4/30/02.

www.odot.state.or.us/tddtpau/HwyNeeds.html Oregon Department of Transportation website. Includes some useful information on the Highway Economic Requirements System/State Model, e.g., GAO report on the Highway Economic Requirements System/State Model. Oregon Department of Transportation, Transportation Planning Analysis Unit, 555 13th St. N.E., Suite 2, Salem, OR 97301-4178. ph: 503-986-4218. Site active 4/30/02.

www.fhwa.dot.gov/infrastructure/asstmgmt/resource.htm US Department of Transportation, Infrastructure Asset Management. Turner-Fairbanks Highway Research Center web site of the US Department of Transportation Federal Highway Administration; site active 4/30/02.

TELUS Website http://www.telus-national.org Institute for Transportation, New Jersey Institute of Technology, University Heights, Newark, N.J. 07102. Phone: 973-596-3000, site active 4/30/02.

APPENDIX A: OPERATING THE HERS/ST MODEL

Introduction

This appendix covers the procedure for operating the Highway Economic Requirements System/State Model. This procedure can be broken down into several distinct steps:

- Downloading the Highway Economic Requirements System/State Model software and documentation
- Modifying the Highway Economic Requirements System/State Model program input files.
- Executing the Highway Economic Requirements System/State Model program
- Viewing the Highway Economic Requirements System/State Model output files

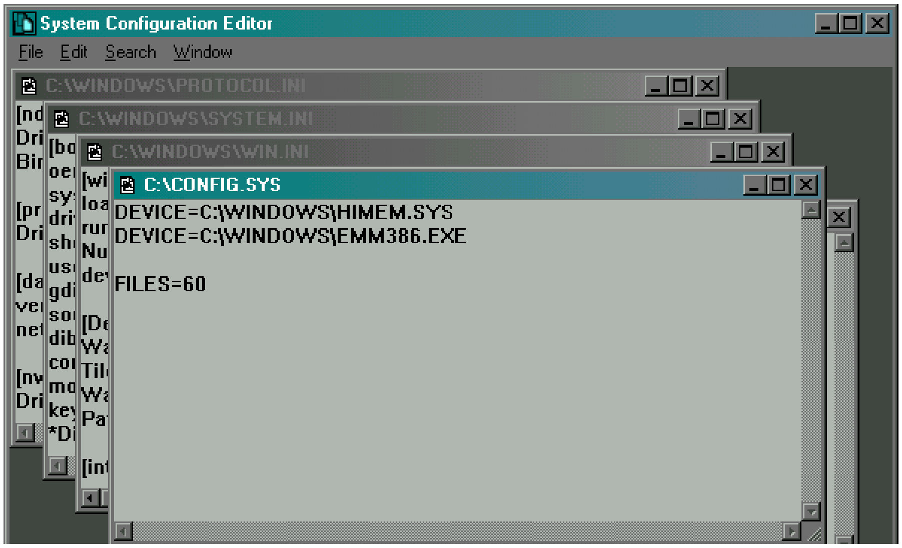
Downloading the Highway Economic Requirements System/State Model

The Federal Highway Administration (FHWA) has made the Highway Economic Requirements System/State Model available to all state DOTs through its website at:

www.fhwa.dot.gov/infrastructure/asstmgmt/hersindex.htm. The Highway Economic Requirements System/State Model program comes in a zipped file that should be unzipped into a single folder. After unzipping the program, it is a good idea to backup all parameter, data, and control files into a separate folder.

For proper Highway Economic Requirements System/State Model program operation, the maximum allowed number of file handles for the operating system must be set. For Windows 95 or 98, edit CONFIG.SYS (usually found in your C: drive root directory) and modify the FILES= line to read: "FILES=60". For Windows NT, edit the CONFIG.NT file (usually found in C:\WINNT\SYSTEM32\) to read: "FILES=100". (See Figure 1)

-    Figure 1 – CONFIG.SYS



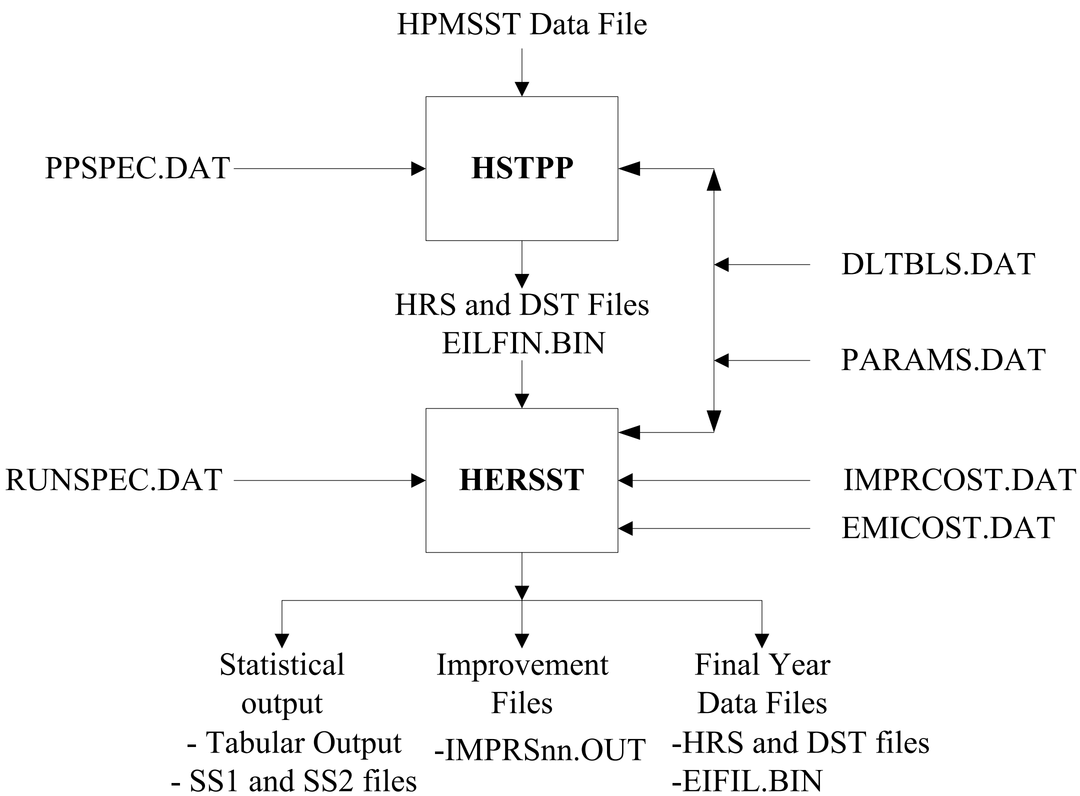
The Highway Economic Requirements System/State Model zipped archive also includes an extensive amount of documentation that is listed below.

- *Highway Economic Requirements System/State Model Overview*
  - Conceptual introduction to the HERS methodology
- *Highway Economic Requirements System/State Model Users Guide*
  - A supplement to the national Users' Guide, focuses on running /ST
- *HERS Users Guide v3.26 (Final Draft)*
  - Addresses the national model, almost universally applicable to /ST
- *Using RunPrep*
  - Guide to using RunPrep to prepare Highway Economic Requirements System/State Model control files (RUNSPEC)
- *HERS Technical Report v3.26*
  - Documents national model
  - Detailed exposition (including theories and derivation) of internal models (demand elasticity, speed calculation, etc.) with algorithms and equations
  - Almost universal application to /ST

Highway Economic Requirements System/State Model Input Files

The Highway Economic Requirements System/State Model uses many input files for data, parameters used during program calculations, and specifications for controlling program operation. The basic structure of the Highway Economic Requirements System/State Model application can been seen in Figure 2.

Figure 2 - HERS/ST SYSTEM STRUCTUE



Highway Economic Requirements System/State Model input files can be divided into the following categories:

Data Files
- HPMS/ST Section Data File

Parameter Files
- Emission Cost Factor File (EMICOST)
- Improvement Cost File (IMPRCOST)
- Deficiency File (DLTBLS)
- Miscellaneous Parameter File (PARAMS)

Control Files
- PreProcessor Control File (PPSPEC)
- Highway Economic Requirements System/State Model Control File (RUNSPEC)

ALL INPUT FILES MUST BE EDITED WITH A TEXT EDITOR, NOT A WORD PROCESSOR. Word processors add special formatting characters to a text file, which will cause the Highway Economic Requirements System/State Model to crash. Notepad is an example of a text editor that comes with Microsoft Windows products. Other text editors are freely available on the Internet.

When editing the input files, it is very important that you maintain line and column alignment, since placing entries in the wrong column can result in truncated entries. Also, inadvertently adding or deleting a line will cause the program to read incorrect values and may result in a program crash. When editing, note the line numbers and column indicators to ensure you are making modifications to the correct parameter. To maintain column alignment while editing, you should also use a "fixed-width" font in the text editor. Several examples of fixed-width fonts include Courier New, Line Printer, Lucida Console, Letter Gothic, FixedSys, and Courier.

(NOTE: For testing and initial program operation, none of the Highway Economic Requirements System/State Model input files need to be modified (with the possible exception of PPSPEC.DAT and RUNSPEC.DAT – see below) for the Highway Economic Requirements System/State Model to operate properly. However, as you become more familiar with the Highway Economic Requirements System/State Model, you will want to "fine-tune" its operation to fit your needs.)

Modifying HPMS section data

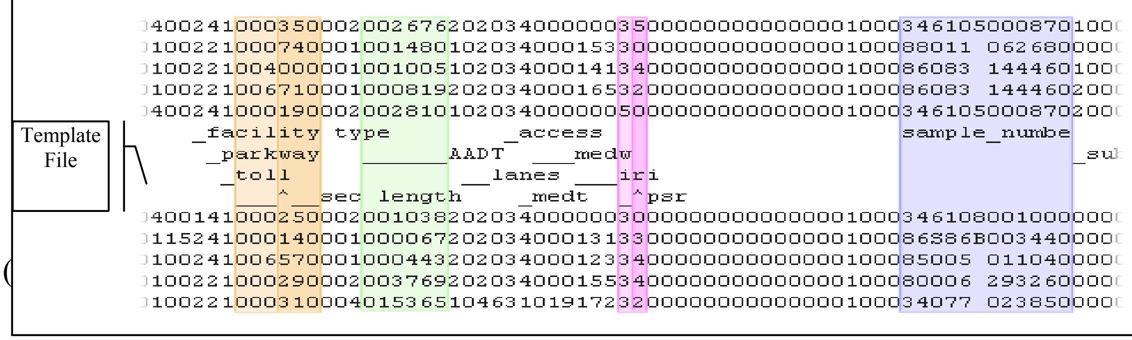
There are several reasons why you may want to modify section data. They include:

- To separate subsets of sections: by county, region, functional class, or specific highways or projects
- To specify exogenous improvements for certain sections (superfields)
- To alter section characteristics (PSR, future traffic, capacity, etc.)
- To set expansion factors to 1.0

Section data files use a modified 1993 HPMS non-delimited format that is described in more detail in the *Highway Economic Requirements System/State Model Users Guide* Table 2.2 and the *HERS Users' Guide* Table 3-1. Superfields can be added to each section to specify any pre-planned or pre-existing improvements for that section (exogenous improvements.) The format for these superfields can be found in the *Highway Economic Requirements System/State Model Users Guide* Table 3.1.

If you decide to modify the HPMS section data file, a template file (FORMAT_ST.TXT) is included in your zip archive. Use Copy and Paste to insert the template into to data file to help identify important data columns. (See Figure 3).

Figure 3 – FORMAT_ST.TXT in a HPMS section file



Editing the Emission Cost File (EMICOST.DAT)

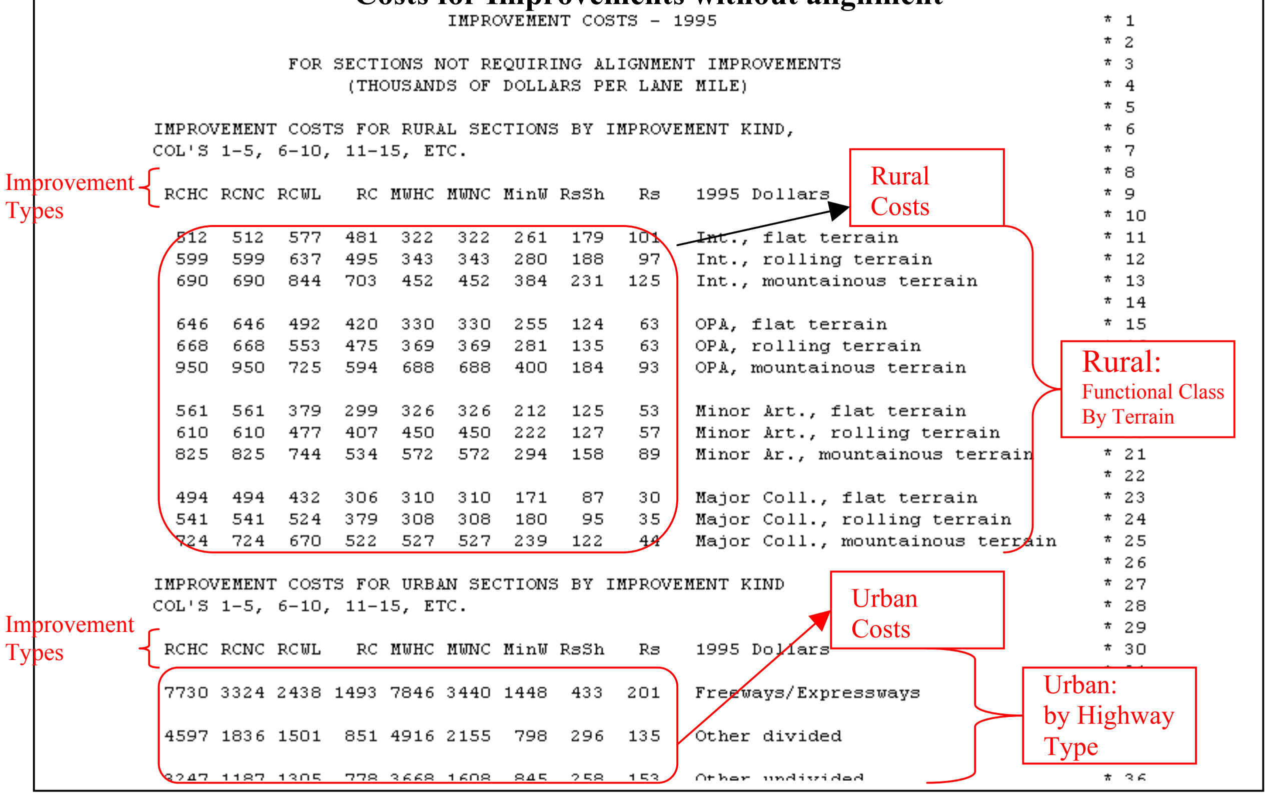
EMICOST.DAT contains values used in emission cost equations. The Federal Highway Administration recommends that no changes be made to this file. For further details about emission cost values used in the Highway Economic Requirements System/State Model, please see the *HERS Technical Report* Section 7.3, Appendix F, and Appendix G, and the *HERS Users' Guide* Section 3.2.4.

Preparing the Improvement Cost File (IMPRCOST.DAT)

IMPRCOST.DAT contains specifications of the costs of highway improvements considered by the Highway Economic Requirements System/State Model. It contains national average costs for improvements without alignment changes in 1995 dollars and national average costs for improvements including alignment in 1988 dollars. For more details, refer to the *Highway Economic Requirements System/State Model Users Guide*, Section 2.4, the *HERS Users' Guide* Section 3.2.3 and Exhibit C-5, and the *HERS Technical Report*, Section 7.4. A sample page from IMPRCOST.DAT is shown in Figure 4.

- Figure 4 – IMPRCOST.DAT

Costs for Improvements without alignment


```
                      IMPROVEMENT COSTS - 1995                              * 1
                                                                            * 2
          FOR SECTIONS NOT REQUIRING ALIGNMENT IMPROVEMENTS                 * 3
               (THOUSANDS OF DOLLARS PER LANE MILE)                         * 4
                                                                            * 5
IMPROVEMENT COSTS FOR RURAL SECTIONS BY IMPROVEMENT KIND,                   * 6
COL'S 1-5, 6-10, 11-15, ETC.                                                * 7
                                                                            * 8
 RCHC RCNC RCWL   RC MWHC MWNC MinW RsSh   Rs   1995 Dollars                * 9
                                                                            * 10
  512  512  577  481  322  322  261  179  101   Int., flat terrain          * 11
  599  599  637  495  343  343  280  188   97   Int., rolling terrain       * 12
  690  690  844  703  452  452  384  231  125   Int., mountainous terrain   * 13
                                                                            * 14
  646  646  492  420  330  330  255  124   63   OPA, flat terrain           * 15
  668  668  553  475  369  369  281  135   63   OPA, rolling terrain
  950  950  725  594  688  688  400  184   93   OPA, mountainous terrain

  561  561  379  299  326  326  212  125   53   Minor Art., flat terrain
  610  610  477  407  450  450  222  127   57   Minor Art., rolling terrain
  825  825  744  534  572  572  294  158   89   Minor Ar., mountainous terrain  * 21
                                                                            * 22
  494  494  432  306  310  310  171   87   30   Major Coll., flat terrain   * 23
  541  541  524  379  308  308  180   95   35   Major Coll., rolling terrain  * 24
  724  724  670  522  527  527  239  122   44   Major Coll., mountainous terrain  * 25
                                                                            * 26
IMPROVEMENT COSTS FOR URBAN SECTIONS BY IMPROVEMENT KIND                    * 27
COL'S 1-5, 6-10, 11-15, ETC.                                                * 28
                                                                            * 29
 RCHC RCNC RCWL   RC MWHC MWNC MinW RsSh   Rs   1995 Dollars                * 30

 7730 3324 2438 1493 7846 3440 1448  433  201   Freeways/Expressways

 4597 1836 1501  851 4916 2155  798  296  135   Other divided

 3247 1187 1305  778 3668 1608  845  258  153   Other undivided             * 36
```


Preparing the Deficiency Level File (DLTBLS.DAT)

DLTBLS.DAT is a parameter file containing design standards and deficiency levels for highway sections by functional system, terrain, and traffic level. Deficiency levels prompt the Highway Economic Requirements System/State Model to consider improvements. You may want to adjust deficiency settings to:

- increase or decrease the number of sections the Highway Economic Requirements System/State Model considers improving
- widen or narrow the range of improvement options on those sections

- influence program run time

To see a detailed listing of parameters contained in DLTBLS.DAT, please refer to the *HERS Technical Report* Section 3 (identifying improvements), especially Sections 3.2 and 3.5, and the *HERS Users' Guide* Section 3.2.2 and Exhibit C-4. An example of data contained in DLTBLS.DAT is shown in Figure 5.

- Figure 5 – DLTBLS.DAT

```
    PAVEMENT CONDITION       "DL&SDLs=TechRep v3.10"                        * 1
 UL     RL    MTC    DL         Rural:                              IROW    * 2
1.8    2.0    3.0    3.2              Interstate:      Flat            1    * 3
1.8    2.0    3.0    3.2                               Rolling         2    * 4
1.8    2.0    3.0    3.2                               Mountainous     3    * 5
1.8    2.0    3.0    3.2              OPA   ADT>6000:  Flat            4    * 6
1.8    2.0    3.0    3.2                               Rolling         5    * 7
1.8    2.0    3.0    3.2                               Mountainous     6    * 8
1.5    2.0    2.8    3.0              OPA ADT<=6000:   Flat            7    * 9
1.5    2.0    2.8    3.0                               Rolling         8    * 10
1.5    2.0    2.8    3.0                               Mountainous     9    * 11
1.2    1.5    2.4    2.6              MA    ADT>2000:  Flat           10    * 12
1.2    1.5    2.4    2.6                               Rolling        11    * 13
1.2    1.5    2.4    2.6                               Mountainous    12    * 14
1.2    1.5    2.4    2.6              MA   ADT<=2000:  Flat           13    * 15
1.2    1.5    2.4    2.6                               Rolling        14    * 16
1.2    1.5    2.4    2.6                               Mountainous    15    * 17
1.0    1.1    2.0    2.4          Coll.'s   ADT>1000:  Flat           16    * 18
1.0    1.1    2.0    2.4                               Rolling        17    * 19
1.0    1.1    2.0    2.4                               Mountainous    18    * 20
0.8    1.1    2.0    2.4        Coll.s ADT=400-1000:   Flat           19    * 21
0.8    1.1    2.0    2.4                               Rolling        20    * 22
0.8    1.1    2.0    2.4                               Mountainous    21    * 23
0.6    0.8    1.8    2.2           Coll.'s   ADT<400:  Flat           22    * 24
0.6    0.8    1.8    2.2                               Rolling        23    * 25
0.6    0.8    1.8    2.2                               Mountainous    24    * 26
2.0    2.2    3.2    3.4         Urban:     Interstate                25    * 27
1.8    2.0    3.0    3.2                    Other Freeway             26    * 28
1.6    1.8    2.8    3.0                    OPA                       27    * 29
1.0    1.1    2.4    2.6                    MA                        28    * 30
0.8    1.0    2.0    2.4                    Collectors                29    * 31
```

Rural: Functional Class and Volume Group by Terrain

Urban: By Functional Class

Preparing the Parameter File (PARAMS.DAT)

PARAMS.DAT contains a wide assortment of entries used in the Highway Economic Requirements System/State Model program calculations. It opens with a block of miscellaneous entries, followed by entries for operating costs, general price indices, entries for 7 subroutines, and state costs factors (all indexed to 1997 dollars). For most cases, you will want to use the default values, but several parameters you may want to change include Widening Feasibility Override factors, the maximum number of lanes allowed (default is 99), and the State Cost Factor. For further details about the contents of PARAMS.DAT, consult the *Highway Economic Requirements System/State Model Users Guide, Section* 2.4 and the *HERS Users' Guide Section* 3.2.1 and Exhibit C-3. An example of the miscellaneous entries (including the Widening Feasibility Override and Max. Number of Lanes) is shown in Figure 6.

- Figure 6 – PARAMS.DAT

```
                              PARAMETERS  - 1997 values  (5/11/00)                  * 1
(for use with 1995 improvement costs)  SAFO_OOR.PAR      v ST1.0                    * 2
                                                                                    * 3
                         **  For COMMON blocks **                                   * 4
20                       DP (1-99) Design period (in yrs), columns 1-2              * 5
                         WDFOVR - Widening Feasibility Override                     * 6
 5  5  5  5                - Rural, by FC, col. 1-2, 4-5, etc.                      * 7
 5  5  5  5  5             - Urban, by FC                                           * 8
99 99 99 99              MAXLNS Max. # lanes - rural, by FC, col. 1-2, 4-5, etc.    * 9
99 99 99 99 99           MAXLNS Max. # lanes - urban, by FC                         * 10
1.5 2.5 3.0 4.0 5.0 5.5 PAVMTH New pavement thickness after reconstruction          * 11
                          of and resurfacing over flexible pavement                 * 12
                          by design number of ESALS (<RNGLIM(1),                    * 13
                          RNGLIM(1) - RNGLIM(2), ..., >RNGLIM(5)),                  * 14
                          columns 1-3, 5-7, etc. (RNGLIM spec. below)               * 15
6.5 6.5 6.5 8.0 9.5 10.5PAVMTH New pavement thickness after reconstruction          * 16
                          of rigid pavement by design number of ESALS,              * 17
                          columns 1-4, 5-8, etc.                                    * 18
1.000 1.000 1.000 1.000 Truck growth factor - rural by FC, col. 1-5, 7-11 etc       * 19
1.000 1.000 1.000 1.000 Truck growth factor - urban by FC                           * 20
1.000                                                                               * 21
```

Editing the PreProcessor Control File (PPSPEC.DAT)

PPSPEC.DAT controls execution of the Highway Economic Requirements System/State Model PreProcessor. It identifies input and output files, sets processing information and error-reporting parameters. To learn more about PPSPEC.DAT, see the *HERS Users' Guide* Section 2.1.1, Table 2-2, and Exhibit C-1.

(NOTE: PPSPEC.DAT MUST be modified to correctly identify the file name of the HPMS data file you wish to process. See Figure 7.)

- Figure 7 – PPSPEC.DAT

Input and Output File Names

```
                                                                              -
Test100.DAT         Original HPMS data file to preprocessed, columns 1-23     * 6
Test100.HRS         HERS data file to be created, columns 1-23                * 7
Test100.DST         Truck VMT distr. file to be created, columns 1-23         * 8
1997                BASEYR: Base Data Year                                    * 9
1.0                 PSR for unpaved sections (must be > 0; if 0 is            * 10
                    specified 1.0 will be used instead), columns 1-3          * 11
25.0                Maximum annual traffic growth rate (in %), col. 1-4       * 12
1                   Description of new traffic growth rate input, column 1    * 13
                       1 - use default value below for every section with     * 14
                           growth rate greater than the above maximum         * 15
                       2 - interactively for every section with growth        * 16
                           rate greater than the above maximum                * 17
25.0                Traffic growth rate for sections whose growth rate        * 18
                    exceeds the maximum, columns 1-4                          * 19
0                   PSERR: Error reporting flag                               * 20
                       0 - do not report missing SNorD and PAVSEC data        * 21
                       1 - print error message for sections missing both      * 22
                           SNorD and PAVSEC                                   * 23
80                  PGTMAX: Top limit for the percentage of green time        * 24
20                  PGTMIN: Bottom limit for the percntg of green time        * 25
65 50 25            PGTRUR: Default prcntg of green time for principal        * 26
                    arterials,minor arterials, and collectors, respectively   * 27
16.                 MAXR: Upper limit for AADT over capacity ratio            * 28
1                   MRERR: Error reporting flag                               * 29
                       0 - do not report AADT over capacity exceeded MAXR     * 30
                       1 - print error message for sections with AADT over    * 31
                           capacity ratio exceeded MAXR                       * 32
25.                 MAXTCD: Upper limit for average number of stop signs      * 33
                      and traffic signals per mile                            * 34
1                   NTDERR: Error reporting flag                              * 35
                       0 - do not report average number of stop signs and     * 36
                           traffic signals per mile exceeded MAXTCD           * 37
                       1 - print warning message for sections with average    * 38
                           number of stop signs and traffic signals per       * 39
                           mile exceeded MAXTCD                               * 40
75                  MAXSPL: Maximum speed limit in miles per hour             * 41
```

Preparing the Highway Economic Requirements System/State Model Control File (RUNSPEC.DAT)

RUNSPEC.DAT can be modified using a text editor or the RunPrep program. RUNSPEC.DAT controls execution of the Highway Economic Requirements System/State Model program. It identifies input and output files, sets Analysis controls (based on funds available or performance goals) and other processing parameters, and determines output options. References for RUNSPEC.DAT are found in the *HERS Users' Guide* Section 2.2.1, Table 2-4, and Exhibit C-2.

(NOTE: RUNSPEC.DAT MUST be modified to correctly identify the file name of Preprocessor binary file you wish to process. See Figure 8.)

- Figure 8 – RUNSPEC.DAT

File Control and Identification

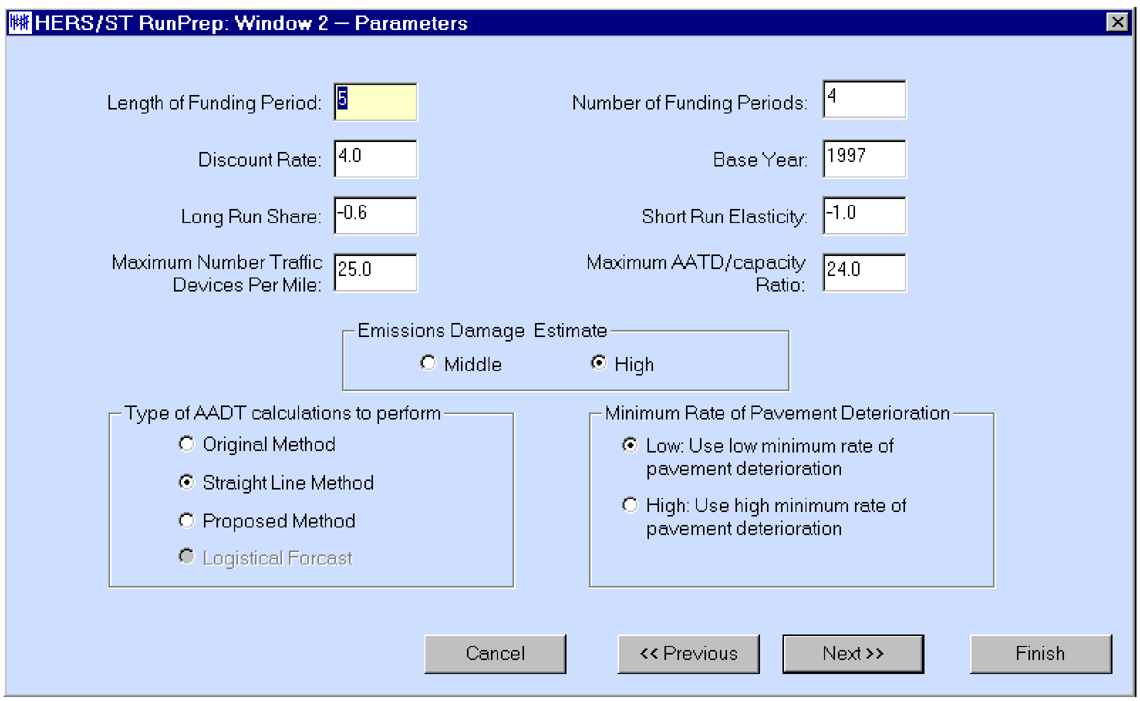
```
                          RUN SPECIFICATIONS      HERS/ST 1.0
                                                              [tlilb 1:2]
                                                              [tlilb 2:2]
Test1                   Run number (to appear at top of every page of report)
                        columns 1-8
                        Run description (to appear at top of every page)
                        columns 1-50, two lines   |<--- col. 50
Test Run  Data base=Test  Economic Efficiency Run

0                       Switch that allows HERS input data file to be
                        overwritten while processing, column 1
                            1 - OK to overwrite
                            0 - Do not overwrite, create a copy
1                       Switch that allows HERS to delete file(s) describing
                        the system(s) at the end of analysis, column 1
                            1 - OK to delete
                            0 - Do not delete
1                       Warning message switch
                             1 - Send to file WARNMSG.OUT
                             0 - Send to screen
TEST.HRS                HERS data file to be processed, columns 1-23
Test.DST                Truck VMT distrib. file, columns 1-23
Test.OUT                The output-tables file (PRN for printer), columns 1-23
1997                    Base Year
5                       Length of funding period, columns 1-2
4                       Number of funding periods to be analyzed, columns 1-2
2                       Type of AADT calculation to perform
                            1 - original method
                            2 - straight line method
                            3 - proposed method
                            4 - logistic forecast
-0.6                    Long Run Share of Elasticity, columns 1-5
-1.0                    Short Run Elasticity, columns 1-5
```

Using RunPrep

RunPrep is designed to simplify the process of editing the RUNSPEC.DAT file. It is a Windows based program, providing a user-friendly interface for editing. Since many RUNSPEC entries are conditional (only used during certain types of analysis), RunPrep guides your entries to only the necessary fields based upon the type of analysis you choose. (RunPrep is further documented in the *Using RunPrep* documentation.) RunPrep can be run simply by double-clicking on the RunPrep.exe icon (in the same folder as the Highway Economic Requirements System/State Model.) A sample screen from the RunPrep program can be seen in Figure 9.

- Figure 9 – Using RunPrep to edit RUNSPEC.DAT



- Highway Economic Requirements System/State Model Program Execution

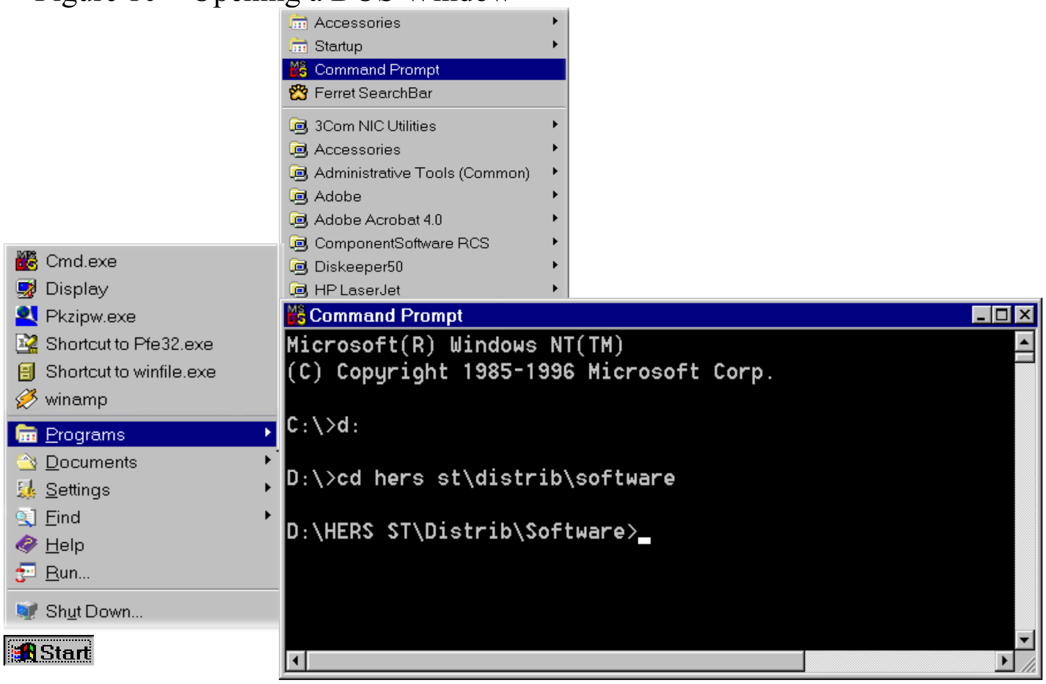
Highway Economic Requirements System/State Model program execution can be divided into 2 basic steps:

1. Running the Highway Economic Requirements System/State Model PreProcessor
2. Running the Highway Economic Requirements System/State Model Main Program.

Running the Highway Economic Requirements System/State Model PreProcessor

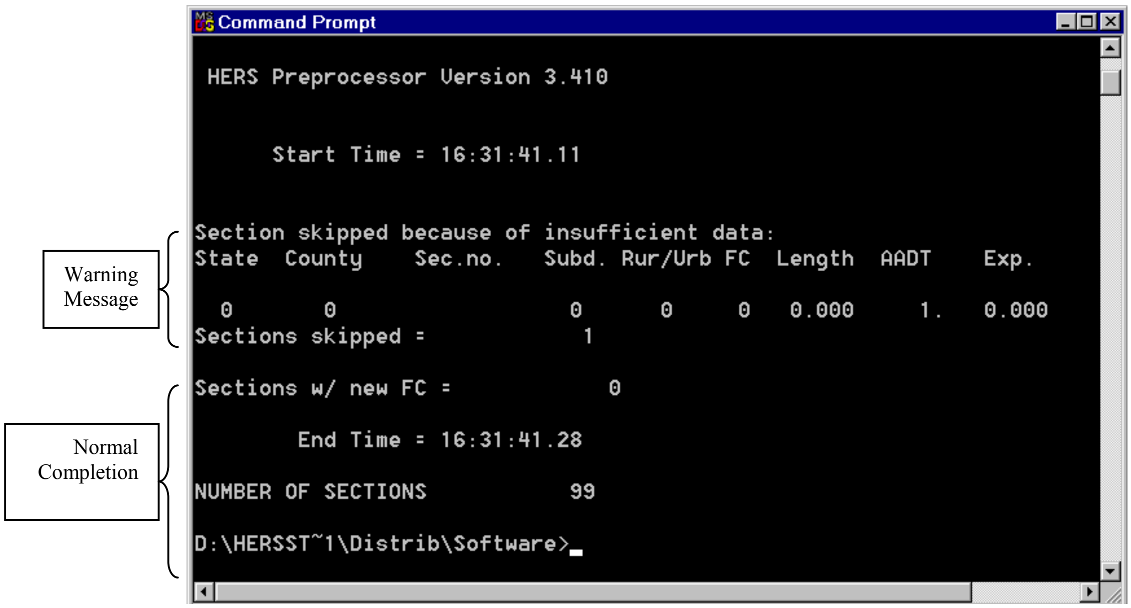
1. After modifying any input files (remember PPSPEC.DAT and RUNSPEC.DAT), open a DOS, or “Command Prompt” window. Once a command prompt is open, change the current directory to the directory where you unzipped the Highway Economic Requirements System/State Model. (See Figure 10.)

- Figure 10 – Opening a DOS Window



2. To execute the Preprocessor, simply type in "HSTPP". The Preprocessor will print output information to the screen, showing the number of sections it processed. It may also display warning messages for sections with insufficient data. (NOTE: if an output file (with .DST file extension) already exists, the Preprocessor will abort operation and display and error message.) See Figure 11 for a typical Preprocessor output.

- Figure 11- Typical HERS/ST PreProcessor Output



The Highway Economic Requirements System/State Model Preprocessor uses 4 input files:

- HPMS Data File
- PPSPEC.DAT
- DLTBLS.DAT
- PARAMS.DAT

It produces 3 output files:

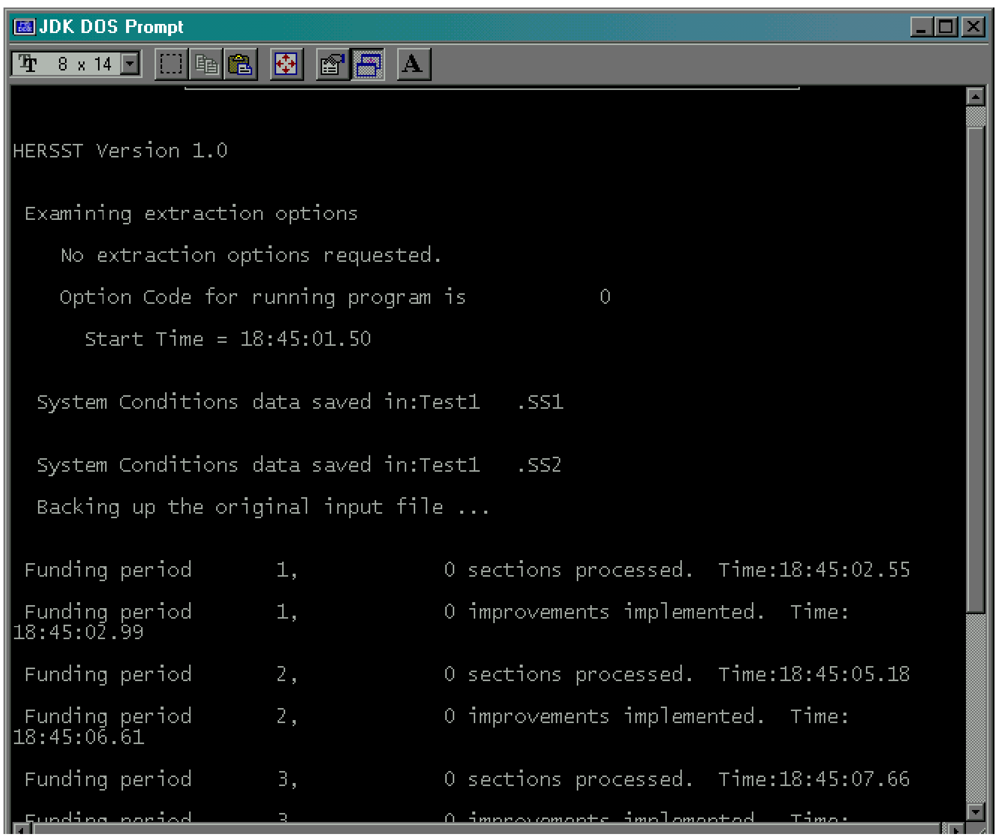
- a binary data file ***.HRS
- a distribution file ***.DST
- a exogenous improvement file EIFIL.BIN

Running the Highway Economic Requirements System/State Model Main Program

1. To run the Highway Economic Requirements System/State Model main program, simply type in "HERSST". The Highway Economic Requirements System/State Model will process the files produced by the Preprocessor using parameters from RUNSPEC.DAT, IMPRCOST.DAT, and EMICOST.DAT. (See Figure 12.) The main program produces 3 groups of output files:
   - Statistical Output (.OUT, .SS*n* files)
   - Improvement Files (IMPRSnn.OUT)
   - Final Year Data Files (.HRS and .DST files)

(NOTE: HSTPP and HERSST will not run if some of their output files (.DST .OUT, etc.) exist. If you get error messages to this effect when trying to run either program, run DELRUNPP.exe and DELRUN1.exe, then make sure all output files are deleted before trying to run the program again.)

- Figure 12 – HERST Main Program Operation



- *Output Files*

Highway Economic Requirements System/State Model output files are grouped as follows:

- Statistical Output (.OUT, .SS*n* files)
- Improvement Files (IMPRSnn.OUT)
- Final Year Data Files (.HRS and .DST files)

The .OUT file produces several System Conditions output pages (Figure 13) categorized by Functional class and an Initial Costs output page for suggested improvements (Figure 14).

- Figure 13 – System Conditions Output Page

HERSST Version 1.0

RUN NUMBER: NatSTb2 Economic Efficiency Run w/ /ST v1.0b using 97 National data, high min pave det rate 12/15/2000

CONDITIONS AT BEGINNING OF ANALYSIS PERIOD

	RURAL					URBAN						TOTAL
	Int.	OPA	MA	Maj. C.	TOTAL	Int.	OFE	OPA	MA	Coll.	TOTAL	
Miles	32823	98313	137724	433267	702129	13281	9020	53109	89247	87976	252635	954765
Average PSR	3.43	3.33	3.32	3.28	3.35	3.12	3.04	2.98	3.24	3.19	3.10	3.20
Average IRI(in/mi)	93	102	107	114	103	114	124	136	118	124	123	115
Average Speed	70.68	55.34	50.87	47.61	55.65	57.11	52.36	26.46	26.55	25.64	33.16	39.27
Congestion Delay (hours/1000 VMT)	0.47	1.20	1.40	0.93	0.96	2.15	2.45	10.07	8.21	6.83	6.29	4.24
Avg.Total Delay (hours/1000 VMT)	0.47	1.60	2.10	2.13	1.51	2.16	2.96	16.59	15.19	15.63	10.65	7.13
VMT (in billns)	238	228	163	201	833	360	158	386	298	126	1331	2164
USER COSTS ($ per 1000 vehicle-miles):												
Trav. Time Costs	273	332	356	379	331	315	336	664	661	685	532	455
Operating Costs:												
- 4-Tire Vehicles	232	214	209	212	217	222	224	232	224	224	226	222
- Trucks	564	495	480	486	524	516	505	493	483	481	501	513
- All Vehicles	312	253	237	236	262	256	244	249	239	238	247	253
Crash Costs	66	146	182	220	148	108	115	263	190	132	175	165
Total User Costs	651	732	776	837	743	680	696	1177	1092	1057	954	873
ANNUAL USER COSTS (in $ millions):	155661	167586	127316	169043	619607	245785	110530	454523	326467	134032	1271339	1890947
CRASH/INJURY/FATALITY RATES (per 100 million vehicle-miles):												
Crashes	85.7	141.0	224.0	222.8	161.3	164.5	220.0	572.4	535.0	443.2	399.1	307.6
Injuries	39.0	89.1	125.7	139.5	94.1	80.7	80.1	235.4	182.0	154.9	155.3	131.8
Fatalities	1.21	2.38	3.05	3.05	2.34	0.63	0.87	1.56	1.27	1.14	1.12	1.59
AVG. ANN. MN. C. ($ per mile)	8522	4047	2321	1720	2482	13168	9282	5732	2743	2143	3944	2869
AV. POLLUTION C. ($ per 1000 vehicle-mile)	20.94	12.82	11.14	15.76	15.53	48.46	44.22	38.04	37.07	37.00	41.29	31.37
% VMT below MTC for:												
- PSR	20.47	21.99	5.51	4.31	14.03	54.56	44.63	40.12	13.03	5.08	35.15	27.02
- V/C ratio	10.41	6.11	3.92	2.32	5.99	30.37	25.59	15.77	12.49	11.12	19.72	14.43
- lane width	0.11	2.14	1.01	5.40	2.12	1.15	0.86	0.55	0.14	0.18	0.62	1.20
- shoulder width	0.34	28.64	37.86	30.33	22.76	2.91	13.23	60.98	76.44	83.56	45.17	36.54
- shoulder type	0.06	12.51	21.22	3.41	8.45	9.89	17.14	56.12	48.12	46.43	36.22	25.53
- surface type	0.30	2.91	0.50	2.29	1.54	0.09	0.23	2.61	1.22	0.17	1.10	1.27
- horiz. alignment	1.78	8.12	14.27	29.35	12.66	1.45	2.46	1.49	0.00	0.00	1.12	5.56
- vert. alignment	0.04	5.85	16.25	7.17	6.55	0.00	0.00	0.00	0.00	0.00	0.00	2.52

NUMBER OF SECTIONS IN THE SAMPLE: 125297

\- Figure 14 – Initial Costs Output Page

RUN NUMBER: NatSTb2 Economic Efficiency Run w/ /ST v1.0b using 97 National data, high min pave det rate 12/15/2000

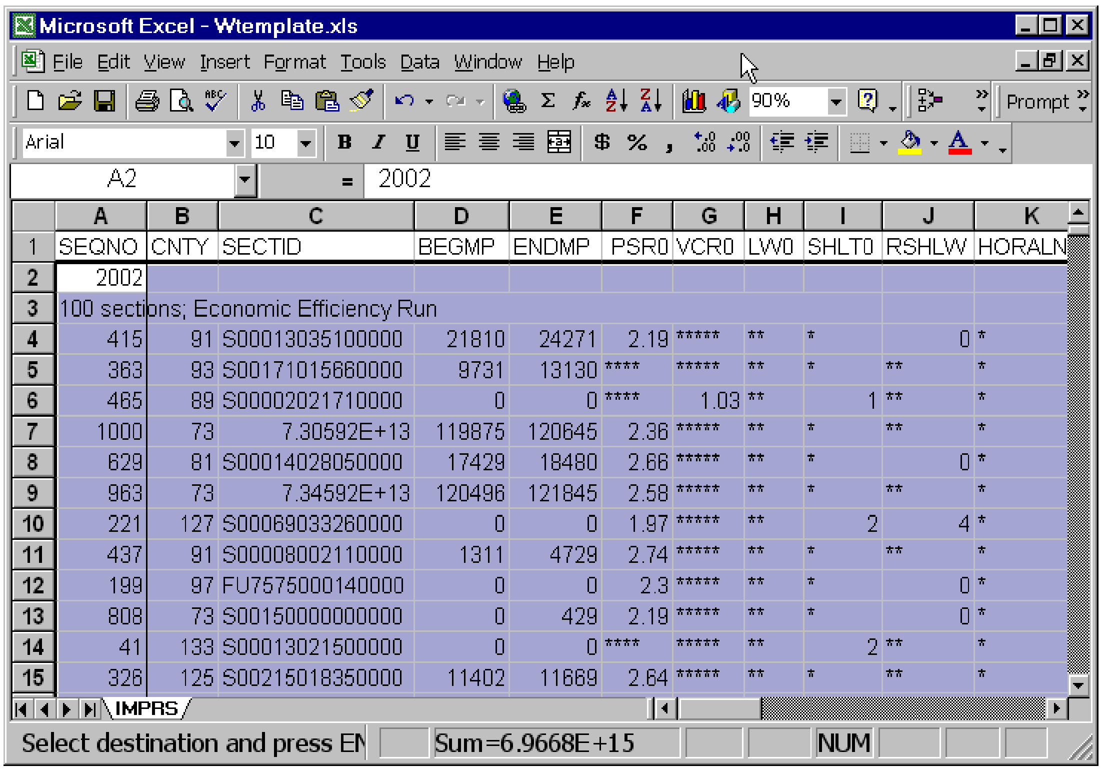
FUNDING PERIOD 1
TOTAL INITIAL COST OF SELECTED IMPROVEMENTS
(IN MILLIONS OF DOLLARS)

	RURAL					URBAN						TOTAL
	Int.	OPA	MA	Maj. C.	TOTAL	Int.	OFE	OPA	MA	Coll.	TOTAL	
All improvements:												
Reconst w/ more high cost lanes	0	0	0	0	0	0	0	0	0	0	0	0
Reconst w/ more avg. cost lanes	572	449	117	3	1142	10587	3758	7863	1170	238	23618	24760
Reconstruction with wider lanes	0	457	225	2896	3578	0	78	3851	1467	473	5870	9449
Reconstruction	246	1252	204	1165	2870	3469	1422	6964	1270	1185	14312	17183
Maj. widening w/ high cost lanes	0	0	0	0	0	0	0	0	0	0	0	0
Maj. widening w/ avg. cost lanes	10266	8161	5613	1861	25903	43024	18740	31351	23263	8611	124990	150893
Minor widening	7	7465	12344	24350	44168	126	917	15125	13280	8583	38034	82202
Resurfacing + shoulder imp's	523	16483	8321	6974	32302	1813	2940	6236	4983	1846	17819	50121
Resurfacing	11948	9025	3356	6829	31159	9033	4076	13397	8602	4039	39150	70310
Special imprs.	0	0	0	0	0	0	0	0	0	0	0	0
Total	23563	43296	30183	44081	141125	68055	31934	84790	54037	24979	263796	404922
Mandatory	0	0	0	0	0	0	0	0	0	0	0	0
Nonmandatory	23563	43296	30183	44081	141125	68055	31934	84790	54037	24979	263796	404921

With improved alignment only:

IMPRSnn.OUT files and .SSn files are in spreadsheet format, ready to import into a spreadsheet program such as Microsoft Excel. The Highway Economic Requirements System/State Model archive even includes an Excel Template file, TEMPLATE.XLS, that the spreadsheet files can be copied and pasted into for easy formatting. (Figure 15)

- Figure 15 – IMPRSnn.OUT pasted into TEMPLATE.XLS



	A	B	C	D	E	F	G	H	I	J	K
1	SEQNO	CNTY	SECTID	BEGMP	ENDMP	PSR0	VCR0	LW0	SHLT0	RSHLW	HORALN
2	2002										
3	100 sections; Economic Efficiency Run										
4	415	91	S00013035100000	21810	24271	2.19	*****	**	*	0	*
5	363	93	S00171015660000	9731	13130	****	*****	**	*	**	*
6	465	89	S00002021710000	0	0	****	1.03	**	1	**	*
7	1000	73	7.30592E+13	119875	120645	2.36	*****	**	*	**	*
8	629	81	S00014028050000	17429	18480	2.66	*****	**	*	0	*
9	963	73	7.34592E+13	120496	121845	2.58	*****	**	*	**	*
10	221	127	S00069033260000	0	0	1.97	*****	**	2	4	*
11	437	91	S00008002110000	1311	4729	2.74	*****	**	*	**	*
12	199	97	FU7575000140000	0	0	2.3	*****	**	*	0	*
13	808	73	S00150000000000	0	429	2.19	*****	**	*	0	*
14	41	133	S00013021500000	0	0	****	*****	**	2	**	*
15	326	125	S00215018350000	11402	11669	2.64	*****	**	*	**	*

APPENDIX B: REPRESENTATIVE HERS OUTPUT

2 pages of 58

HERSST Version 1.0

RUN NUMBER: Test1   Test Run Data base=Test Economic Efficiency Run

CONDITIONS AT BEGINNING OF ANALYSIS PERIOD

	RURAL					URBAN						
	Int.	OPA	MA	Maj. C.	TOTAL	Int.	OFE	OPA	MA	Coll.	TOTAL	TOTAL
Miles	996	1185	1257	4505	7944	172	95	1028	1275	1749	4320	12264
Average PSR	3.96	3.59	3.60	3.41	3.72	3.42	3.32	4.02	4.07	3.90	3.85	3.80
Average IRI(in/mi)	61	89	88	101	79	90	96	62	58	68	70	73
Average Speed	75.02	47.31	50.75	47.04	57.35	54.15	54.84	27.30	27.02	27.44	31.40	37.30
Congestion Delay (hours/1000 VMT)	0.27	1.84	1.49	1.27	0.95	3.37	2.46	10.15	9.54	6.21	7.64	5.30
Avg.Total Delay (hours/1000 VMT)	0.27	2.43	1.95	1.99	1.29	3.37	2.56	15.81	15.74	12.44	12.00	8.25
VMT (in mlns)	5956	2351	1872	3016	13197	4018	2511	9365	5690	2983	24569	37766

USER COSTS ($ per 1000 vehicle-miles):

Trav. Time Costs	260	386	359	391	326	339	325	659	670	651	574	487
Operating Costs:												
- 4-Tire Vehicles	224	198	195	204	210	209	206	207	207	206	207	208
- Trucks	563	451	444	460	524	498	461	463	478	462	474	497
- All Vehicles	316	229	224	237	269	259	232	237	241	229	240	250
Crash Costs	61	126	130	149	102	111	96	289	199	144	202	167
Total User Costs	637	742	714	778	699	710	654	1186	1111	1025	1017	906
ANNUAL USER COSTS (in $ millions):												
	3795	1745	1338	2348	9227	2854	1644	11109	6323	3059	24991	34219
CRASH/INJURY/FATALITY RATES (per 100 million vehicle-miles):												
Crashes	80.9	122.0	160.0	149.8	115.2	165.5	171.6	631.9	559.9	471.7	472.5	347.6
Injuries	36.8	77.1	89.8	93.8	64.5	81.2	62.5	259.9	190.4	164.9	182.9	141.5
Fatalities	1.14	2.06	2.18	2.05	1.66	0.63	0.68	1.73	1.33	1.21	1.29	1.42
AVG. ANN. MN. C. ($ per mile)	4649	2661	1436	890	1712	7657	8931	4062	2039	1532	2692	2057

APPENDIX C: ASSET INFORMATION DATA WAREHOUSE DATA

DATA SUBJECT	ATTRIBUTES	SOURCE SYSTEM/FIELD	PROCESSING RULES
Static Data			
Date Dimension	Day		Load 10 years worth, from RDBMS.
	Day of Week		Load 10 years worth, from RDBMS.
	Holiday		Load 10 years worth, from RDBMS.
	Type of Day		Load 10 years worth, from RDBMS.
	Calendar Week		Load 10 years worth, from RDBMS.
	Calendar Month		Load 10 years worth, from RDBMS.
	Calendar Quarter		Load 10 years worth, from RDBMS.
	Calendar Year		Load 10 years worth, from RDBMS.
	Fiscal Week		Load 10 years worth, from RDBMS.
	Fiscal Month		Load 10 years worth, from RDBMS.
	Fiscal Quarter		Load 10 years worth, from RDBMS.
	Fiscal Year		Load 10 years worth, from RDBMS.
	Need price index(es) by year, in order to calculate current cost / value from original costs, and vice versa.		
Ownership Dimension	City		
	County		
	State		
Jurisdiction Dimension	Division		
	Section		
	Function		
	Org		
	Name		
	Address		

	Manager		
	Contact Info		
	Level		
	Aggregating-to Org		
Project Dimension	Project 5		
	Sub-Project		
	Phase		
	Activity		
	Project Name		
	Project Manager		
	Start Date		
	End Date		
	Authorized Date		
	Current Budget Amount		
	Status		
	Road Closure (no of days)		
	Sponsor		
Asset Dimension	State		
	District		
	Functional Category		
	Functional Classification		
	Asset		
	Route Number		
	Route Type		
	Bridge Structure Number		
	ROW Id		
	Fixed Asset Id		
	Feature		
Pavement	Type		
	Location (Route, Milepost, Offset)		
	Geo-Reference		
	Date Installed		
	Cracking Standard		
	Roughness Standard		
	Rutting Standard		
	Flushing Standard		
	Friction Standards		
Sign	Type		

	Location (Route, Milepost, Offset)		
	Geo-Reference		
	Date Installed		
	Standard		
Signal	Type		
	Location (Route, Milepost, Offset)		
	Geo-Reference		
	Date Installed		
	Standard		
Rest Area	Type		
	Location (Route, Milepost, Offset)		
	Geo-Reference		
	Date Built		
	Standard		
	Active Flag		
FMS/TOC	Type		
	Location (Route, Milepost, Offset)		
	Geo-Reference		
	Date Built		
	Standard		
	Active Flag		
Guardrail	Type		
	Location (Route, Milepost, Offset)		
	Geo-Reference		
	Date Installed		
	Standard		
Drainage	Type		
	Location (Route, Milepost, Offset)		
	Geo-Reference		
	Date Built		
	Standard		
Landscaping	Type		
	Location (Route, Milepost, Offset)		
	Geo-Reference		
	Date Built		
	Standard		
Lighting	Type		

	Location (Route, Milepost, Offset)		
	Geo-Reference		
	Date Built		
	Standard		
Bridge	Structure Number		
	Location (Route, Milepost, Offset)		
	Geo-Reference		
	Date Built		
	Standard		
	Length, Width		
	Capacity		
	Clearance		
	Funding Source		
	Rating		
	Rating Suffix		
	Active Flag		
ROW	Parcel Number		
	Location (Route, Milepost, Offset)		
	Geo-Reference		
	Date Acquired		
	Source		
	Landscape		
	Ownership		
	Original Value		
	Acreage		
Dynamic/ Transaction-based			
Financial	Arizona Department of Transportation Construction Admin Costs		
	Arizona Department of Transportation Construction Equipment Costs		
	Arizona Department of Transportation Construction Labor Costs		
	Contractor Construction Costs		

	Right of Way Cost		
	Right of Way Value		
	Expense Labor Costs		
	Expense Equipment Costs		
	Expense Material Costs		
	Expense Admin Costs		
Reference Files			

APPENDIX D: REVIEW OF OTHER STATES' ASSET MANAGEMENT SYSTEMS

Presentation material used by other states in presenting their approach to asset, management and GASB planning was reviewed to determine if there were other management information systems or data warehouse and On-Line Analytical Processing software that was being used in asset planning and project selection. A summary review of this material follows.

The Team conclusion was that there was nothing available that would generate any interest.

Colorado *(Presentation Charts, Colorado Dept. of Transportation, Asset Management Implementation Plan, Peggy Catlin, Deputy Director)*

They plan on removing the office of Asset management. They plan on using performance based budgeting and management systems to manage assets. The two main assets they plan to manage are pavement and bridges. They are planning moving from an information tool to a budgeting tool for the Pavement Management program. Bridges management system is mainly a condition inventory tool based on points with some budgeting decisions.

Montana *(Presentation Charts- Montana Department of Transportation, Performance Programming Process, Sandra Straehl, Chief-Program & Policy Analysis Bureau, July 18, 2001)*

Asset management is reflected in resource allocation and project selection. Performance Programming uses pavement, congestion, bridge, and safety management systems to develop funding plans, support capital program development and come up with the best mix of funds to achieve strategic objectives.
The Management Systems analyzes the overall system performance that can be achieved based on various funding levels and to determine the best mix of funds to achieve strategic objectives. The system would allow users to nominate projects consistent with project mix developed in the funding plan and district personnel to choose projects based on engineering judgment.

Washington *(Presentation Charts- WSDOT: Using Asset Management to Implement Infrastructure Reporting under GASB 34, WASHTO July 2001)*
Current asset management systems at WSDOT are pavement, bridge, and capital facilities system. The initial implementation is to be within minimum GASB requirements. They are going to use goals for each asset to determine success.

Oklahoma *(Presentation Charts- GASB 34 Compliance-Peer Exchange: What, Why, and How, April 25, 2001, Nashville, Tennessee, Break Out Session Report)*
GASB 34 and asset management is not the same thing. Compliance with GASB is flexible it allows the state to use its judgment and choose the approach modified or depreciated to determine standards.

APPENDIX E: QUESTION LIST FOR THE ARIZONA DEPARTMENT OF TRANSPORTATION CONCERNING SUPPORT FOR TRANSPORTATION ASSET MANAGEMENT AND PRIORITY PLANNING FUNCTIONS

The following questions were asked of individuals responsible for the functional databases.

1. Who in your organization is currently making trade-off analysis? Decisions?

2. What are the tools you currently use to perform trade-off analysis? (Software, manual labor, etc.)

3. What is the typical process of trade-off analysis?

4. What input data is currently used in trade-off analysis?

5. Who generates trade-off reports?

6. What are the general contents of the trade-off reports?

7. What do you think are the major requirements and problems in the current trade-off analysis systems?

8. What problems do you expect the Highway Economic Requirements System/State Model to solve?

9. Who exactly will be users of the Highway Economic Requirements System/State Model or any other trade-off analysis tool and the Asset Information Data Warehouse itself?

10. Do you believe the input data in your system to conduct trade-off analysis is available in Asset Information Data Warehouse?

11. What data with which you are familiar is being used for decision support that is not in the system?

12. Are there data in the existing systems (HPMS, MMS, ABISS, other) that are not integrated?

13. Who actually does budget recommendation/ allocation? What's the interaction between this person and other people in the organization?

14. What questions are you being asked by upper management, FHWA, counties, municipalities, and others regarding asset management that is not being answered?

15. Are there questions being answered but not to a desired depth?

16. Can you provide samples of tables, data dictionaries, or presentations that will show the information and data that you use to support the Transportation Asset Management and Priority Planning functions.

Responses were received from the following Arizona Department of Transportation Individuals.

Name	**Database**
Arnold Burnham	Priority Program Planning (PPSDW)
Mark Catchpole	Traffic & hwy log (ATIS)
Jean Nehme	Bridge (ABISS)
Yongqi Li	Pavement Mgmt (PMS)
Jim Dorre	Maintenance (MMS)
Mike Manthey	Traffic & safety (ALISS)