BRIDGIT: User-Friendly Approach to Bridge Management

HUGH HAWK
National Engineering Technology Corporation, Canada

ABSTRACT

BRIDGIT is a bridge management system (BMS) software package intended to meet the needs of state, local, and other bridge agencies by providing guidance on network-level management decisions and project level actions. BRIDGIT was developed under the AASHTO-sponsored National Cooperative Highway Research Program (NCHRP Projects 12-28(2) A,B and C) and is a multi-user PC-based system that is user-friendly, easy to implement, and satisfies all of the FHWA requirements for BMS.

BRIDGIT uses a project-level-based optimization strategy to provide network-level recommendations. BRIDGIT provides guidance on how best to allocate funds on your bridge network, thus optimizing network performance. It also recommends specific actions for each bridge, consistent with overall network strategy. This is done by considering the costs and benefits of many possible actions on every bridge. BRIDGIT can quickly handle bridge inventories of hundreds, thousands or tens of thousands of bridges.

BRIDGIT is able to quickly handle various “What If?” funding scenarios, providing the user with the immediate feedback desirable in the budgeting and programming process. Additionally, with project-level recommendations and its own maintenance, repair, and rehabilitation (MR&R) module, BRIDGIT is useful to all areas in the bridge office, from network budgeting and programming to project selection to bridge maintenance cost tracking.

STATUS OF BRIDGIT

Version 3.0 was released in early 1998 to all of the US state DOTs. Version 3.0 is a fully functional Windows based multi-user system, meeting FHWA and AASHTO guidelines for bridge management systems. It is planned to move BRIDGIT into AASHTOWare in mid-1999.

WHO SHOULD USE BRIDGIT?

Large DOTs

BRIDGIT has the capacity to handle bridge inventories of many thousands of bridges and therefore is suitable for implementation at a state or country-wide level. All US state DOTs have already received a copy of BRIDGIT 3.0 software and manuals from NCHRP.

BRIDGIT is also ideal for smaller DOTs that do not have Information System staff resources to dedicate to the maintenance of their BMS. BRIDGIT is easy to implement and operate for occasional users and therefore does not require extensive training. It is a complete BMS that does not require the purchase of any additional licenses or third party software.

DOTs that have already begun the implementation of the Pontis BMS may wish to complement their bridge management efforts by running BRIDGIT in parallel to Pontis. BRIDGIT can offer a second independent analysis of their bridge network and provide an independent set of recommended repair actions. Since BRIDGIT can upload Pontis inspection data and can handle Pontis CoRe elements, BRIDGIT can easily augment Pontis when inspection data is available.

Districts, Counties and Other Highway Agencies

BRIDGIT 3.0 is ideal for smaller agencies because:

- it is a complete BMS including analysis and a full NBI Inventory
- it does not require the purchase of any additional software or software licenses
- it has minimal hardware requirements (it can be installed on a fairly minimal PC)
- it is a true project level system that analyses each bridge separately
- it is easy to implement
- it is easy to operate for occasional users and therefore does not require extensive training
- it can upload US National Bridge Inventory data directly from the DOT's NBI file and produce meaningful reports within minutes of installation.

BASIC MODULES

Inventory Module

BRIDGIT provides a very flexible inventory database which allows agencies to create an unlimited number of data items for each bridge or crossing in the network, as well as for individual spans, piers, abutments, joints and bearings of a bridge. For example, it may be desirable to keep track of the height, width and thickness of each pier of a bridge. This can be accomplished by creating three data items in the PIERS table. The system will automatically adjust table structures, give access to the new data items in ad-hoc reporting and incorporate user supplied picklists and validation. BRIDGIT is supplied with a set of data items common to most agencies, including all FHWA mandated National Bridge Inventory (NBI) items. Figure 1 shows a typical inventory screen.

The Bridge Definition Routine is used to define the physical make-up of each bridge or crossing in the network. Bridges may be divided into any number of "segments," permitting condition information to be reported for selective parts of a bridge. The various elements and protection systems which comprise each segment are also defined. Bridge elements are categorized by deck, superstructure, pier, abutment, railing, joint and bearing groups. Protection systems are categorized as paints or overlays.

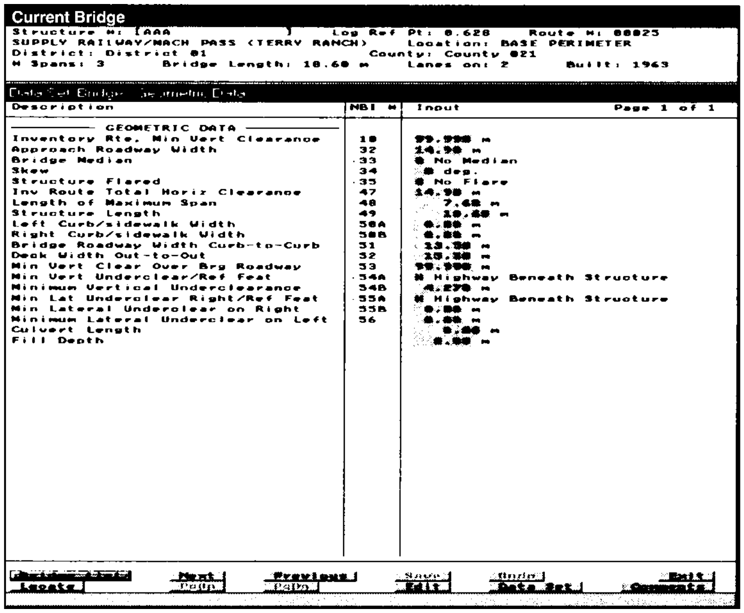


Figure 1: Sample inventory screen.

Inspection Module

This module permits agencies to view or edit inspection information for each bridge element or protection system as well as to view specific or summarized historical data for the bridge population. Users are also able to store information concerning future routine and special inspections for a bridge.

BRIDGIT incorporates the same type of condition rating system used in the FHWA sponsored Pontis software to identify the nature and extent of deterioration of all bridge elements and protection systems in the network. Condition information to be input includes the quantities of an element reported in each of the condition states defined for that element. Condition states for an element or protection system are described by types of physical as well as functional performance defects.

BRIDGIT also permits users to break down the reported condition state quantities into “portions.” For example, the deck element and protection system in the “East Approach” segment can be reported for groups of spans (i.e., Span 1, Spans 2 to 6, etc.). In this way, condition deficiencies in specific portions of a bridge segment can be identified. Figure 2 shows a typical inspection screen including a plot of the element’s projected deterioration over time.

Maintenance, Rehabilitation and Replacement (MR&R) Module

The MR&R module provides the capability for agencies to plan, schedule and monitor multi-year work programs. Agencies can also track historic work actions and related costs for individual bridges in the network. Figure 3 shows a typical MR&R screen.

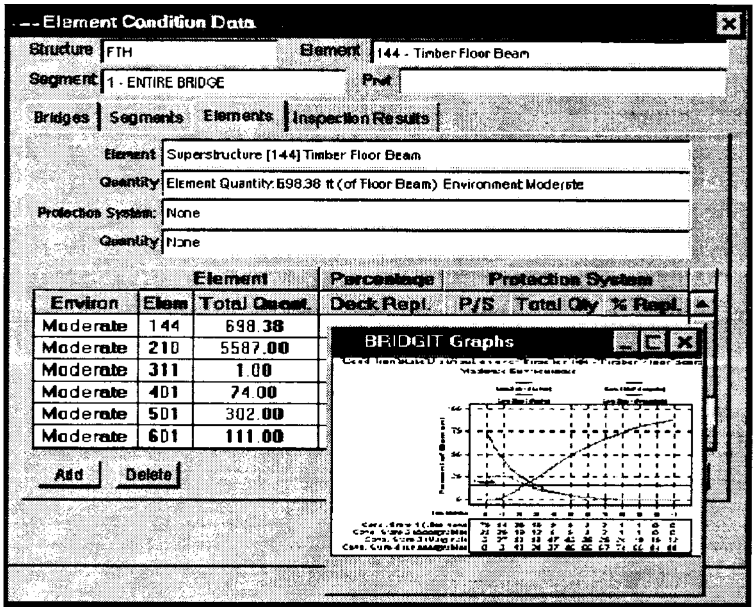


Figure 2: Sample inspection screen.

Routines have been provided to:

a) schedule and track MR&R activities carried out by in-house as well as contracted forces.
b) record a historical log of MR&R activities completed for each bridge in the network.
c) provide a Project Cost Estimate routine to allow users to create detailed cost estimates for MR&R or improvement projects.
d) maintain a standard list of MR&R activities to be tracked.

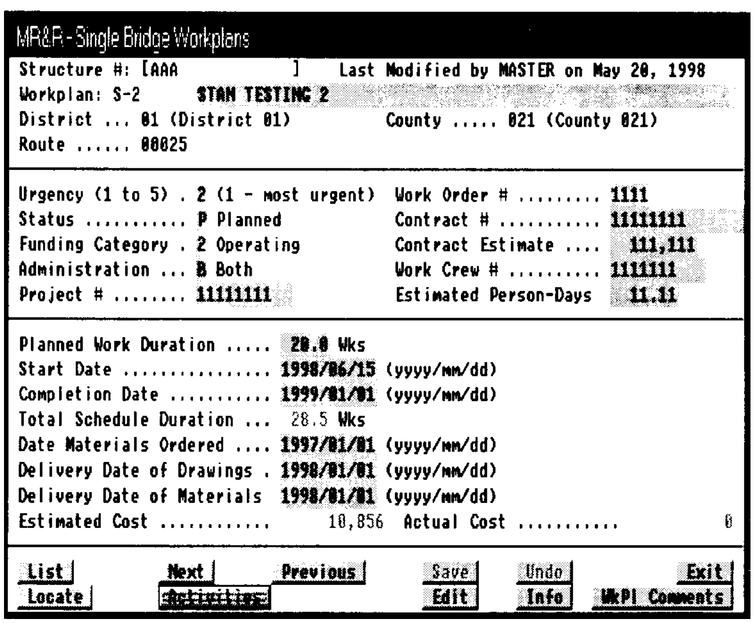


Figure 3: Sample MR&R screen.

Analysis Module

This is the most sophisticated module in BRIDGIT and draws on information stored within the Inventory module, Inspection module and Models module to produce optimized workplans for all or part of the bridge population, over a defined analysis horizon. As shown in Figure 4, users may define the following parameters to be used in the optimization analysis:

Level of Service Goals: In addition to evaluating bridge improvement actions due to condition related deficiencies, the optimization analysis also considers improvement actions to remove functional performance deficiencies. To accomplish the latter, agencies must define acceptable and desirable level of service goals for bridge deck width, vertical clearance and load capacity. In addition, the programming horizon (i.e., Immediately, 10 year, 20 year or “Only if Economical”) in which these goals are to be satisfied must be input. BRIDGIT will select appropriate rehabilitation actions to remove all functional deficiencies within the defined time horizon providing sufficient funds have been budgeted.

Available Annual Budgets: Users are required to identify the budgets available for each year of the analysis horizon of 20 years through an on-screen table. It is possible to define either the Total Annual Budget or multiple annual budgets portioned into Maintenance, Rehabilitation and Replacement amounts.

The optimization model performs an analysis in two steps. First, different life cycle activity profiles are developed for each bridge in the network, or selected shortlist, to estimate the present and future costs of various repair options. Second, an optimization analysis is performed to prioritize needs and to select the most cost effective improvement options satisfying the defined constrained or unconstrained budget cases as well as the level of service goals.

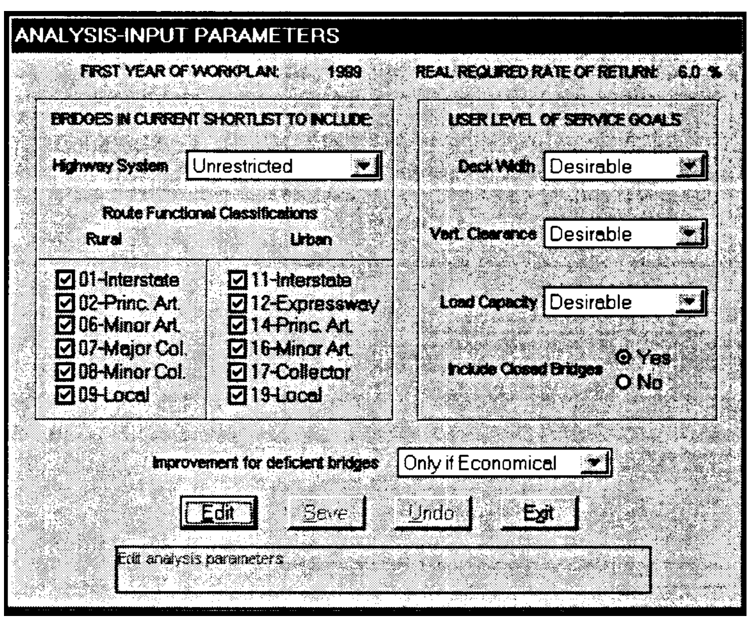


Figure 4: Analysis parameters.

Models Module

This module permits users to view or modify the various models and tables to be used in the optimization analysis. This enables a bridge agency to customize BRIDGIT to suit the uniqueness of its own bridge network and to identify its Maintenance, Rehabilitation and Replacement (MR&R) and Functional Improvement policies.

The following routines are included in the Models module:

Element and Protection System Models Routine

BRIDGIT allows an agency to create an unlimited number of bridge elements and protection systems. Elements are used to define the physical make-up of each bridge in the network.

In addition, various types of paint and overlay protection systems may also be defined. The reason for distinguishing protection systems from elements is that the maintenance and replacement of protection systems are prioritized differently than for elements. Protection systems do not influence the structural performance of a bridge.

The following information is required to define an element or protection system model:

Condition State Actions, Costs, Thresholds and A/M/U Factors: For each condition state, an action and associated unit cost may be defined. (Note: BRIDGIT automatically considers the replacement and “Do-Nothing” alternatives for an element or protection system, therefore it is not necessary to define these actions). It is assumed that an action will restore a condition state quantity to a State 1 level. BRIDGIT uses this information to calculate the costs associated with maintenance or rehabilitation of the element based on the quantities of element reported in each condition state during inspection. In addition, a Threshold Value must be defined to represent the maximum permissible quantity (in percent) of an element which may be present in its worst condition state before a rehabilitation action should be triggered. This value is used by BRIDGIT to determine the timing of certain condition improvement actions for an element or protection system.

The A/M/U Factor is an indicator which identifies whether a condition state is considered to be Acceptable, Marginally acceptable or Unacceptable as defined by the agency. For example, Condition State 1 usually represents a condition which would not require any remedial actions and is always considered to be acceptable. Condition State 2 may represent only a small amount of deterioration and would involve only preventive maintenance actions. It would also be considered acceptable. Condition State 3 may represent significant deterioration but with no loss of structural capacity or performance. It would be considered Marginally acceptable. In other words improvement actions will be performed only if sufficient funds are available. Condition State 4 may represent significant deterioration with loss of structural capacity or performance. This state would no doubt be considered unacceptable and would require rehabilitation action if the reported quantity of element exceeds the Threshold Value defined for the element.

Maintenance Actions and Costs: Agencies may define preventive maintenance actions and costs associated with each condition state of an element or protection system. This information is used to calculate the annual routine maintenance costs for each bridge in the network.

Element Deterioration Models: For each element and protection system, a deterioration model must be defined. It is necessary to specify the percentage quantity of element that will be present in each lower condition state (or worse) after a specified number of years. Figure 5 shows a sample deterioration model for a Concrete Deck element. For a moderate environment, 25% of the total quantity of element in an average bridge is expected to be in Condition State 3 or worse after 20 years. Stated another way, it will take 20 years for 25% of the element to deteriorate from Condition State 1 to Condition State 3 or worse. This type of information is required for each condition state as well as for the four possible environments (Benign, Low, Moderate, Severe) in which the element may exist.

For deck elements and overlay protection systems, it is also necessary to specify a factor to represent the increase in the rate of deterioration of an element due to the effects of average daily traffic and due to previous repairs. In the latter case, BRIDGIT uses this factor to accelerate the deterioration of any deck elements or overlays that are reported to have been previously repaired.

This information is used to project the quantities of a bridge element which will move to a lower condition state in a defined time horizon. This information is essential for estimating the deterioration of an element or protection system over time and the cost effectiveness of different MR&R improvement actions. Because little information is currently available to assist agencies in initially defining deterioration model parameters, BRIDGIT provides a routine for automatically updating the models from an analysis of historical inspection data.

Replacement Bridge Models Routine

This routine permits the bridge agency to define standard Replacement Bridge models for different route classifications and for different ranges of span lengths. These models are

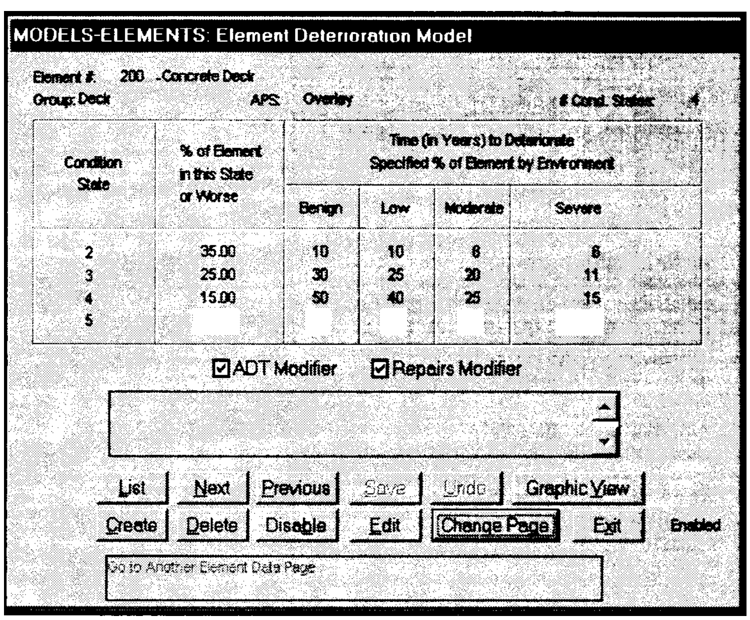


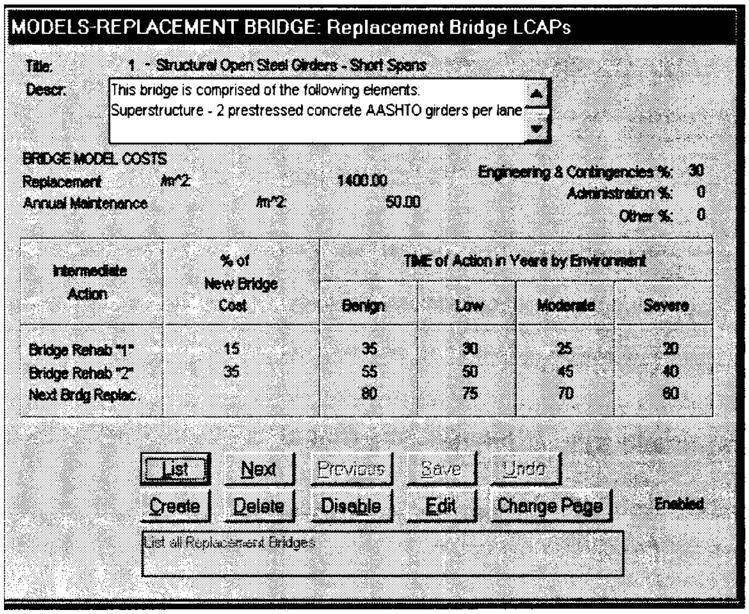
Figure 5: Element deterioration model.

used to develop the Replacement LCAP's (Life Cycle Activity Profiles) for each bridge in the network during the optimization analysis. A sample model is shown in Figure 6.

Level of Service Tables Routine

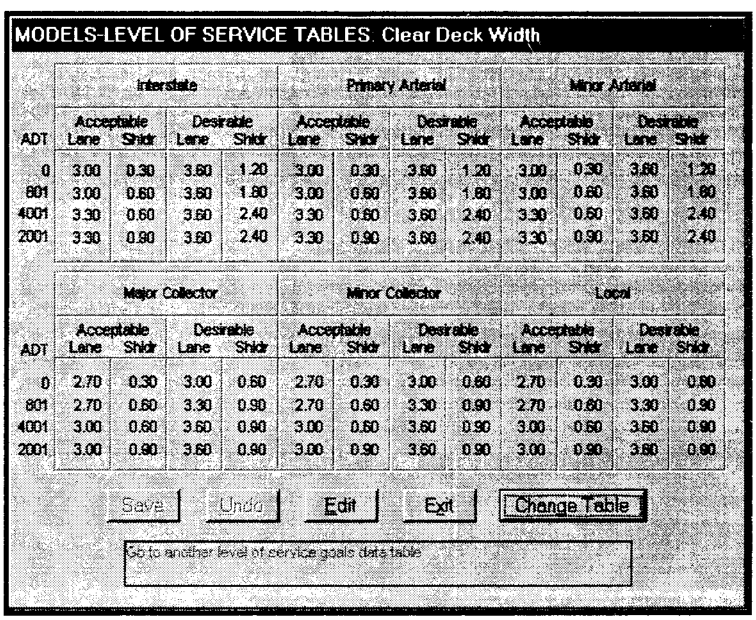
This routine permits agencies to view or modify the acceptable and desirable Level of Service goals for each of the parameters listed below.

This information is recorded in a tabular format, classified by type of route. A sample Level of Service table is shown in Figure 7.



Intermediate Action	% of New Bridge Cost	TIME of Action in Years by Environment			
		Benign	Low	Moderate	Severe
Bridge Rehab "1"	15	35	30	25	20
Bridge Rehab "2"	35	55	50	45	40
Next Brdg Replac.		80	75	70	60

Figure 6: Bridge replacement model.



	Interstate				Primary Arterial				Minor Arterial			
	Acceptable		Desirable		Acceptable		Desirable		Acceptable		Desirable	
ADT	Lane	Shldr	Lane	Shldr	Lane	Shldr	Lane	Shldr	Lane	Shldr	Lane	Shldr
0	3.00	0.30	3.60	1.20	3.00	0.30	3.60	1.20	3.00	0.30	3.60	1.20
801	3.00	0.60	3.60	1.80	3.00	0.60	3.60	1.80	3.00	0.60	3.60	1.80
4001	3.30	0.60	3.60	2.40	3.30	0.60	3.60	2.40	3.30	0.60	3.60	2.40
2001	3.30	0.90	3.60	2.40	3.30	0.90	3.60	2.40	3.30	0.90	3.60	2.40

	Major Collector				Minor Collector				Local			
	Acceptable		Desirable		Acceptable		Desirable		Acceptable		Desirable	
ADT	Lane	Shldr	Lane	Shldr	Lane	Shldr	Lane	Shldr	Lane	Shldr	Lane	Shldr
0	2.70	0.30	3.00	0.60	2.70	0.30	3.00	0.60	2.70	0.30	3.00	0.60
801	2.70	0.60	3.30	0.90	2.70	0.60	3.30	0.90	2.70	0.60	3.30	0.90
4001	3.00	0.60	3.60	0.90	3.00	0.60	3.60	0.90	3.00	0.60	3.60	0.90
2001	3.00	0.90	3.60	0.90	3.00	0.90	3.60	0.90	3.00	0.90	3.60	0.90

Figure 7: Deck width level of service.

User Cost Tables Routine

This routine accesses and allows modification of the following information associated with the calculation of user costs for each MR&R alternative to be considered during the optimization analysis.

Fuzzy Conversion Tables Routine

The Models Module also includes a routine containing Fuzzy Conversion Tables to be used to perform the following condition data conversions:

a) Conversion of NBI condition ratings to BRIDGIT element condition states and estimated quantities;

b) Conversion of any Agency defined condition ratings to BRIDGIT element condition states and estimated quantities;

c) Conversion of Pontis element condition states and reported quantities to BRIDGIT element condition states and quantities as shown in Figure 8.

'Other' Module

This module is used to transfer information into and out of BRIDGIT from other systems as well as to provide tools for overall system administration. One such routine is described below.

Import ASCII Data

This Import Data routine is used to transfer information to system databases from metric or US customary NBI files, from ASCII files, from bridge definition files, from condition inspections, from Pontis and for user specified data items. Figure 9 shows some of the options available.

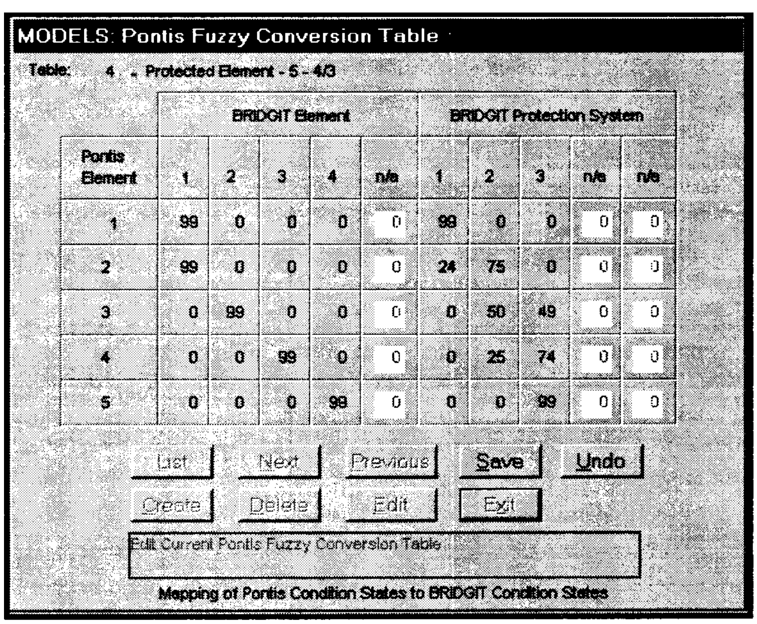


Figure 8: Pontis conversion table.

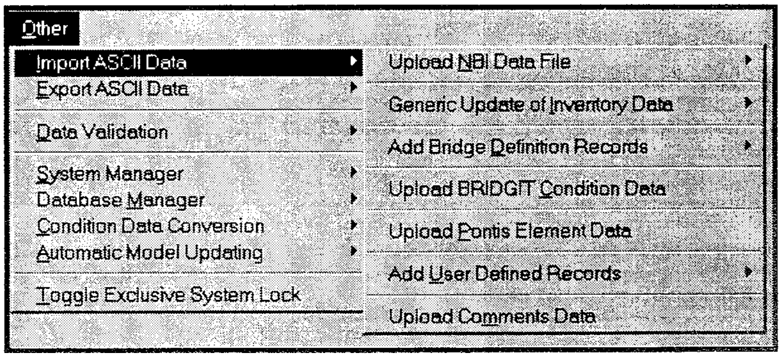


Figure 9: Main menu snippet.

PROJECT LEVEL ANALYSIS

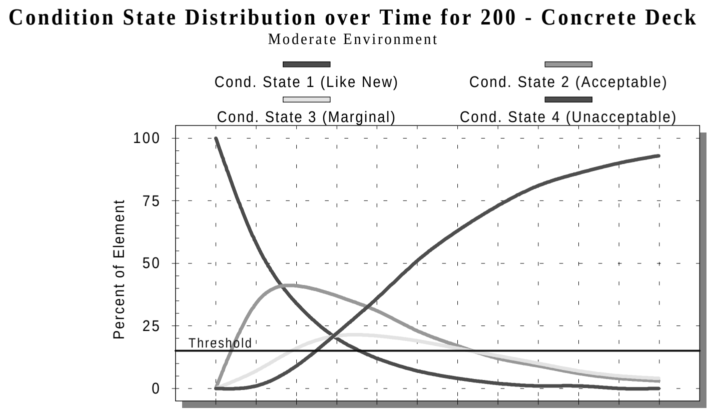
BRIDGIT uses a "bottom up" approach to network analysis. The development of alternatives includes inventory information, element condition and user costs specific to *each bridge* in the network to estimate the present and future costs of various repair and improvement scenarios. The optimization analysis is performed to prioritize needs and to select the most cost effective options satisfying the defined constrained or unconstrained budget cases as well as the level of service goals. After the most cost effective option is selected for each structure, the results of the analysis are summarized back up to the network level to determine the level of funding required to address network deficiencies for a given period of time.

Multi-Period Analysis

The system is developed in a modular fashion structured around a Visual FoxPro database and compiled for use on a PC platform. The goal of the system is to develop optimized analysis work-plans for preservation and improvements over a defined analysis horizon. The method of optimization is unique in that multi-period analysis is performed as opposed to sequential period analysis. Thus, the optimal action is considered in conjunction with the optimal timing. Actions may be delayed to later years where they would be more cost-effective, which is particularly useful in constrained budget scenarios.

Deterioration Modeling

BRIDGIT utilizes Markovian deterioration models to predict the future condition states of unprotected elements, protective systems and protected elements. The model is applied at the element level with transition probability matrices pre-defined on the basis of the condition states. Units of elements and protective systems may be in any one of the condition states at a given period of time. BRIDGIT is supplied with default deterioration models, which may be altered to reflect conditions of the bridge owning agency if desired. Historical information can be used to update the deterioration transition probabilities over time. Figure 10 shows a typical plot from BRIDGIT.



Years into Future	0	10	20	30	40	50	60	70	80	90	100	110
Cond. State 1 (Like New)	100	58	34	20	12	7	4	2	1	1	0	0
Cond. State 2 (Acceptable)	0	34	41	37	31	23	17	12	9	6	4	3
Cond. State 3 (Marginal)	0	7	16	21	21	19	16	13	10	7	5	4
Cond. State 4 (Unacceptable)	0	1	9	22	36	51	63	73	81	86	90	93

Figure 10: Condition state quantities through time.

Load Capacity Modeling

Load carrying capacity is used to determine user costs associated with detouring. The current load capacity is considered together with deterioration of load capacity over time, which permits the prediction of future capacity. The load capacity in good condition, or the projected capacity after repair, is used to assess the effect of actions taken. General rules may be used to calculate the load capacity after repair depending on the level of repair performed.

Combining this information with load capacity level-of-service goals enables isolation of obsolete bridges and associated user costs.

Life Cycle Activity Profiles

BRIDGIT employs a bottom-up optimization procedure based on various life-cycle activity profiles (LCAPs) calculated for the bridges in the network. Agency costs and user costs are considered in the development of these life-cycle activity profiles. Agency costs include initial first costs of actions and future repair or improvement actions over the life of the structure. The user costs incurred due to functional deficiencies are isolated through comparison of physical features of the bridges with the Level-of-Service (LOS) standards defined in the system. The LCAPs are then determined for scheduled actions and repairs, protective system or element replacement, component (such as the superstructure) replacement, improvements (strengthening, widening or raising), and bridge replacement.

Expected agency and user costs over time are used to develop the life-cycle activity profiles. The cost effectiveness of different MR&R and improvement actions is considered by assessing the present value of the life cycle costs and benefits. Alternatives considered are dependent upon the deterioration rates and changing level of service goals. Feasible activities are determined using knowledge based decision rules. The costs and benefits resulting from immediate and future actions are considered.

Every bridge is assumed to require maintenance, repair, rehabilitation and eventually replacement over the life span of the structure. Replacement costs include unit construction costs, administrative and operational markup percentages and markup percentages for contingency costs. With replacement, it is assumed that all functional deficiencies are corrected.

Optimizing Budgets

The BRIDGIT optimization model uses incremental benefit cost analysis to select optimal repair and functional performance improvement actions for each bridge in the network over a multi-year analysis horizon. Unconstrained and constrained budget scenarios are considered. For constrained situations, multiple budget sources may be defined. The analysis is performed over a 20 year horizon with computations divided in 5 time periods for analysis: 1–2, 3–5, 6–10, 11–15 and 16–20 years. Figure 11 shows the budget profile output for 182 bridges. As can be seen by examining the graph, the system has successfully matched the chosen repair costs to the specified budgets (constrained vs budgeted) but the unconstrained analysis (the top line) shows that the most cost effective budgets should be much higher and that the needs are especially high beyond year 10.

The approach taken in BRIDGIT provides guidance on optimal resource allocation to the bridge network given constrained and/or unconstrained budgets. While optimizing network performance, it also recommends specific actions for each bridge, consistent with overall network strategy, by considering the costs and benefits of many possible actions on every bridge. Various "What If?" analyses may be performed, providing the user with the immediate feedback desirable in the budgeting and programming process. The components, as described, make BRIDGIT useful to all areas in the bridge office, from network budgeting and programming to project selection to bridge maintenance cost tracking.

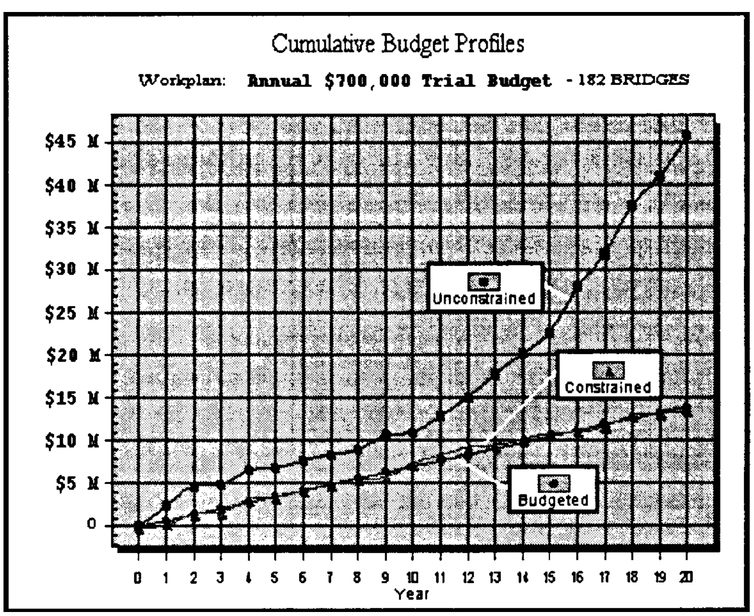


Figure 11: Cumulative budget profiles.

SAMPLE OUTPUT

The following sample graphs, based on an actual bridge population, illustrate the types of information available from BRIDGIT. The first graph, Figure 12, shows the distribution of the Federal Sufficiency Index (FSI). This measure is a combination of bridge condition, safety aspects and functional importance and is used by the U.S. Federal Highway Administration to apportion funds to the states for bridge replacement needs.

The next set of graphs illustrate the types of executive level reporting available in BRIDGIT.

The first set of three graphs, Figures 13 to 15, show the trends in overall population condition over 20 years for the cases of constrained budgets, unconstrained budgets and minimum expenditures (no workplan). The no-workplan case still includes routine maintenance, scheduled actions such as painting and overlays, and mandatory repairs to satisfy LOS goals. The unconstrained case represents a summation of the best economic alternatives for each bridge based on highest benefit-cost ratio. For no workplan condition drops over time from an index of 62.5 to less than 59. For the constrained budget, condition drops from 62.5 to about 60 and for the best case (unconstrained budgets) the condition increases to 64.0. By adjusting budget levels it is thus feasible to predict the level of budget necessary to maintain overall condition at existing levels.

It is also possible to assess the number of load deficient bridges over time. BRIDGIT, using its load deterioration models, predicts the future load capacities and hence the number of load deficient bridges. This is shown as Figures 16 and 17 for the cases of no workplans and unconstrained budgets.

Likewise, it is also possible to predict the reduction in user costs that can be achieved by following different budget scenarios. This is shown in Figures 18 and 19 by comparing the no workplan and unconstrained budget cases. Notice that the scale for

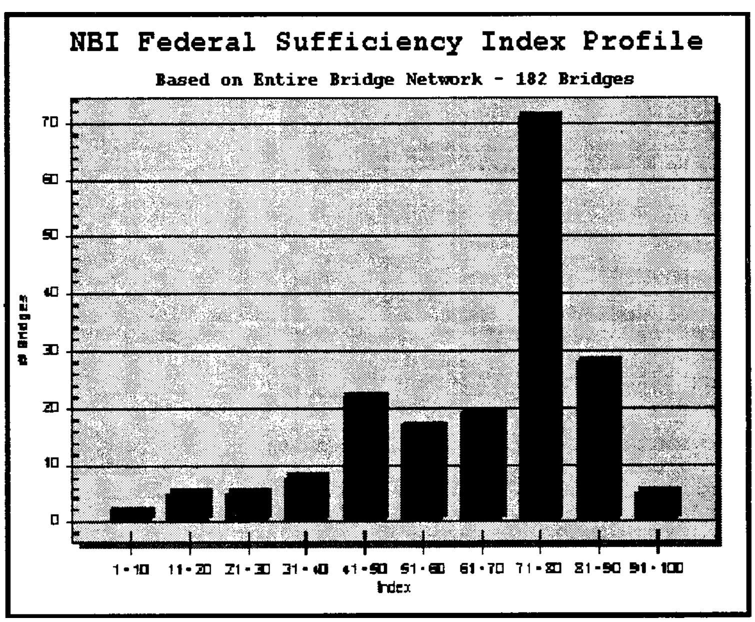


Figure 12: Federal sufficiency index.

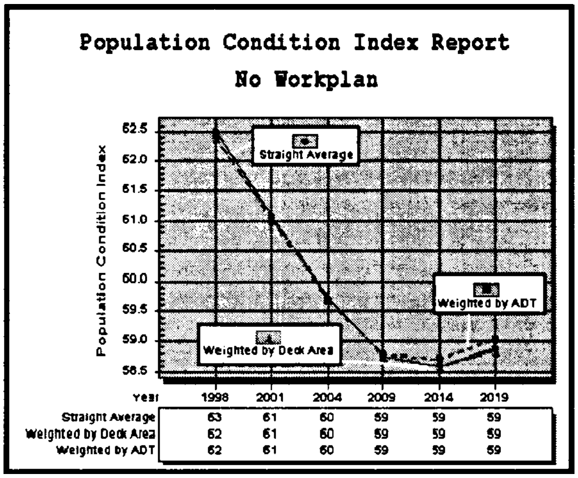


Figure 13: PCI/no workplan.

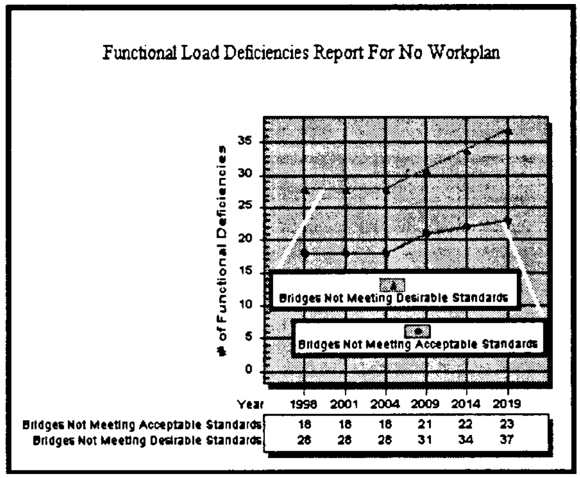


Figure 16: Load deficiencies/no plan.

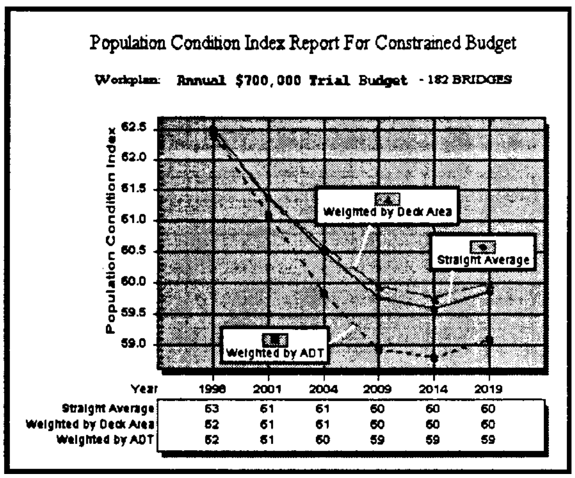


Figure 14: PCI/constrained budget.

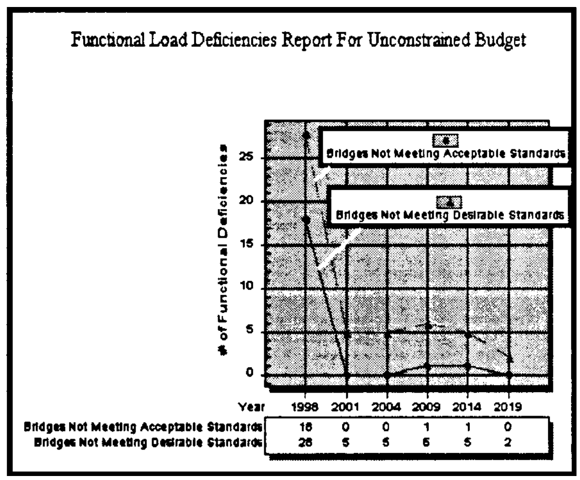


Figure 17: Load def./unconstr. budget.

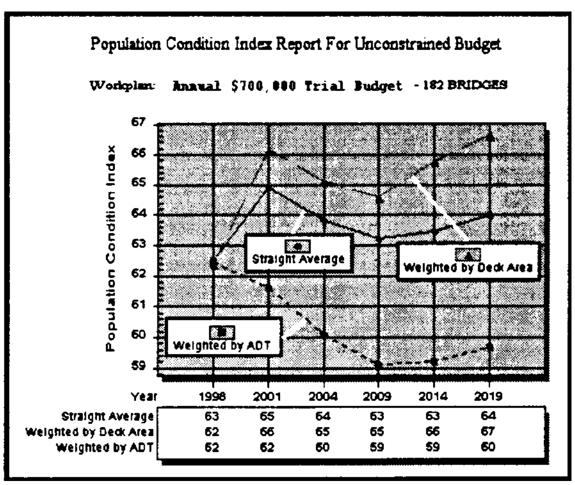


Figure 15: PCI/unconstr. budget.

costs in the no workplan case is an order of magnitude higher than the unconstrained budget case.

SUMMARY

DOTs have a vested interest in conducting bridge management in an effective manner that minimizes long term costs while maintaining a high level of functionality and public safety.

As funds become more scarce and the efficient use of resources more

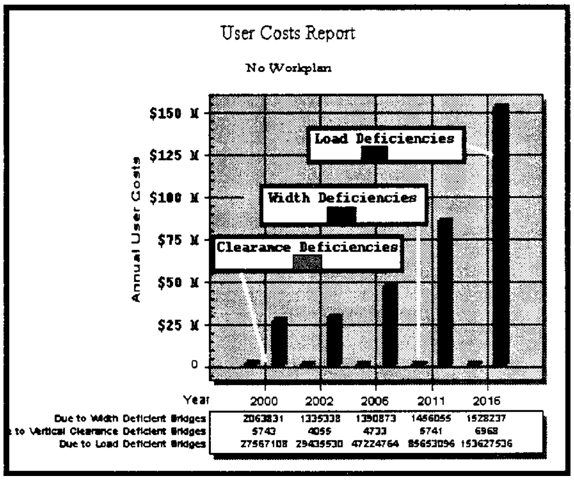


Figure 18: User costs/no workplan.

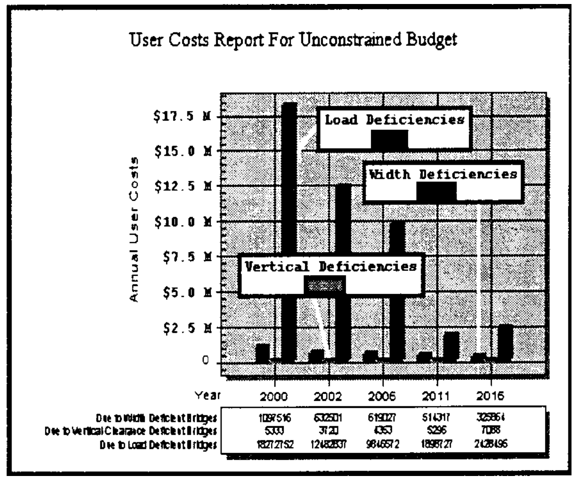


Figure 19: User costs/unconstr. budget.

important, agencies which manage valuable assets require more and more sophisticated tools to effectively preserve those assets.

BRIDGIT aids in the development of bridge maintenance, rehabilitation and replacement programs based on life-cycle costing and incremental benefit cost analysis. Preservation considerations capitalize on Markovian deterioration predictors. A level of service approach is employed for improvements, which includes the consideration of user costs associated with traffic accidents and detouring.