Implementation of a Bridge Management System In The Province of Nova Scotia

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ABSTRACT

Nova Scotia Department of Transportation and Public Works (NSTPW) is responsible for the safety and management of approximately 4000 bridges on the provincial highway system in Nova Scotia. A large percentage of the bridges have either reached the end of their useful life or have passed their midlife and will require major repairs in the near future. In order to help balance limited resources and funding with the increasing needs for the bridges, Nova Scotia decided in 1999 that a Bridge management system should be implemented. The Department recognized that a BMS would provide many benefits including the enhancement of safety and bridge service life, accurate and meaningful data for the performance conditions and costs of a bridge, and the better management of the bridge inventory.

Through the Department led Transportation Management Information System (TMIS) initiative, staff defined their preferred vision of managing bridges. This was the foundation on which a bridge management strategy was developed and the basis for selection of a bridge management system software solution. As the Department implements it bridge management strategy it will move towards a goal of having a systematic transportation infrastructure.

A detailed study of current bridge management systems was made to determine which system would best suit Department requirements. The Department found that the Ontario Bridge Management System (OBMS) offered features not available in other bridge management systems and that it was particularly suited for Canadian codes and practice. In fall 2003, Nova Scotia TPW retained Stantec Consulting Ltd. to implement a customized version of the Ontario Bridge Management System.

Stantec developed an implementation plan which accommodated the business practice and needs of NSTPW, providing a customized version of the OBMS in less than 6 months. A method was developed to successfully migrate the existing Nova Scotia inventory data to the BMS. The result is a state-of-the-art BMS which fits the business practices of the Department and contains all relevant inventory data for all bridges in the network.

This paper will share some of the challenges in selecting and implementing a Bridge Management System and will provide an update to the status of the implementation. The paper should be of interest to any provincial or municipal agency considering implementation of a Bridge Management System.

Background

Nova Scotia officially entered the "modern" era of highway transportation in 1883 with the passage of the "Highway Act". This act provided for the construction of permanent bridges with masonry or concrete substructure and metal superstructure to replace the short-span timber bridges, which were prone to washout from heavy rains. Nova Scotia has approximately 4000 bridges on the provincial highway system of which 60% are timber, 20% are concrete, and 20% are steel. Many of the bridges have either reached the end of their useful life or have passed their midlife and require major repairs in the near future. In order to best manage the limited funding allocated for bridges each year and at the same time keep all bridges in a condition that is safe to the traveling public, it was decided that a bridge management system would be required for Nova Scotia.

In 1998 the Transportation Management Information System Project (TMIS, 1) was launched in Nova Scotia to help the Department achieve its mandate of: safe highways, cost-effective highway infrastructure management, public satisfaction and support for economic development. The two main objectives of the project were – 1) to develop a detailed understanding of the business scope and context for TMIS for user groups, including: Professional and Technical support staff, Managers, Directors, and Executives responsible for highway system service delivery and management; Information Technology; and Policy and Planning, and - 2) to develop a detailed understanding of the business scope and context for TMIS in terms of four business areas:

- Managing Bridges
- Managing Pavements
- Managing the Traffic Census
- Managing Highway Safety Information

As a continuation of the TMIS project it was decided a Bridge Management System (BMS) be implemented for Nova Scotia. A bridge management system would provide a set of tools and procedures for a systematic method of recording inventory and inspection data, assessing maintenance needs, determining optimal use of budgets, and improving planning and scheduling of bridge improvements. A series of consultation sessions with Department personal produced a Department vision of bridge management, which was the foundation in the development of a comprehensive bridge management process.

The Department's vision for the future was to become a North American recognized leader in bridge management. Preventative maintenance was to be well planned and cost effective. Safety, rideability, durability, appearance and workmanship would be a priority for all structures. Repair and rehabilitation strategies would extend the life of all bridges and ensure the optimal use of resources. Reliable and up-to-date information would drive the repair, rehabilitation, replacement and closure decisions. Priority-setting, planning, costing and project selection would be guided by automated life cycle cost analyses. An inspection program that provides elemental condition ratings and structural appraisals would support a comprehensive inventory database. Cost and repair histories are to be readily available.

Based on the Department's vision a project plan was drawn up. The objective of the BMS development project would be to select a bridge management platform and implement a bridge management system which would allow for data collection and condition analysis along with network and project level reporting of the bridge inventory and current needs. The project would include all required training in the management of bridge data within a bridge management system.

The project was to encompass two main activities;

<u>BMS selection and acquisition</u>

- The Department BMS team would conduct a review and evaluation of selected bridge management systems (The Ontario Bridge Management System (OBMS) and PONTIS, 4) and provide a recommendation as to the most appropriate platform for the Department.

<u>Internal Department Implementation Process</u>

- The Department implementation process would include the following activities;

    - retain consultant services to develop an implementation plan and lead the BMS implementation process within the TMIS data model for the data collection and condition reporting functions,
    - implement corporate policies supporting data collection (inventory and inspection protocols) and condition analysis reporting
    - general and application specific training, and
    - assign the responsibility for bridge management to one group (the owner), which would coordinate development and growth of the full TMIS BMS process.

The key deliverables were to be:

- A detailed implementation plan outlining the specific tasks, deliverables, resources, timelines for implementing initial BMS capabilities with the Department.
- BMS software and application specific training. Knowledge building and skills transfer would be key components of the plan.

A BMS evaluation team was chosen to review OBMS and PONTIS. The BMS chosen was to provide the following minimal requirements (AASHTO, 3) of a BMS:

- Describe the current "health" (condition) of the bridges on a roadway network based on recognized method of field inspection.
- Project the current "health" (condition) of bridges on the network over time as a function of the funds available.
- Identify the funding required to bring bridges from their current condition to desired levels.
- Identify the current costs to road users of deficiencies in load capacity and horizontal and vertical clearances.
- Determine the optimal mix of maintenance and improvement projects over time given budget constraints.
- Identify the least cost set of maintenance actions, the costs of deferred maintenance, and the savings of preventive maintenance.
- Provide priority lists of rehabilitation, replacement, and improvement projects.
- Produce specific bridge programs for single or multi year planning horizons.
- Provide a means to analyze alternative funding scenarios, cost assumptions, and "what if" questions.

In Fall 2000, product presentations were arranged with AASHTO/FHWA for PONTIS and Stantec Consulting Ltd., developers of OBMS for the Ministry of Transportation of Ontario (MTO). Copies of PONTIS and OBMS were received and tested by the BMS evaluation team. The evaluation team investigated several key issues related to the development and use of PONTIS and OBMS including;

- Business architecture development of PONTIS/OBMS
- Canadian bridge management practice
- Safety evaluation
- Performance/deterioration modeling
- Canadian installed base

In spring 2001 the Evaluation team requested the expert assistance of Paul D. Thompson Consulting to access the fundamental differences between PONTIS and OBMS and how these differences would affect Nova Scotia's approach to bridge management as defined in the TMIS initiative. Mr. Thompson is a recognized expert in bridge management and was one of the principal consultants in the development of PONTIS and OBMS. Other risks to the project implementation were discussed with Mr. Tony Merlo, Head Bridge Management System & Design Standards, Ontario Ministry of Transportation.

Consensus of the evaluation team was that OBMS most closely met the needs of Nova Scotia and would be implemented. Some of the main reasons for this decision were as follows:

- A survey of Canadian DOT's did not reveal any agency was using the PONTIS computer program to support their bridge management system.

- OBMS incorporates features of the Canadian Bridge Design Code and is more suited to Canadian bridge design practice.
- PONTIS uses a network level analysis in its models whereas OBMS uses element level, project level, and a network level analysis in its modeling that are mutually consistent
- OBMS incorporates detailed inspection data, which more precisely describes major components such as bridge decks and paint systems, and better supports analysis of their condition and needs. Default Canadian based cost models are available in OBMS.
- The management of the bridges in Ontario is carried out through five regional offices throughout the province and a central office known as the Bridge Office. This is similar to Nova Scotia where there are four regional offices and a central Bridge office.
- Long-term interests for Nova Scotia would best be served through the adoption of Ontario practices. As Ontario's practices continue to evolve so will the practices of Nova Scotia, which would place Nova Scotia in a good position to readily incorporate revisions/updates. An example of this would be the future incorporation of a Bridge Condition Index being developed by Ontario and Stantec. A Bridge Condition Index is a single number assessment of bridge condition based on the remaining economic worth of the bridge and uses actual inspection data of various bridge elements to determine the current bridge value.
- Nova Scotia could adopt existing manuals in place in Ontario including the Ontario Structures Inspection Manual (2) and the Ontario Structure Rehabilitation Manual (5)
- In the future user groups could be set up between Ontario, Nova Scotia, and other provinces which may adopt the OBMS to discuss future research and improvements to the BMS.

In May 2003, a decision was made to proceed with the implementation of the OBMS. The decision to adopt MTO's bridge management software was predicated on the assumption that the Department would also adopt MTO's bridge management process (policies, procedures, standards) and adapt them to meet the needs of Nova Scotia. This would allow the Nova Scotia bridge management program to evolve in parallel with MTO's with a minimum of modifications to the supporting bridge management policies and procedures or software.

In June 2003, representatives of the Department traveled to Ontario to visit with the MTO OBMS Project Manager, Tony Merlo and the MTO district engineers using OBMS. The intention of the site visit was to develop an understanding of the practical problems associated with implementing OBMS and ascertain the supporting infrastructure requirements in terms of; inspection process/manuals, policies and procedures, support requirements (technical, IT).

In the fall of 2003 Nova Scotia Department of Transportation and Public Works entered into a contract with Stantec Consulting Ltd. for the implementation of the Nova Scotia Bridge Management System. Dr. Reed Ellis of Stantec in conjunction with the Department developed a multi-phase implementation plan.

IMPLEMENTATION PLAN

The five phases of implementation were:

- Phase 1.0 *Project Definition, Planning and Initial Training*
- Phase 2.0 *Basic Customization and Data Migration*
- Phase 3.0 *Engineering Customization*
- Phase 4.0 *Implementation Completion And Final Training*
- Phase 5.0 *Software Maintenance And Support*

In Phase 1.0 *Project Definition, Planning and Training*, a series of workshops were held in order to review the latest version of the BMS, determine customization needs for Nova Scotia specific labels, picklists, bridge inventory data, and determine strategy for migration of existing data. A database strategy and security protocol was established for initial implementation, and for the long term. Hardware platform requirements for Head Office, Districts, and Inspectors were defined.

Also in Phase 1.0, an image storage strategy was recommended. A Bridge Management and BMS Training Course was provided along with Bridge Inspection Training to the OSIM and BMS Standard. Implementation of the BMS GIS / Mapping interface was discussed but deferred to future.

Since all inspectors had been trained to FHWA standards the new bridge inspection training was considered updating training, training in the use of the Ontario Structures Inspection Manual, and training in the use of the BMS.

In Phase 2.0 *Basic Customization and Data Migration*, workshops were held to finalize basic picklist customization to suit Department needs (inventory and appraisal screens). A very successful data migration process was implemented which enabled Stantec to salvage as much data as possible from existing FoxPro and Oracle databases. Almost all inventory data on bridges was obtained from this process, including Nova Scotia specific data that was new to the BMS.

Phase 3.0 *Engineering Customization*, is set to begin in Fall 2004. A detailed workshop will be held to review default engineering models, and develop (customize) new models to suit Department needs and differences in practice between the OBMS default models and Nova Scotia practice. This includes bridge element models for deterioration, treatments, unit costs, action effectiveness. Focus will be on timber bridges, steel and AASHTO precast concrete bridges, trusses, and decks. Cost and treatment models developed will be for unit costs, not tender item costs, although the BMS accepts tender items. Some specific customized reports will be developed beyond default reports.

During Phase 4.0 *Implementation Completion And Final Training*, the implementation will be complete and final training will be provided. If desired, addition of GIS mapping module could be done at this time. The Map module is built with Microsoft Visual Basic and MapObject. Basic functions include (not limited to): zoom in, zoom-out, filter, search, color by value range (thermal map), show bridge information (items in Identification screen), link to BMS software (so user can find all information about the bridge which user searched from map), entry point to full system, etc.

In Phase 5.0 *Software Maintenance And Support*, a period of maintenance and support is provided to enable NSTPW to gain experience and confidence in using the software while having knowledgeable support available. This support will make use of Stantec's on-line training facilities.

NOVA SCOTIA BRIDGE MANAGEMENT SYSTEM

The resulting NS BMS is a customized version of the Ontario Bridge Management System that is specific to Nova Scotia. The OBMS was designed to be flexible in its architecture to allow customized fields for different agencies, while maintaining critical core functionality. This means that agency specific names, terminology, and inventory data can be added to the system without affecting the critical analytical features of the BMS. This enables the agency to feel immediately comfortable in using the system. By maintaining core functionality, users from any jurisdiction perform the basic functions and analysis in the same way, and can readily compare information such as bridge condition or other performance measures.

The important features of the system are described in the following.

INVENTORY AND INSPECTION

Since a bridge management system is only as good as the data provided to it, the inspection method was a priority in the selection of the OBMS. The inspection methodology of the *Ontario Structure Inspection Manual* (OSIM, 2) was selected. Not only is this a widely accepted method of bridge inspection, but the element level condition state inspection is known to provide a more reliable and repeatable form of inspection than simple numerical rating systems. It is especially reliable as compared to systems which rate the only the ‘worst component’ without considering the overall condition of the remainder of the components.

Inspection Manual

In Part I of OSIM, the manual describes the various components of a bridge and details the types and severities of material and performance defects for these components. The second part of the manual groups the components into convenient elements for inspection and describes the inspection procedure. A list of the components or elements to be inspected is contained in Table 1. The inspector has the option to sub-divide these components further to identify particular areas where defects may be more prominent. For example the ends of girders at expansion joints can be identified as a sub-element to the main girder element.

The inspection philosophy is to record defect severity and extent separately, requiring the inspector to record the quantity of defects in each of 4 condition states for each bridge component. These condition states are Excellent, Good, Fair and Poor. Each condition state combines defects on the basis of their severity. For example, the Good condition state refers to an element (or part of an element) where the first sign of “Light” (minor) defects is visible. Material specific condition state tables are used to describe the severity of defects and assign this to the appropriate condition state. For example, concrete components might have “No Observed Defects” (Excellent), “Light Scaling” (Good), “Medium Scaling” (Fair), or “Severe to Very Severe Scaling” (Poor).

By recording the quantities and severity-extent condition state distribution of each element, repair quantities are directly estimated, and types of repairs can be recommended by the BMS. Hence this method provides a means to quantify repair costs directly, as well as forecast quantities for repairs in the future. Deterioration is forecast as distributions amongst the four conditions states, as predicted using Markov chain deterioration models.

OSIM and BMS also record Performance Deficiencies for each component. The main purpose in recording the performance deficiency is to flag that some follow-up action may be required such as a “Strength Evaluation” . Performance Deficiencies include “Excessive Deformations”, “Seized Bearings”, or “Jammed Expansion Joints”.

The inspector is required to record any maintenance related work as selected from a standard list of Maintenance Needs which are typically carried out by Department staff or maintenance service providers. The inspector is also required to record a recommendation for capital work including the timing. Although the system generates recommended work automatically based on element level needs, this recommendation is useful when reviewing any work recommendations generated by the system.

System Capabilities

The BMS contains all inventory and inspection data for all bridges on highways under the jurisdiction of the NSTPW. Three ways are provided to navigate among them:

- Table View lists all structures in the database in a Table form along with data about each structure. Filters can be built to select a sub-set of structures. The data in Table View can be exported to MS Excel for building reports or charts, and the inspector can also print blank inspection reports directly.
- Map View (Figure 1) presents a set of bridges through a GIS interface. Built within OBMS using Map Objects, the Map View can be used to locate and select a bridge site or to build a thematic map by building a filter or by specifying ranges for the values of a particular field.

- Detail View (Figure 2) presents a drop-down list of sites and a tree showing the various screens for viewing the data about any selected bridge. Detail View is launched from Table View or Map View when a site is selected. It is within Detail View that the user can see all inventory, inspection, and project level data associated with a specific bridge.

There are three bridge-level inventory screens within Detail View: Identification, Description and Appraisal. The Identification screen (Figure 2) describes the location of each bridge, a general elevation photograph of the bridge, the type of bridge, and other general information. This screen generally requires the most number of customization changes to suit specific agency.

-The Description screen as shown in Figure 3 contains span data, services on and under the structure, utilities, and some overall dimensions. The Appraisal screen contains data which enables the system to evaluate the structure in terms of Load Capacity, Seismic, Scour and Flood, Fatigue, Barriers and Geometrics (Figure 6).

For each bridge, a list of elements is recorded, as described above and classified according to Table 1. Once the elements of a bridge have been defined, the inspection data can be entered in the Inspection screen as shown in Figure 5. The inspector can also view inspection photographs and print inspection reports from this screen. Electronic documents such as reports, plans, and photographs can be linked to the bridge site and viewed in the Document screen (Figure 7).

In addition to specific data about the bridge structure, the system also stores data regarding the roadways associated with the bridge. These data include the type of roadway, speed, lane widths, traffic volumes, % trucks etc. These are to be updated annually, for future use in a model of functional needs and user costs.

An entirely new screen was developed for Watercourses, namely streams, creeks, rivers, seaways, canals etc. that the bridge structure cross (Figure 4). In this screen, hydrotechnical data pertaining to any number of relevant watercourses are displayed. This makes the system useful for storing and retrieving hydrotechnical data for use by non-traditional BMS users.

Implementation Experience

An important factor in the successful implementation of the BMS was the selection of an implementation team, consisting of Department and Stantec staff who together have detailed knowledge of the bridge inventory, the expectations of the new BMS, and detailed technical knowledge of the BMS software. Bridge management system implementation is best thought of as a process directed by the implementation team. The first steps of this process involve training, planning, design, customization, and data migration as described above in Phases 1.0 and 2.0. These activities are best accomplished through workshops led by the consultant with participation of the entire team. When the various options and implications of certain planning options are understood, design and customization follow. The flexibility of the software to basic customization was a beneficial feature of the OBMS.

Successful implementation was made possible through strong participation in the data migration process by District representatives as well as Head Office personnel, through workshops conducted during the first few months of the project. Working in partnership with Stantec staff, this helped to ensure that data being migrated from different sources was interpreted correctly and loaded by Stantec into the BMS. Head Office and District staff also participated in the customization process which designed modifications to the base software in the form of changes to labels, picklists, and other inventory data important to NSTPW. Ontario specific inventory data that was not needed by NSTPW was deleted.

Another important factor in successful implementation is training. Training was provided at the earliest stages of the project in order to help NSTPW staff become familiar with the use of the BMS and with OSIM bridge inspection. Having the field inspection training near the start of the project enabled staff to begin new bridge inspections immediately, before the final software was customized. Inspections carried out this way on paper, are entered into the BMS at a later date.

NEXT STEPS IN IMPLEMENTATION

As of May 2004, NSTPW is set to begin Phase 3.0 of the implementation plan, *Engineering Customization.* This will review default engineering models in the BMS and produce new (customized) models to suit Department needs and differences in practice between the OBMS default models and Nova Scotia practice. This includes bridge element models for deterioration, treatments, unit costs, and action effectiveness. Focus will be on timber bridges, steel and AASHTO precast concrete girder bridges, trusses, and decks. Cost and treatment models developed will be for unit costs, not tender item costs, although the BMS accepts tender items.

Once Phase 3.0 is complete, Phase 4.0 *Implementation Completion And Final Training* can proceed. At this stage, NSTPW will be in a position to begin the process of learning and using the software's analytical capabilities. Some of these features are described below.

DECISION SUPPORT

The BMS contains bridge management decision support models designed to meet the needs of several potential user groups within NSTPW. The decision-making processes served by the system include:

- Inventory – Reviewing and reporting on inventory information.
- Monitoring – Inspection and inventory updating, reviewing, and reporting.
- Needs identification – Analysis of bridge and element data to decide what work is needed on each bridge, and recommended timing.
- Policy development – Analysis of the economic implications of planning models and policies.
- Priority setting – Deciding on the order and timing of projects.
- Budgeting and funding allocation – Tradeoff analysis of funding vs. network performance.

Figure 8 depicts the main features of the decision support model. There are three levels of analysis in OBMS – element, project and network level. The three levels of analysis in Figure 8 are interrelated and influence each other in the following ways:

- The element level uses a deterioration model and a set of feasible treatments to produce multiple Element Alternatives, each of which is a possible corrective action to respond to deteriorated conditions.
- The project level combines Element Alternatives into Project Alternatives, each of which represents a possible multi-year strategy to maintain service on a bridge. The tool uses models of initial costs and life cycle costs to evaluate the Project Alternatives.
- The network level combines the Project Alternatives on multiple bridges into Program Alternatives, each of which is a multi-year plan for work on all or part of a bridge inventory, designed to satisfy budget constraints and performance targets while minimizing life cycle costs.

Element Level Analysis

The element level analysis of OBMS produces a life cycle cost profile of a single element based on a deterioration model, a set of feasible treatments, and a long-term cost model. The result is a set of Element Alternatives, which is used further in the project level.

Figure 9 shows the OBMS screen for navigating among elements and element alternatives for project planning.

Project-Level Analysis

OBMS generates and evaluates a set of Project Alternatives for the 1-5 Year and 6-10 year implementation periods for each bridge. Each is defined as a combination of Element Alternatives defined in the element level analysis (Figure 10). The alternatives evaluated by the models are:

- One Do-Nothing alternative, where no treatment is applied to any element in any period. Life cycle costs are based on element-level long-term costs, which are based on the predicted conditions of the elements at the end of the program horizon for the do nothing Element Alternatives.
- Two Replacement Alternatives, one in each period. The cost of this work is estimated from a unit cost per sq.m. of deck area. Life cycle costs include the initial cost plus element-level long-term costs. The latter are estimated for each element based on its replacement Element Alternative.
- Two optimum Preservation Alternatives, one in each period, produced by an optimization process. This process finds the combinations of Element Alternatives that minimize life cycle costs. Life cycle costing uses the project level cost model and long-term costs from the selected Element Alternatives.

These projects are available to review on a project basis, and are available to the network analysis. Consistency is maintained between all three levels of analysis.

Network-Level Analysis

The network level of OBMS operates on the entire inventory or a subset of the inventory as selected in Table View. It identifies a set of Project Alternatives that maximizes the economic benefit of the bridge program by minimizing life cycle costs, subject to budget constraints (Figure 11 upper). It also reports on predicted future performance measures as they are affected by the amount of funding available (Figure 11 lower).

Each bridge has a list of Project Alternatives provided by the project-level analysis. For each Project Alternative, the following quantities are needed:

- Cost, the initial agency cost of the project, defined as the amount of money to be deducted from the budget during the period of the project.
- Benefit, the savings in life cycle cost, relative to the do-nothing alternative. In general, only projects with positive benefit are considered.
- Performance measures.

On any given bridge, only one of the alternatives can be chosen. The network-level optimization finds the set of Project Alternatives that satisfies the budget constraint while maximizing benefits (Figure 11 upper). Inputs to the analysis are constraints and targets that the model attempts to satisfy, including:

- Budget constraints, the total funding available in each planning period. (Figure 11 lower)
- Allocation targets, the percent of the budget to be allocated to each subdivision of the inventory, usually each region.
- Performance targets, desired levels of a selected performance measure.

The network-level analysis uses an incremental benefit/cost procedure to optimize the selection of projects. Since OBMS overall is architected as a system of cooperating objects, it has very fast access to the data it needs to conduct this analysis. As a result, the budgeting module (Figure 11 lower) is highly interactive: slide the budget level up or down, and performance measures adjust themselves accordingly. The quickness of this tradeoff analysis makes it easy to answer some very important budgeting questions, such as:

- How much improvement in performance can be purchased at any given budget level?
- How much will it cost to maintain performance at its current level?
- What is the true cost of favoring one part of the inventory over another in funding allocation?

- If funding is tightly constrained today, what effect will this have on future costs?

CONCLUSIONS

NSTPW has taken significant steps forward in achieving the bridge management objective of the TMIS project. By implementing a customized version of the Ontario Bridge Management system, NSTPW was able to achieve the advantages of a state-of-the-art BMS in a very short timeframe. Inventory and inspection data, as well as images and other documents are readily available for department use. As the NSTPW begins to use BMS analytical features, the department will reap additional benefits. And as the user base in other provinces grows, sharing of data and comparison of performance measures becomes possible.

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TABLE 1 OSIM Structural Elements **

Group	Element name and units	Group	Element name and units
Abutments	Abutment walls (sq.m.) Ballast walls (sq.m.) Bearings (each) Wingwalls (sq.m.)	Embankments & Streams	Embankments (all) Slope protection (all) Streams and waterways (all)
Approaches	Approach slabs (sq.m.) Curb/gutters (m.) Drainage system (all) Sidewalk (sq.m.) Wearing surface (sq.m.)	Foundations	Foundation (below ground, no units)
Barriers	Barrier/parapet walls (sq.m.) Hand railings (m.) Posts (sq.m.) Railing systems (m.)	Joints	Armouring/retaining devices (m.) Concrete end dams (sq.m.) Seals/sealants (m.)
Beams/Main Longitudinal Elements	Diaphragms (each) Floor beams (sq.m.) Girders (sq.m.) Inside boxes (sq.m.) Stringers (each)	Piers	Bearings (each) Caps (sq.m.) Shafts/columns/pile bents (sq.m.)
Bracing	Bracing (each)	Retaining walls	Barrier Systems on walls (sq.m.) Walls (sq.m.)
Coatings	Railing coatings (sq.m.) Structural steel coatings (sq.m.)	Sidewalks/curbs	Curbs (sq.m.) Sidewalks and medians (sq.m.)
Culverts	Barrels (sq.m.) Inlet components (sq.m.) Outlet components (sq.m.)	Signs	Signs (each)
Decks	Deck top (sq.m.) Drainage system (all) Soffit – inside boxes (sq.m.) Soffit – thick slab (sq.m.) Soffit – thin slab (sq.m.) Wearing surface (sq.m.)	Trusses/Arches	Bottom chords (sq.m.) Connections (each) Top chords (sq.m.) Verticals/diagonals (sq.m.)

**** OSIM - Ontario Ministry of Transportation Bridge Structure Inspection Manual**

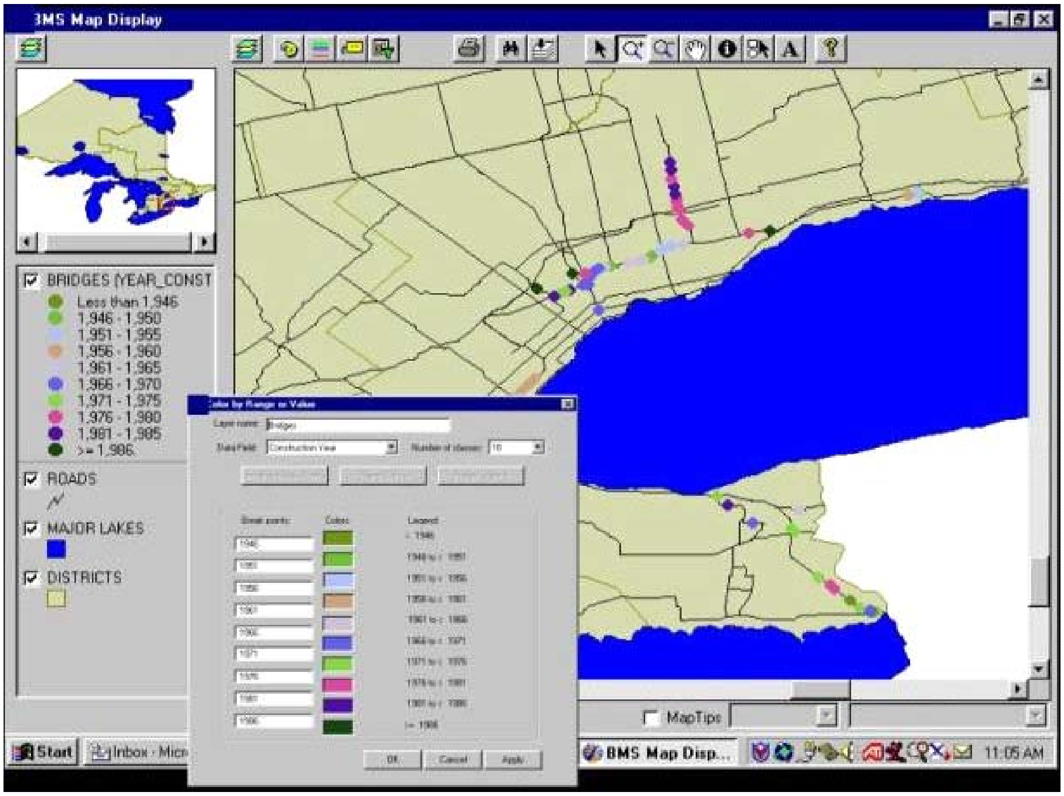

FIGURE 1 Map View.

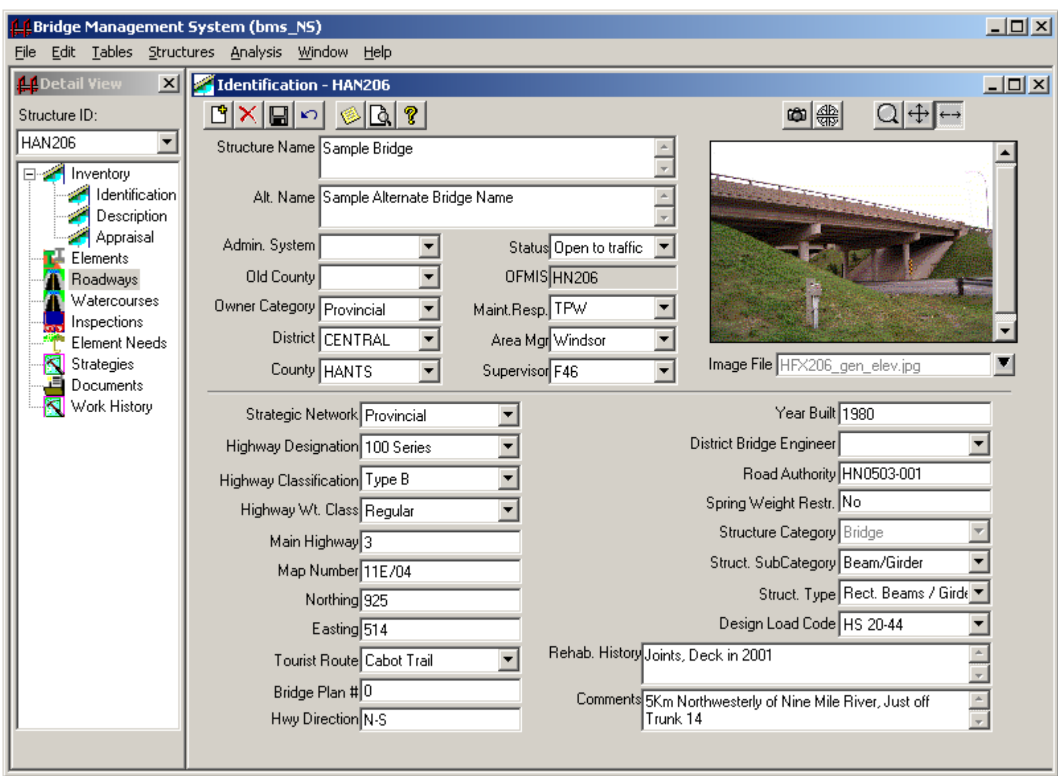

FIGURE 2 Inventory Identification Screen (bridge is fictitious)

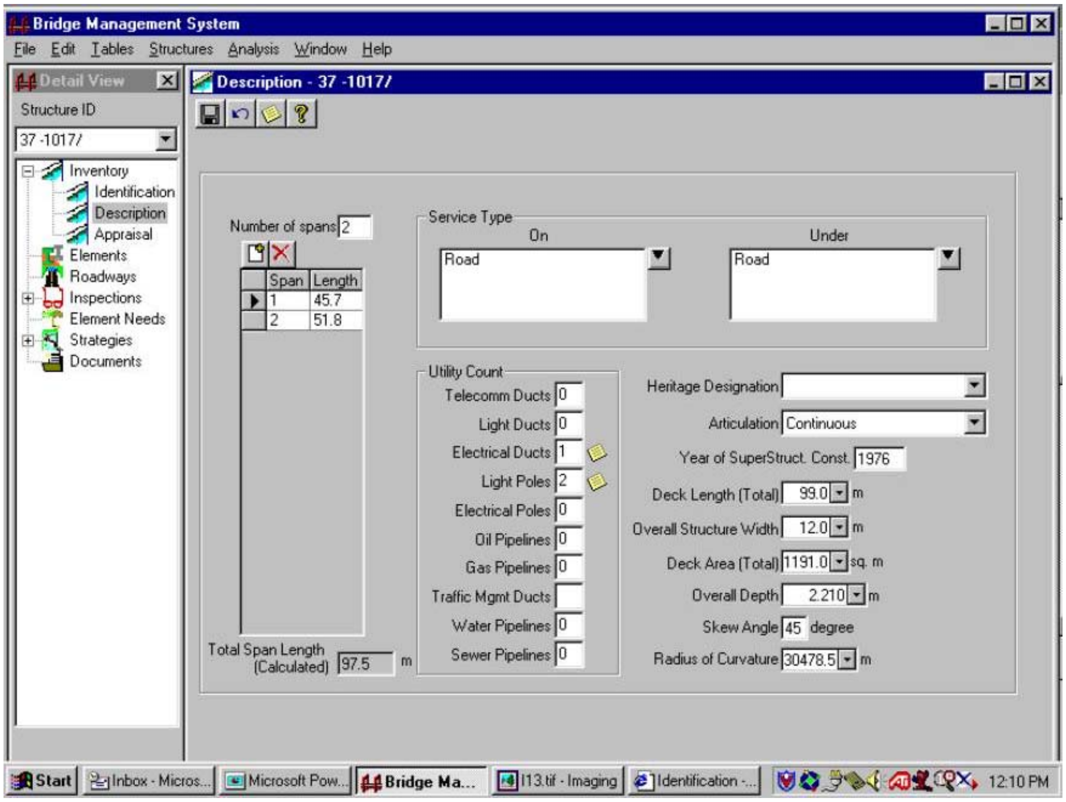

FIGURE 3 Bridge Description Screen.

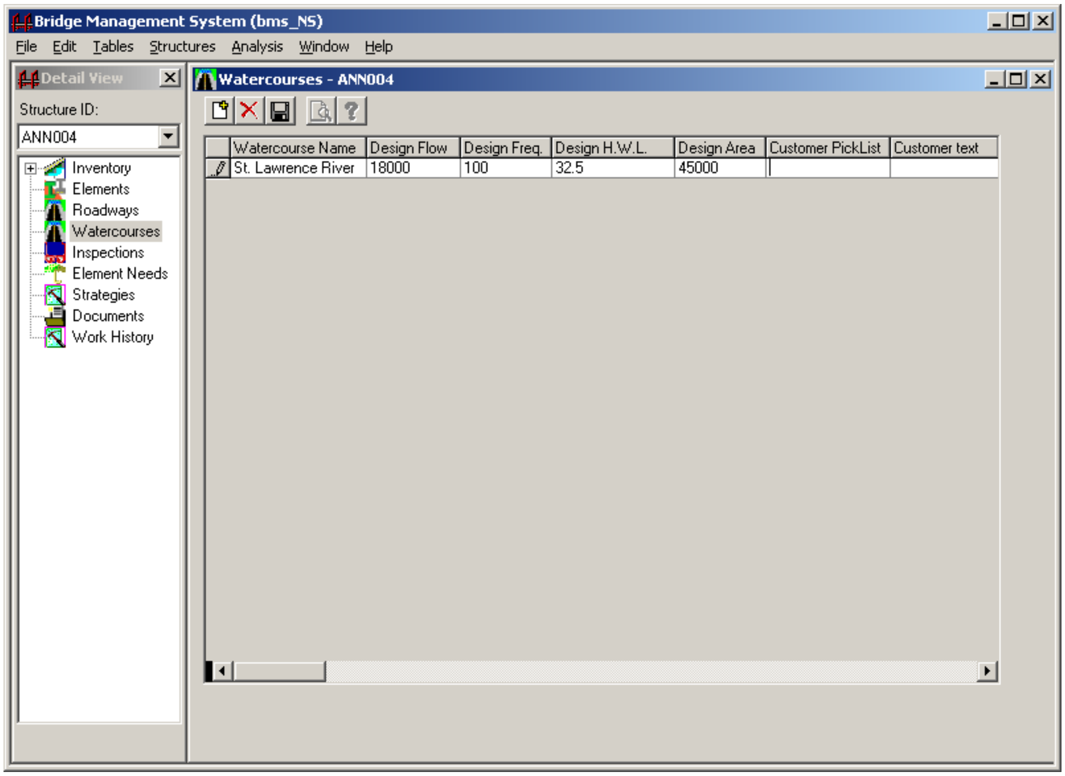

FIGURE 4 Watercourses (Hydrotechnical Information).

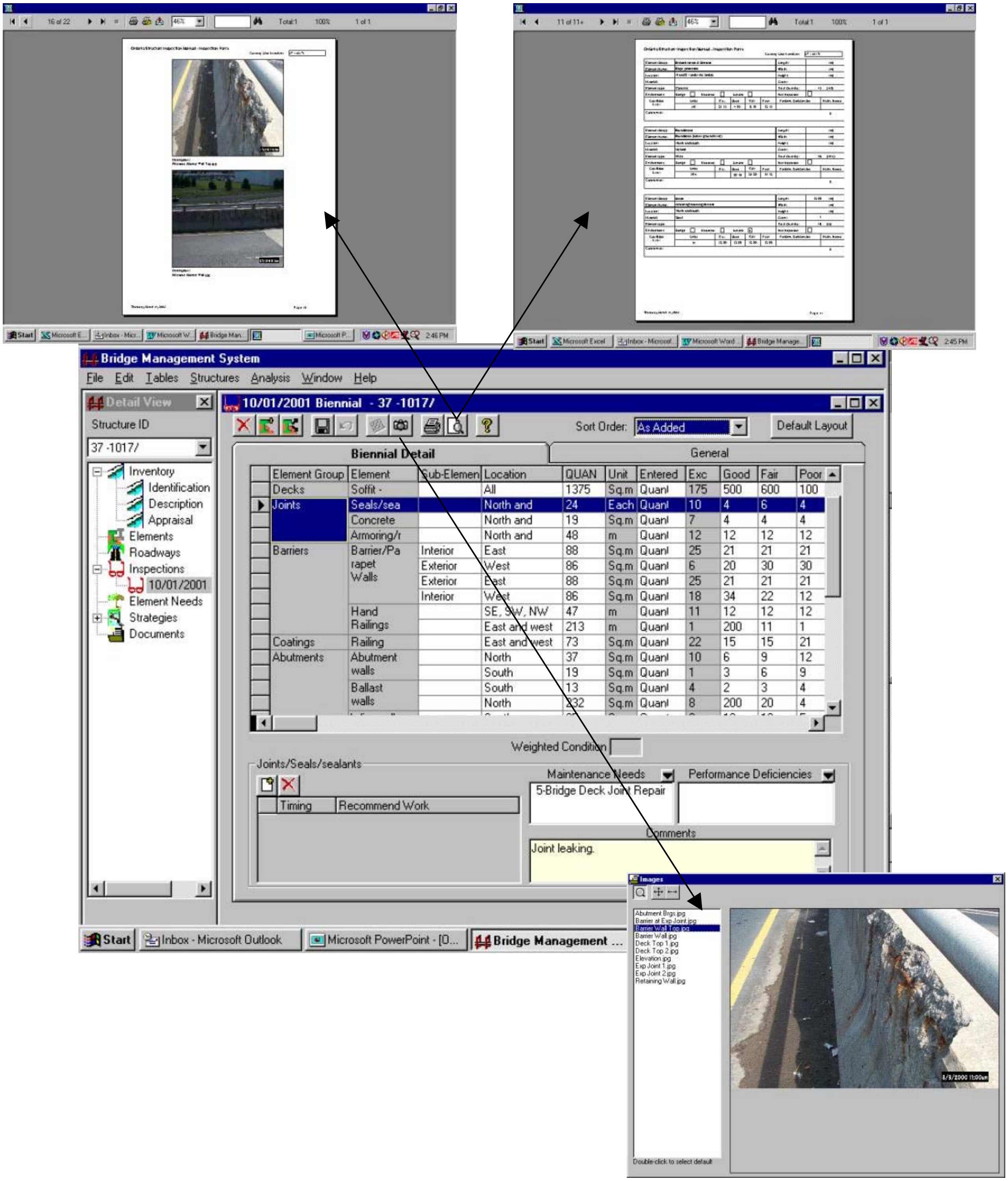

FIGURE 5 Element Inspection Screen.

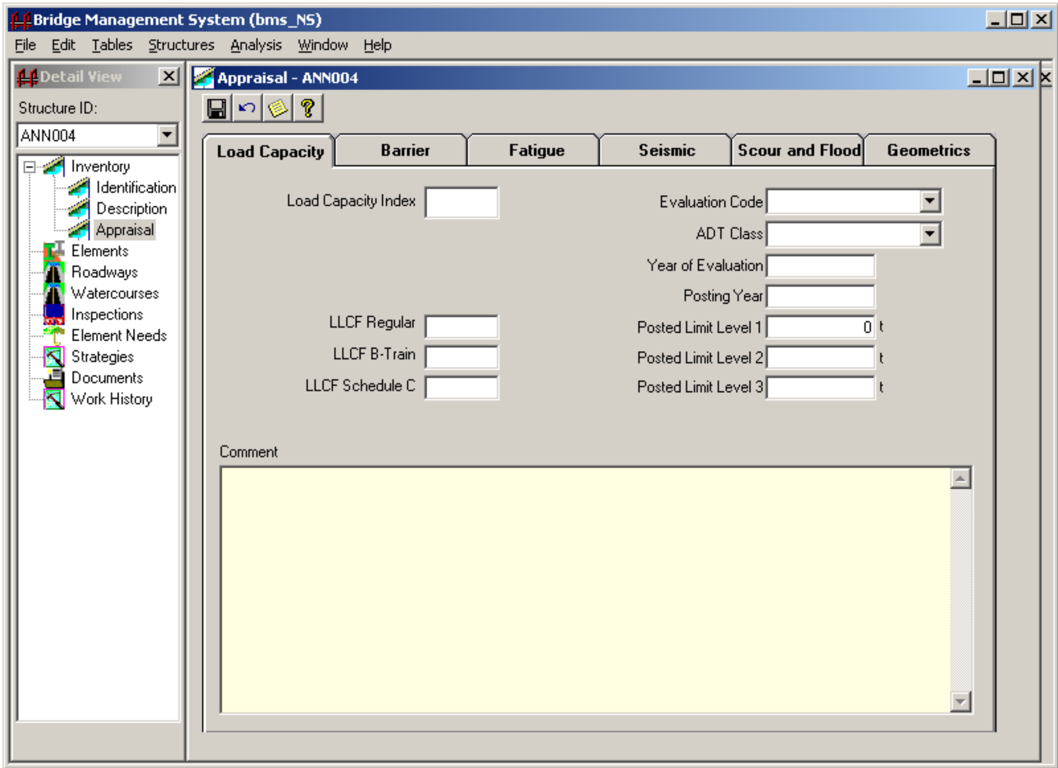

FIGURE 6 Bridge Appraisal Rating and Information.

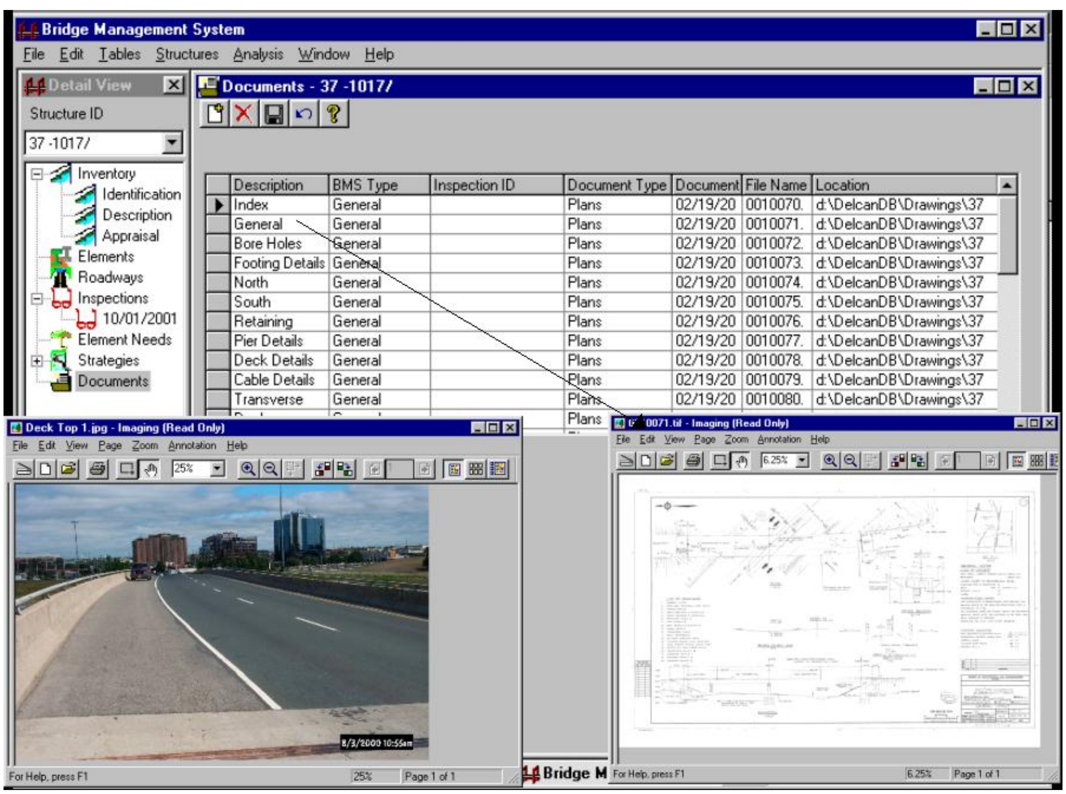

FIGURE 7 Document Access Screen.

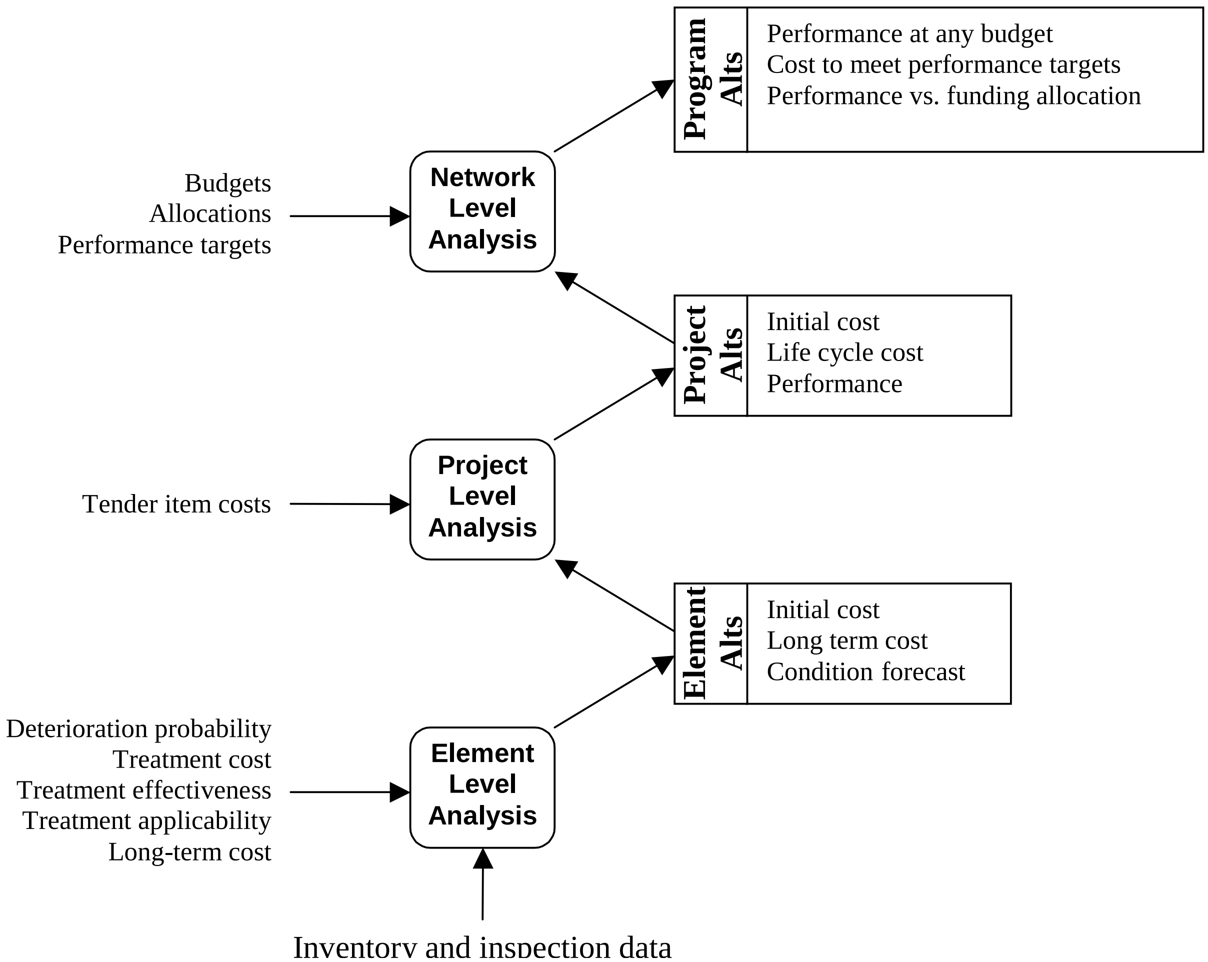

FIGURE 8 Inputs and Outputs of Primary Models.

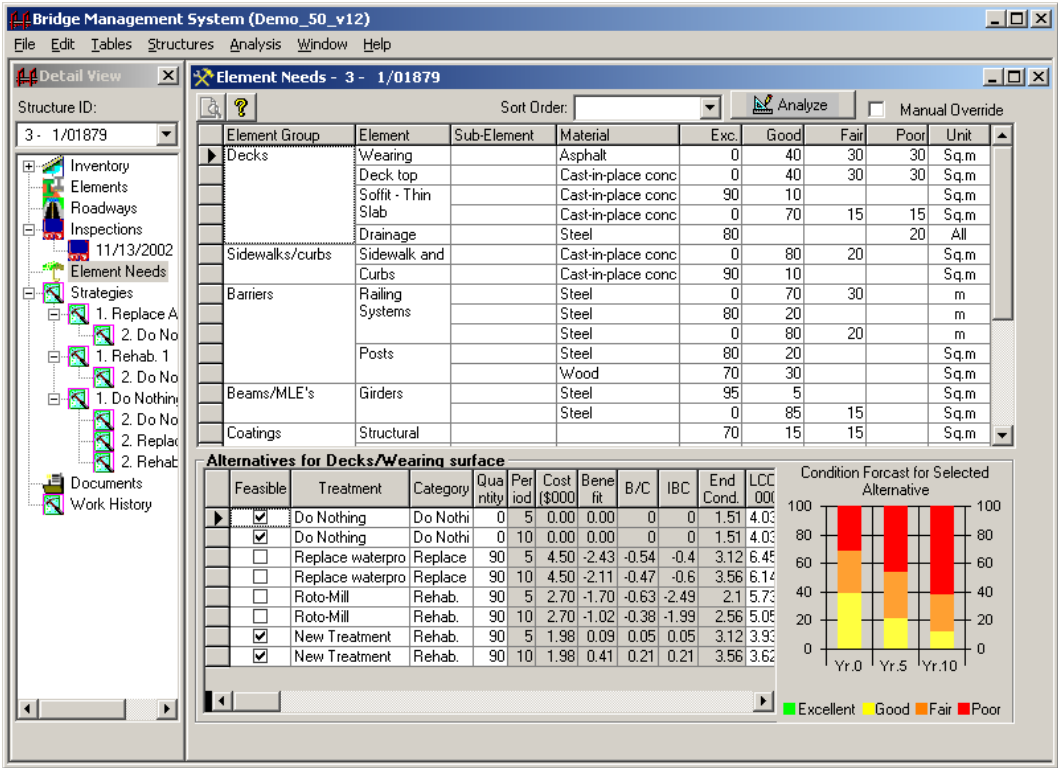

FIGURE 9 Element Level Analysis.

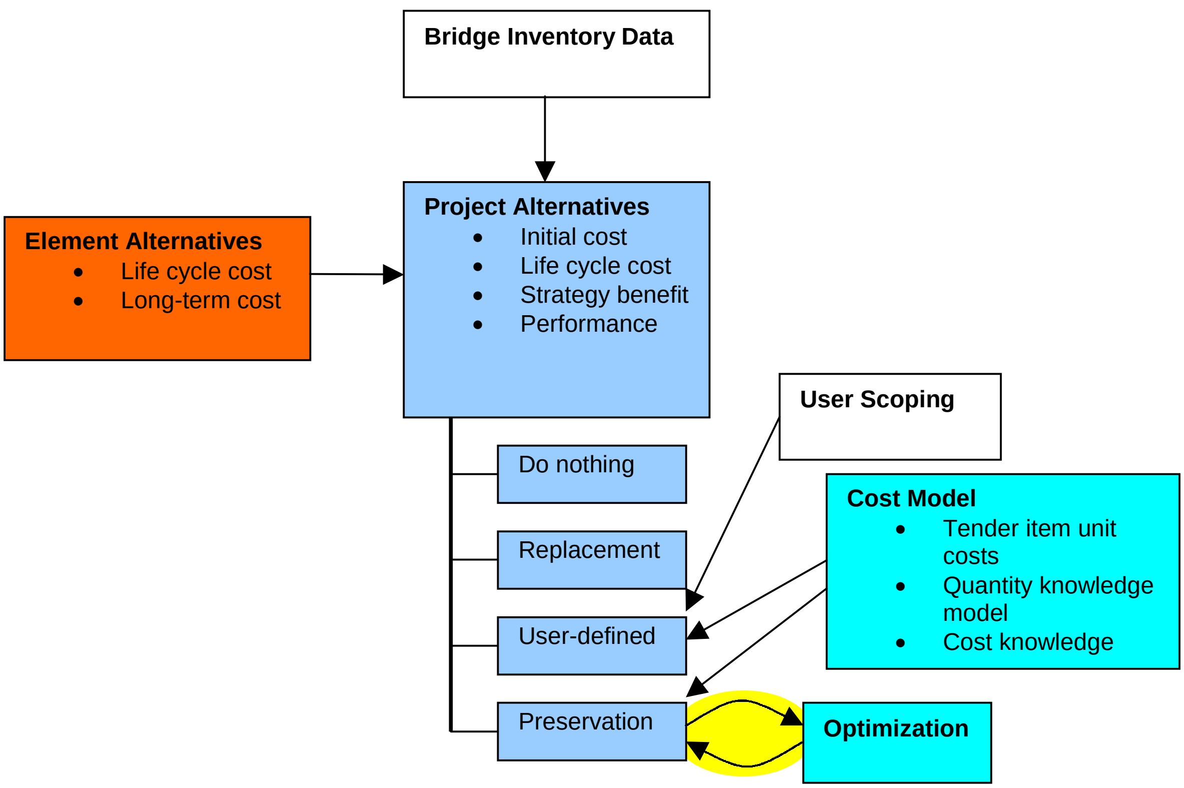

FIGURE 10 Project Level Analysis.

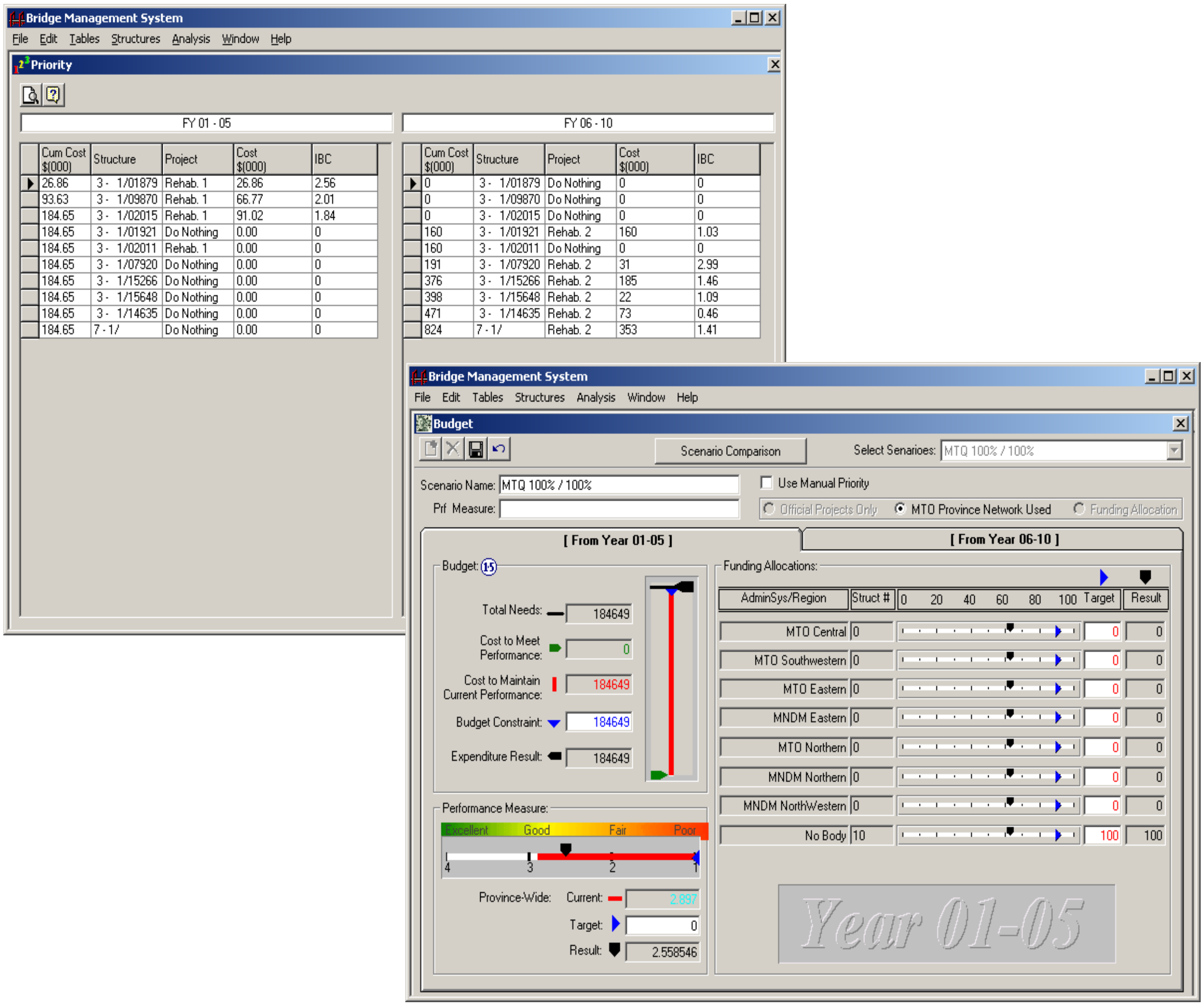

FIGURE 11 Network Level Analysis and Budget Setting.

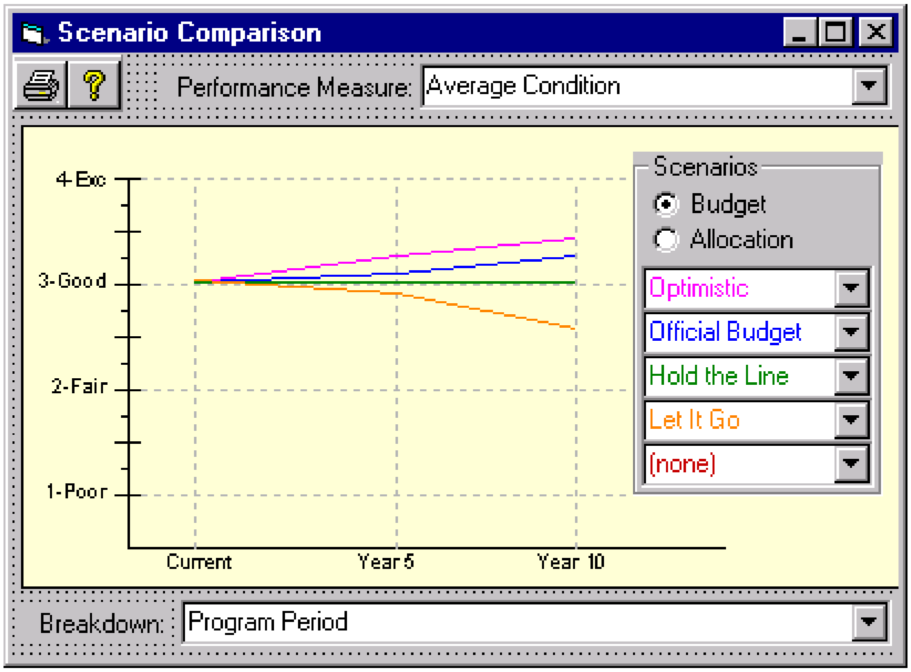

FIGURE 12 Network Performance vs. Funding Levels.

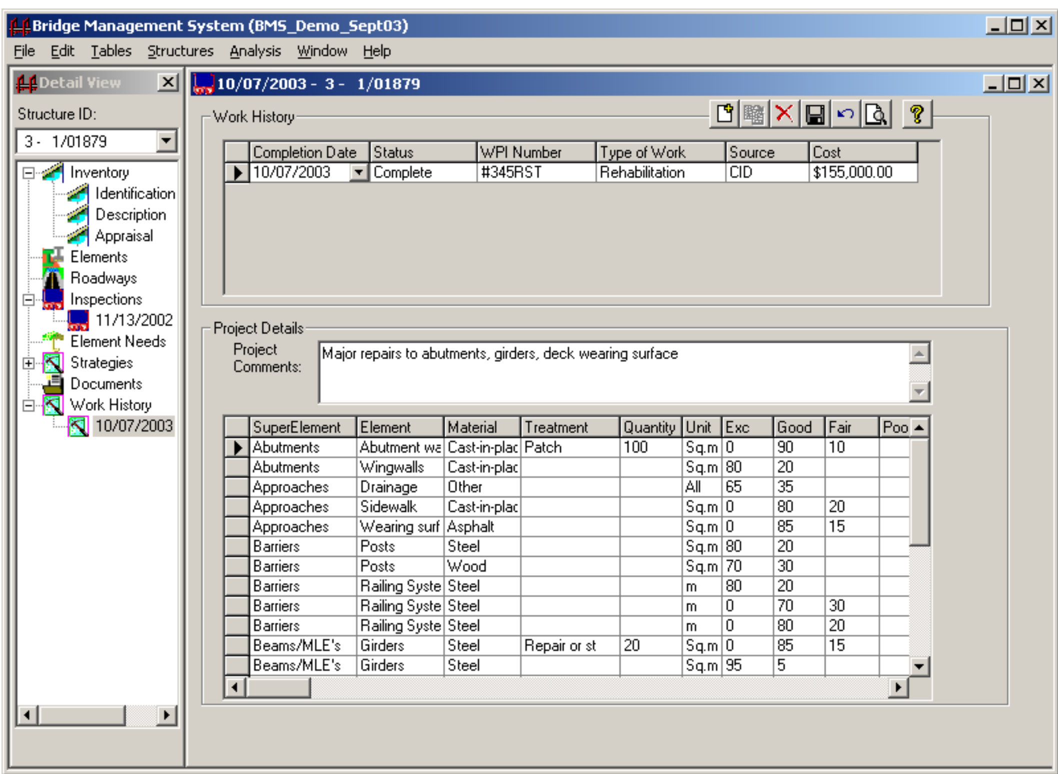

FIGURE 13 Work History