USERS MANUAL

PROJECT LEVEL ANALYSIS TOOL

Release 2016

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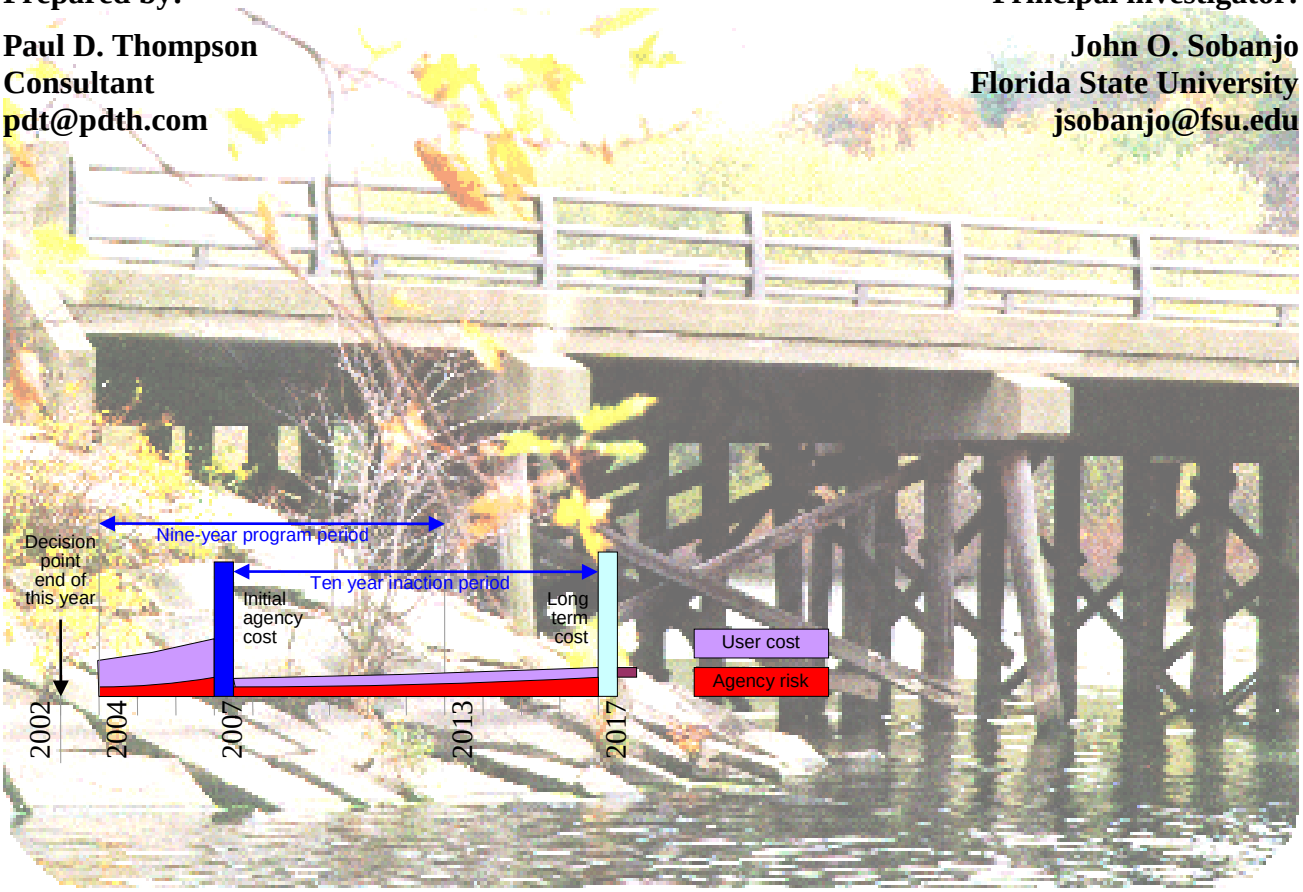

Prepared for:

State Maintenance Office
Florida Department of Transportation
Tallahassee, FL 32309

February, 2016

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Overview

BACKGROUND

Since 1997, the Florida Department of Transportation (FDOT) has been implementing the Pontis® Bridge Management System (subsequently renamed AASHTOWare Bridge Management, or BrM), provided by the American Association of State Highway and Transportation Officials. More than 30,000 public bridges and other structures located statewide have been inventoried and inspected, including all bridges over 20 feet long and numerous sign structures, high-mast light poles, mast arms, and retaining walls. A centralized BrM database with all of this information is accessible to, and primarily maintained by, the eight district offices.

Front-line FDOT decisions regarding the maintenance, repair, rehabilitation, improvement, and replacement of more than 12,000 state-maintained bridges and other structures are made by District Structures and Facilities Engineers (DSFEs). On a few major routes some of this decision-making responsibility has been delegated to consultants through Asset Management contracts. The DSFEs and their staff also provide technical assistance and inspection services to local governments for more than 6,000 additional structures. As in most transportation agencies, decision-making authority is shared: DSFEs initiate work plans, but these are negotiated in an annual process with the Headquarters Maintenance Office, from a policy perspective, and the Work Programs Office, from a funding perspective.

The Department has engaged in a series of research projects to adapt Pontis and BrM to its own needs and to provide the necessary planning input data for the system's decision support models. These efforts have resulted in several products:

- A new user cost model with economic parameters derived from earlier research within Florida. A significant part of this model is a new accident risk model based on bridge roadway width, approach alignment, traffic volume, number of lanes, length, and functional class. This was developed using Pontis bridge data and a Florida database of crash statistics (Thompson and Najafi, 1999). A companion model was developed for bridges where no detour exists (Sobanjo and Thompson 2011).
- Unit costs of all maintenance, repair, and rehabilitation actions defined in BrM for Florida's structural elements. Florida uses most of the AASHTO standard elements (AASHTO 2013) as well as a set of custom elements for moveable bridge components, sign structures, light poles, decks, joints, and drainage systems. These were derived from historical project data in three existing information systems, supplemented by expert judgment (Sobanjo and Thompson, 2001). They were updated in 2016.
- Transition probability models to predict element deterioration for all Florida elements. These were first developed using an expert elicitation process (Sobanjo and Thompson, 2001). Improved deterioration models were developed based entirely on Florida's 14 years of element inspection history (Sobanjo and Thompson 2011), and were updated in 2016 to conform to changes in the element manual. The new model includes an innovative new technique for modeling the onset of deterioration, and an innovative new method for estimating transition probabilities from historical inspection data.
- Truck height histogram, describing the fraction of the traffic stream composed of trucks above any given height. This is used in estimating the detour costs associated with bridges having impaired vertical clearance. The truck height histogram was derived from new measurements of actual traffic using laser equipment (Sobanjo and Thompson 2004).
- Truck weight histogram, describing the fraction of the traffic stream composed of trucks above any given weight. This is used to estimate the user costs of bridges with low operating ratings. The model was derived from weigh-in-motion data collected in Florida (Sobanjo and Thompson 2004).
- User cost model for moveable bridge openings, contributing to the justification for replacement of moveable bridges, which are quite numerous in Florida (Sobanjo and Thompson 2004).

- A Project Level Analysis Tool (PLAT), incorporating all the products of the earlier research, to give DSFEs a clear picture of the economic health of a bridge and the economic implications of scoping and timing decisions for structure maintenance, repairs, rehabilitation, improvement, and replacement (Sobanjo and Thompson 2004).
- A Network Analysis Tool (NAT), which combines the results of PLAT analyses to provide a network level perspective on the tradeoffs between funding and performance of the bridge inventory as a whole (Sobanjo and Thompson 2006).
- An improved NBI translator, to convert element inspection data and element condition forecasts into NBI bridge component condition ratings. This will enable familiar NBI condition ratings to be used as a performance measure for evaluating future bridge investments. (Sobanjo and Thompson 2011).
- A new risk analysis model, based on extensive study of historical data, provides a long-term forecast of the economic consequences and impacts of natural and man-made hazards, including hurricanes, tornadoes, wildfires, floods, vessel collisions, over-height truck collisions, overweight vehicles, other truck collisions, advanced deterioration, and fatigue (Sobanjo and Thompson 2013).

PLAT is designed to be compatible with, and take advantage of, the models under development for AASHTOWare BrM, but is intended to be used as a part of project-level decision-making. This means adapting the BrM economic definitions and life-cycle cost model so that they are most useful in the context of individual structures, adding a few additional sub-models to address certain project-level concerns, and building a display tool that is informative for scoping and timing decisions.

OBJECTIVES AND PHILOSOPHY OF PROJECT-LEVEL ANALYSIS

Florida, like most states, has decision-making processes at both the network level and project level. The requirements of project-level decision support can readily be explored by contrasting it with the network level:

- Network level focuses on the uniform processing of groups of bridges, while project level focuses on just one bridge at a time.
- Network level inputs concentrate on uniform rules for scoping and cost estimation, while at the project level engineers are expected to make these decisions individually.
- Network level analysis uses techniques, like simulation, suitable for automating decisions over large groups of bridges, while the project level uses techniques that provide quick feedback on a larger number of bridge-specific decision variables.
- The primary modes of presentation at the network level are lists of bridges and network-wide summaries, while the primary modes at the project level are lists of elements and needs on one given bridge, and predictions of future conditions and performance of that bridge and its elements.
- Network level optimization most conveniently divides the inventory by element type, while project level analysis divides it by bridge.
- Network level can use only data that can be cost-effectively collected systemwide. Project level can use data that may be collected for only a few bridges.
- Network-level costing has, as its most important objective, using methods that produce network-wide budgetary requirements that are sufficient and realistic, even if project-level estimates are imprecise. Project level is more concerned with precision and realism of each bridge individually and not as concerned that a methodology can be automated across the whole inventory.
- At the network-level, every bridge contributes probabilistically, in at least a small way, to the expected value of funding requirements during the programming horizon. At the project level, only a few bridges are realistically considered for implementation.

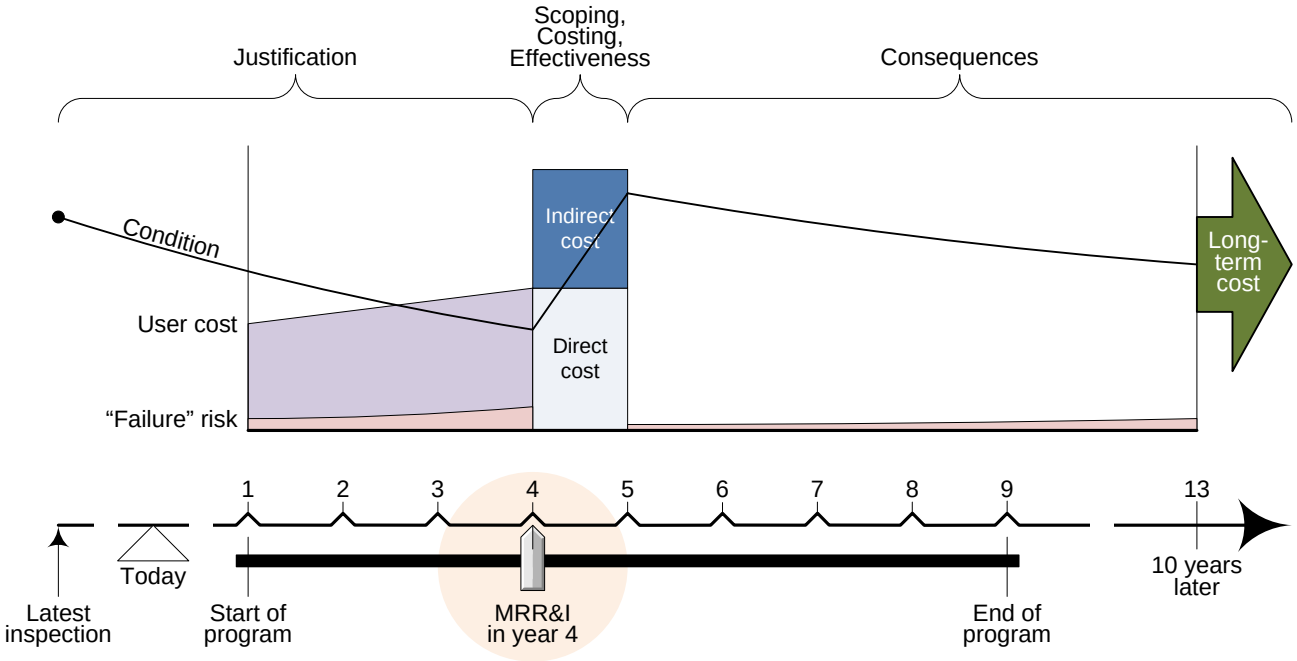
Obviously the network level and project level are very different. They are complementary, because both perspectives can be used together in an agency's bridge management process. They also are linked: the network level contributes predictive models (e.g. deterioration, life cycle costs) needed by the project level for evaluating possible outcomes of decisions; and the project level produces a set of candidate projects, with costs and benefits, that can readily be used in a network level priority-setting and budgeting analysis.

Significantly, the project level perspective allows more data to be collected cost-effectively because such data are needed only on a small number of bridges. Some of the most difficult issues in bridge management today may benefit from this orientation. For example, a project-level deck analysis can incorporate material testing data; cost models can include indirect costs and work zone user costs; and vulnerability analysis can focus on those structures where vulnerability is an issue. The project-level analysis tool can be a powerful test-bed for new research in these areas.

For more immediate use with currently-available knowledge, the main benefit of a project level model is the ability for project level decision-makers, primarily the District Structures and Facilities Engineers (DSFEs) and others with which they must cooperate, to interact with BrM data at a level with which they are comfortable where they can take maximum advantage of the resources available in BrM. Much of the usage of the tool will be during an annual process of program negotiation known as "gaming," which occurs during the fall of each year for the program period beginning the following year.

LIFE CYCLE COSTING FRAMEWORK

The figure below presents a schematic example of a project level model framework designed to satisfy these goals. The scale in the lower portion of the diagram shows the relationship in time between the point of decision ("today"), the most recent inspection, the time frame in which candidate projects are to be developed (start and end of program period), and the long-term outcome of the decision. On the vertical scale, filled areas indicate cost streams during and after the program period. The line chart overlaid on this depicts the typical pattern of bridge condition, expressed as a Health Index (Shepard and Johnson 1999). The overall pattern of costs over time, is called a Life Cycle Activity Profile (NET 1996).



The programming process within FDOT considers specific projects as far as nine years in the future, though only bridge replacement projects are important to the process that far out. Maintenance projects are programmed only three years into the future. It is assumed that, once a project has taken place on a bridge, that bridge is not revisited until the tenth year following the project. A long-term cost model provides a

general estimate of life cycle costs for the time beyond this required interval. As a matter of convention, inspections and condition forecasts are assumed to occur at the end of a year, while projects (including their costs and improved conditions) are assumed to occur at the beginning of a year.

The engineer is asked to make decisions about the scope and timing of candidate projects. Although the decision support tool supplies a great deal of useful information about bridge economics, the engineer also must rely on significant inputs from other sources:

- Status of the ongoing project development workflow affecting the readiness of individual projects;
- Information about funding availability for various types of work, from the Work Programs Office;
- Policy guidance from the Maintenance Office;
- Information about inter-relationships with other projects, including those of other districts, local governments, and asset management contractors; and non-bridge projects.

During the 2-4 months of the gaming process, the dynamic nature of these inputs and decisions will cause numerous adjustments in the scope and timing of work candidates. The project level models need to be sensitive to these adjustments, to inform decision-makers of their implications. Much of this feedback is given in the form of conditions, deficiencies, and life cycle costs. The figure above shows the life cycle cost components that are modeled, organized into three phases:

- Justification phase, which predicts deterioration from the latest inspection up to the year in which a candidate is being considered. If functional deficiencies (e.g. narrow bridge roadway, limited load capacity, impaired vertical clearance, and moveable bridge openings) are present, there may be a user cost representing the adverse effect on the public. If conditions are very deteriorated, there may be a risk of loss of functionality, necessitating emergency repairs and service disruption. Risks from natural and man-made hazards also contribute to potential agency and user costs.
- Scoping and costing phase, where predicted needs at the investigated point in time are converted to a definition of a realistic candidate project. This candidate has direct costs and indirect costs, the latter consisting primarily of maintenance of traffic and mobilization. It has an immediate effect on condition. The engineer can adjust the action selection and quantity at the element level.
- Consequence phase, predicting the long-term outcome resulting from the considered project. No further work is done for 10 years after completion of the project, during which time the bridge deteriorates. A risk of loss of functionality may occur, especially if the candidate project did not address all of the needs present on the bridge. A user cost may occur if functional deficiencies were not remedied. Beyond this 10-year waiting period, the life cycle cost analysis provides a probabilistic estimate of subsequent costs, sensitive to the ending condition of each element.

All of these costs are discounted to present value. If the timing of a candidate is delayed, user costs and risk costs may increase. Needs may increase, forcing an increase in the scope and cost of work. Offsetting these effects, the initial cost and long-term cost are discounted by a greater amount since they are farther away in time. If a candidate is downscoped, then not all of its needs will be met. Even though the initial costs are lower, this may be offset by higher risk, possible user costs, and higher long-term costs.

All candidates are evaluated in comparison to a default “do nothing” candidate. This is the same as postponing work to beyond the end of the program period. The life cycle cost of Do Nothing includes an elevated risk and long-term cost because of uninterrupted deterioration. A user cost may also be present. A work candidate is considered beneficial if it reduces user cost, risk, and long-term cost by an amount greater than its initial cost, all on a discounted basis. Economic benefit is calculated as the difference between the life cycle cost of doing nothing, and the life cycle cost of the candidate under consideration. Any benefit greater than zero is desired.

The project level analysis automatically generates separate preservation and replacement candidates for each year of the program period, to give the engineer a starting perspective on scope and timing. Typically the

engineer then may adjust the scope of the candidates to more realistically describe the choices available on the bridge. The tool responds by providing new evaluation results from the life cycle cost model.

Justification

Justification is defined here as the portion of life cycle costs that accumulate when needed work is not conducted on a structure. It consists of cost components that could be avoided if all deficiencies were to be relieved at the beginning of the program period. By convention, avoidable life cycle costs are not recognized prior to the start of the first year of the program period (called the "base year"). By this definition, avoidable costs include the effect of all past and future deterioration and functional deficiencies up to (but not including) the year in which a candidate project is contemplated, so it includes the avoidable portion of the effective cost of past deferred maintenance. If implementation of a candidate is delayed for any reason, its justification normally increases.

The FDOT project-level analysis tool currently estimates the following components of the justification phase of life cycle costs:

- Risk of natural and man-made hazards, including hurricanes, tornadoes, wildfires, floods, vessel collisions, over-height truck collisions, overweight vehicles, other truck collisions, advanced deterioration, and fatigue. These are all quantified as social costs to the agency and to the public.
- User cost of functional deficiencies. This includes the cost of excess accident occurrence and truck detours, according to the FDOT user cost model (see example in the figure below).
- User cost of moveable bridge openings. This includes the delay to all road users caused by frequent opening of moveable bridges to allow passage of ships.

WIDENING of roadway on the structure

INPUT DATA (all lengths in feet)

On_under:	On	DeckWidth:	32.800	FuncClass:	2	ApprAlign:	9
Length:	134.843	RoadWidth:	30.100	ADT (now):	3,342	DkRating:	6
Lanes:	2	ApprWidth:	34.000	Growth%	2.537		

This is a short bridge (<=200 ft.)

Required width: ReqWidth = ApproachFrac*ARoadWidth = 0.9 * 34.000 = 30.600 ft.

Design width: NewWidth = ApproachFrac*ARoadWidth = 0.9 * 34.000 = 30.600 ft.

***** RoadWidth<ReqWidth and RoadWidth<NewWidth so roadway needs widening.**

ACCIDENT COST PARAMETERS based on the FDOT accident risk model

Name	Coefficient	Description
Coef1	-377.3701	Constant (based on urban arterial functional class)
Coef2	0.7323	Coefficient for Lanes * Length
Coef3	0.4531	Coefficient for ADT * Lanes / RoadWidth (based on ApprAlign and DkRating)
AccCost	126,445	User cost per accident
Weight	1.0000	User cost weight

Accident risk = (Coef1 + Coef2*Lanes*Length + Coef3*ADT*Lanes/RoadWidth) / 1000

Excess cost = (Unimproved minus improved accident risk) * AccCost * Weight (but not less than zero)

Since ADT varies by year due to traffic growth, so does accident cost.

EXCESS ACCIDENT COST BY YEAR

Year	ADT	OldRisk	NewRisk	ExcessCost
2017	3,427	0.021	0.016	699
2018	3,514	0.030	0.024	717
2019	3,603	0.039	0.033	735
2020	3,694	0.048	0.042	754
2021	3,788	0.057	0.051	773
2022	3,884	0.066	0.060	793
2023	3,982	0.076	0.070	813
2024	4,083	0.086	0.080	833
2025	4,187	0.096	0.090	855

Long-term potential user cost (perpetuity with no growth) is $17,135 discounted to $10,533.

This is not yet capped at replacement cost.

Widening will add 431.496 sq.ft of deck area and cost $105,860 ($245.33/sq.ft).

To calculate these quantities as well as those needed for subsequent phases, the model simulates the deterioration of each bridge element from the most recent inspection to the year in which a candidate project is contemplated, using the same Markovian transition probabilities used in BrM (example below). A bridge that is badly deteriorated, or is in a situation where it is vulnerable to various natural and man-made hazards, may start to incur hazard costs.

Certain bridge elements, namely coatings, deck wearing surfaces, cathodic protection, expansion joint seals and drainage systems, exist primarily to slow the deterioration of other elements. The effect is significant and therefore is addressed at the project level. During the simulated deterioration, this effect is modeled by accelerating the deterioration rate of protected elements (most superstructure and substructure elements), according to the predicted condition of protector elements on the same bridge.

Implementation

Evaluation of the economic implications of project decisions — rather than automation of those decisions — is the main purpose of the project level analysis tool. Therefore, automatic scoping of projects is not in itself a desired feature of the system. Nevertheless, it is very convenient for the tool to be able to create reasonable first-cut candidates, which minimize life cycle costs and respect certain constraints on realism of candidate definitions. These initial candidates are not optimized, but they do provide a reasonable measure of need, project urgency, and economic merit. It is expected that the engineer will revise the scope of the project based on his or her own knowledge of the bridge.

Three candidate types are always generated automatically:

- Do Nothing - no action in any year of the planning period;
- Auto MRR&I - do a reasonable set of actions in response to all maintenance, repair, rehabilitation, and improvement needs on the bridge, in one year of the period (a separate life cycle activity profile is generated for each of 9 possible implementation years);
- Auto Replace - replace the bridge in one year (again a separate definition for each of the 9 years).

DO-NOTHING DETERIORATION RESULTS BY YEAR

Year	ProtFac	State1	State2	State3	State4	Modifier	HealthIx	Needs	OptLTC	DNLTC
Insp 2013		100.00	0.00	0.00	0.00		100.00	0	1,917	1,917
Now 2016	1.311	74.66	25.10	0.24	0.00		91.47	4	4,998	4,999
Base 2016	1.305	74.66	25.10	0.24	0.00		91.47	4	4,998	4,999
2017	1.305	64.95	34.52	0.52	0.01		88.14	16	6,269	6,270
2018	1.301	55.76	43.33	0.90	0.02		84.94	42	7,539	7,540
2019	1.295	47.30	51.30	1.37	0.04		81.95	87	8,781	8,784
2020	1.289	39.69	58.33	1.92	0.07		79.21	157	9,983	9,989
2021	1.281	32.96	64.38	2.55	0.11		76.73	255	11,140	11,149
2022	1.273	27.12	69.49	3.24	0.16		74.52	386	12,251	12,265
2023	1.265	22.10	73.70	3.97	0.23		72.56	553	13,321	13,341
2024	1.256	17.85	77.09	4.74	0.32		70.82	759	14,355	14,382
2025	1.248	14.30	79.74	5.54	0.42		69.30	1,008	15,359	15,396

ProtFac is the protection factor, based on previous year's protective system conditions.
Conditions are shown at the end of the indicated year. So the base condition is just before the first program year.
Modifier is this element's contribution to the next year's protection factor, if this is a protective element (blank otherwise).
HealthIx = Health index. (Channels and defects are excluded.)
Needs = Total agency cost of the optimal actions on the element.
OptLTC= Total long-term cost of the optimal actions on the element.
DNLTC = Total long-term cost of doing nothing on the element.

In addition, the engineer may specify up to three additional candidate scopes, and analyze each one in any implementation year.

The process for generating the Auto MRR&I candidates is very similar to what is planned in the BrM program simulation, using life cycle cost analysis to identify preservation actions on each element, and using level-of-service standards to identify functional improvements. A few refinements are imposed on this process to generate realistic project candidates:

- Minimum and maximum thresholds for feasible scale of actions.
- A rule requiring replacement of railings, joints, and wearing surfaces any time a deck is replaced.
- A threshold criterion for replacing the entire paint system on a bridge, rather than spot or zone painting.
- The quantity of an action is allowed to be larger or smaller than the quantity in states for which the action has been defined.

The latter point is especially important, because it gives the engineer a great deal of flexibility to scope a candidate project in any way necessary. An output prediction model in the system divides up each scope item and assigns the parts to preservation actions in a manner as reasonable as possible to determine the cost and effectiveness of the work.

A cost model estimates the direct and indirect costs of each candidate. Currently both direct and indirect costs are proportional to the quantity of work, but in the future the framework is designed to allow indirect costs to be constant or to vary in a non-linear way with quantity. This is a high priority topic for future research, that may require collection of new data on traffic control and mobilization activities. Addition of a work zone user cost model is also a high priority.

Consequences

In the idealized life cycle cost analysis, costs of a candidate project are assumed to occur on the first day of its implementation year, followed by 10 years of inactivity when the bridge is allowed to deteriorate. User costs may occur during this period if any functional needs are left uncorrected.

At the end of the 10-year hiatus, it is not necessary to plan specific projects, but it remains necessary to estimate residual life cycle costs. Such an estimate must be sensitive to the ending condition of each element: if work is done during the program period, ending conditions will be relatively good, and further needs will be relatively small, compared with the do-nothing case. The model provides an estimate of long-term costs, sensitive to the starting condition state and choice of action. To use this as an estimate of long-term residual costs, only a few refinements are necessary:

- Model 10 years of do-nothing deterioration from each condition state, then calculate long-term costs from the resulting conditions using actions that minimize life cycle costs.
- Whenever a portion of an element reaches a deteriorated state, recognize the risks of this situation using agency and user costs.
- Long-term costs are assumed to occur starting at the end of the hiatus period.

If any functional needs or hazard vulnerabilities are uncorrected, they are either assumed to continue indefinitely beyond the hiatus period, or a bridge replacement cost is incurred, whichever gives the lowest life cycle costs. In the former case, traffic growth is assumed to stop.

DECISION SUPPORT TOOL

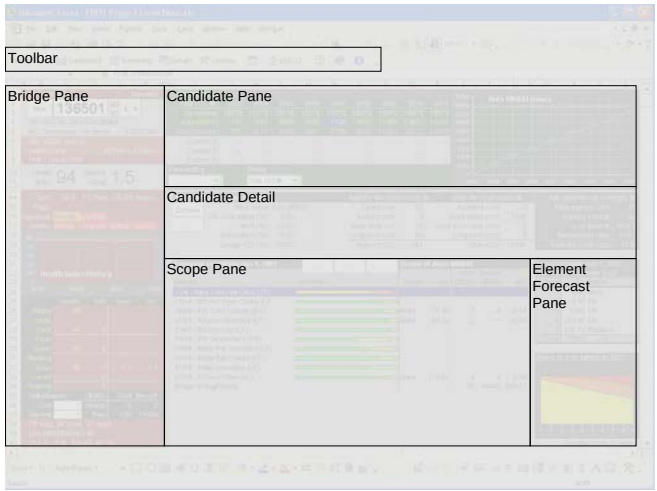
The framework described here was implemented as an Excel spreadsheet model, with most of the analysis written in Visual Basic for Applications. This proved to be a very effective tool, in terms of system development cost as well as execution speed. Built-in features of Excel were used for most of the data management and user interface needs, so the majority of new software code was devoted to the analysis. Excel's programming model is quite stable, its worksheets easy to modify, and the analytical code non-proprietary. Together these factors make the software an attractive test bed for further development of bridge management models in a research setting.

The current version of PLAT works on Excel versions 2007 or later, with Windows 7 or later.

For production use, the system is very fast, and is sufficiently secure for its intended use as a means of displaying analysis results. It does not write data to the BrM database, but stores all its results in Excel worksheets and a separate PLAT Results Database. A full screening analysis of all 30,000 Florida structures takes less than a minute. In normal usage where only one bridge at a time is accessed, the total time to access, analyze, and display the results is well under a second. This speed is extremely important to the usefulness of the system, as it encourages engineers to experiment with many alternative project definitions until they are satisfied with the results. This gives it the potential to become a true programmatic design tool.

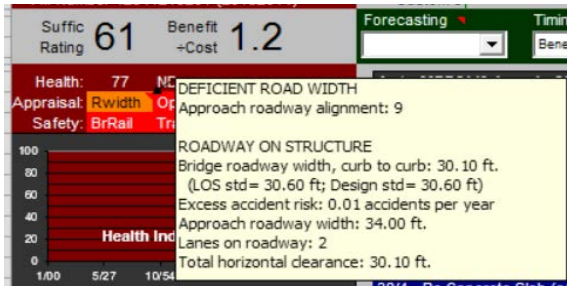
All of the primary functionality of the tool is presented on one screen, as indicated schematically below. This Excel worksheet is called the digital "dashboard" because, like the dashboard of a truck, it presents an organized set of gauges and controls for the model. The dashboard worksheet is divided into panes, labeled in

the figure. The Bridge Pane contains inventory, current status, and historical information; the Candidate Pane and Candidate Details show predicted future cost and performance if a particular candidate project is implemented in a particular year; the Scope Pane shows more detail about a specific Candidate and year, for the elements on the bridge; and the Element Forecast Pane predicts future condition for one selected element.

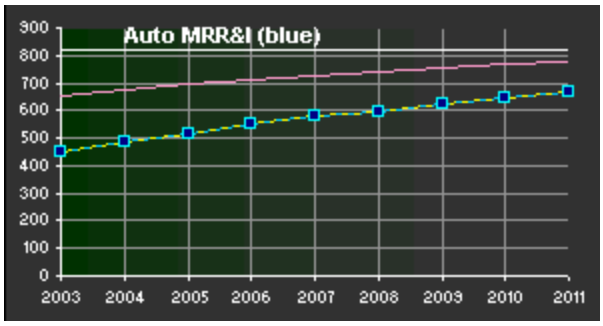


Examples of some of the contents of the dashboard worksheet are:

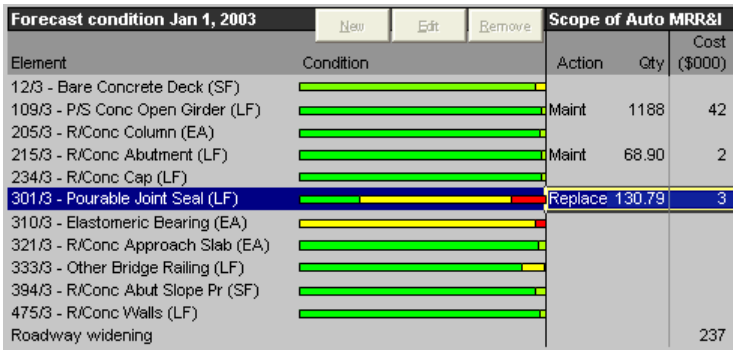
- Flags indicating functional deficiencies and vulnerabilities, including Smart Flags (AASHTO 2013) noted in the bridge inspection process.



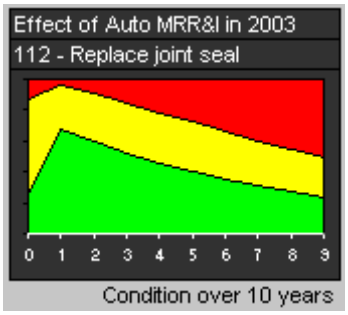
- A life cycle cost analysis sensitive to project timing. This example compares Do Nothing (white), Auto Replace (red), and Auto MRR&I (blue). This analysis can show total life cycle costs as in the example, or agency and user costs separately. It can also compare the timing implications of initial cost, action type, benefits, and benefit/cost ratio.



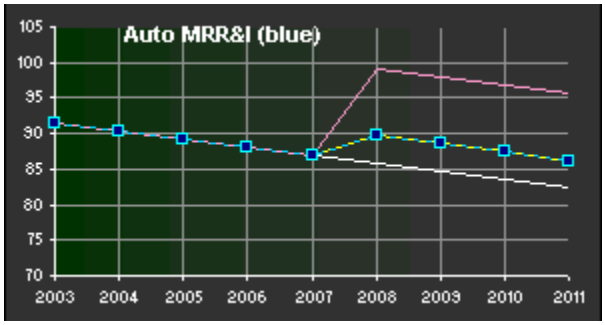
- The prediction of element conditions and anticipated preservation needs in any year in which a candidate project is being considered. The bar graph is interactive, changing to show condition each year as the cursor is moved, helping the engineer to visualize the relative deterioration rates of the various elements on a bridge.



- A forecast of future condition trends of an individual element if a candidate is implemented in a given year. The example shows an immediate improvement in condition in the first year if deteriorated joint seals are replaced, followed by normal deterioration.



- A forecast of the future condition trend of the bridge, if a candidate is implemented in a given year. This example compares Do Nothing (white), Auto Replace (red), and Auto MRR&I (blue). This can be expressed as a health index, as in the example, or preservation needs, benefit/cost ratio, user cost, or excess accident risk.



- An analysis of the risks faced by each bridge, given its current location, vulnerability, and condition.

Risk analysis for structure '010076' in 2014

	Hurricane	Tornado	Wildfire	Flood	Vessel	Height	Weight	Crash	Decay	Fatigue	Total
Hazard prob (%)	8.45	0.62	15.31	1.00	0.00	0.00	0.00	0.31	1.45	0.00	27.13
Agency cost ($k)	0.02	0.01	0.05	0.00	0.00	0.00	0.00	0.02	21.83	0.00	21.93
…as % of repl cost	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.47
User cost ($k)	0.03	0.01	0.04	0.00	0.00	0.00	0.00	0.03	5.01	0.00	5.12
…minutes per car	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.09
Total risk ($k)	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.1	26.8	0.0	27.1

Engineers use the dashboard to determine at-a-glance the economic health of a structure. They also use it as a design tool for candidate projects to enter the programming process. When the engineer modifies a candidate by changing element action selections, quantities, or various cost factors, the dashboard responds as a spreadsheet is expected to do, by immediately updating its predictive results.

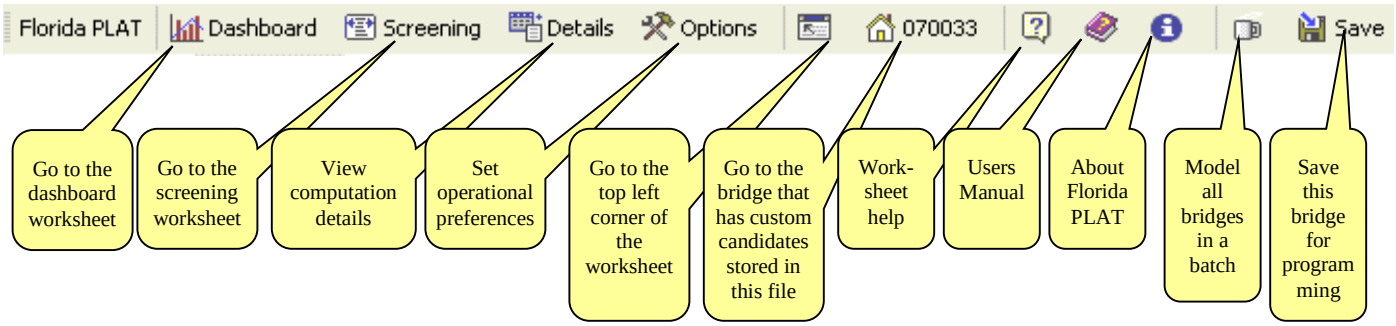
In addition to the dashboard, the system has a Screening worksheet containing a list of bridges in a selected subset of the inventory. This list may be sorted by various screening criteria, such as the sufficiency rating, NBI condition ratings, health index, type of work, cost, benefit, benefit/cost ratio, and economic urgency of actions. Economic urgency in this system is defined as the difference in life cycle costs between the first and second years, of the Auto MRR&I candidate generated by the models. It shows how much is lost by delaying action.

Screening

Please click a Bridge ID to select it.

Bridge ID	Structure Name	Custodian	District	Facility Carried	Feature Intersected	Action Cat	Total Cost ($000)	Urgency	Suffi-iciency Rating	Replace ment Rank	Health Index	Avg Condi-tion
136501	KEY ROYAL DR OVER BIMINI	4	01	KEY ROYALE DRIVE	BIMINI BAY	500	65	31.17	34.8	5.0	94.1	6.5
164137	ROCKRIDGE RD OVER GATOR	2	01	ROCKRIDGE ROAD	GATOR CREEK	600	84	9.41	38.2	5.7	87.7	6.8
030059	US41 ovr DRAIN CANAL 059	1	01	US41	DRAINAGE CANAL 059	500	47	8.66	68.0	8.4	97.0	7.0
030060	US41 ovr DRAIN CANAL 060	1	01	US41	DRAINAGE CANAL 060	500	47	8.61	68.0	8.4	97.0	7.0
030074	US41 OVER ROSTOV CANAL	1	01	US41	ROSTOV CANAL	500	48	8.61	67.8	8.4	88.7	7.0
030066	US41 ovr DRAIN CANAL 066	1	01	US41	DRAINAGE CANAL 066	500	48	8.56	68.0	8.4	94.6	7.0
030067	US41 ovr DRAIN CANAL 067	1	01	US41	DRAINAGE CANAL 067	500	48	8.51	68.0	8.4	87.6	7.0
030089	US-41 SR-90 / MAXS CANAL	1	01	US-41 SR-90	MAXS CANAL	600	57	8.13	51.5	7.9	72.4	6.8
030061	US41 ovr DRAIN CANAL 061	1	01	US41	DRAINAGE CANAL 061	500	55	7.41	68.0	8.4	97.0	7.0
070032	CR-833/DEVILS GARDEN CAN	2	01	CR 833	DEVILS GARDEN CANAL	500	36	7.13	74.3	8.3	68.5	7.0
070051	CR-833/JUDY'S CROSSING	2	01	CR 883	JUDY'S CROSSING	500	36	6.86	66.3	6.9	69.7	7.0
030065	US41ovr DRAIN CANAL 065	1	01	US41	DRAINAGE CANAL 065	500	63	6.54	68.0	8.4	93.9	7.0
160010	CR 64 OVER ARBUCKLE CRK	2	01	CR-64	ARBUCKLE CREEK	500	162	6.53	28.2	6.6	91.4	6.3
030070	US41 ovr DRAIN CANAL 070	1	01	US41	DRAINAGE CANAL 070	500	63	6.52	68.0	8.4	89.4	7.0
030068	US41 ovr DRAIN CANAL 068	1	01	US41	DRAINAGE CANAL 068	500	63	6.50	68.0	8.4	85.9	7.0

A third worksheet provides a detailed rationale for the results reported on the dashboard, describing the effects of each part of the project level model. The three main worksheets, supporting functionality, and help features are all accessed by means of a custom toolbar. The toolbar appears on the Add-Ins ribbon.



CONCLUSIONS

The Pontis/BrM analytical framework has always had the potential to support project-level decision-making, but up to now it has not been easy to find this information or use it effectively. Project-level decisions are often influenced by non-economic considerations, such as project readiness and inter-relationships with other activities. Timing of the work, in particular, is an important decision variable.

By adopting a project-level perspective on the analysis, it is possible to define a new analytical framework that is sensible and valid when evaluating potential work on an individual bridge, while remaining compatible with a network-level bridge management perspective. When this information is presented in a suitable way, engineers who are planning a multi-year bridge work program can use the analysis to gain a quick, intuitive view of the economic health of a bridge and the urgency of completing work on it.

Getting Started

Welcome to the Florida project level analysis tool! This is an Excel model designed to work with BrM, using life cycle cost analysis to give you a concise snapshot of the economic health and future prospects for a structure. Think of it as a diagnostic instrument for your bridges.

To use the system, you need Microsoft Excel 2007 or higher, and Adobe Acrobat Reader 6 or higher (just for the Users Manual). Your BrM administrator should have posted an Excel template file and a Users Manual in the directory where your Microsoft Office templates normally are found, and should have sent you a Windows Shortcut file for launching the system. If this is not the case, you can prepare the system for normal use by consulting the Chapter on Administration.

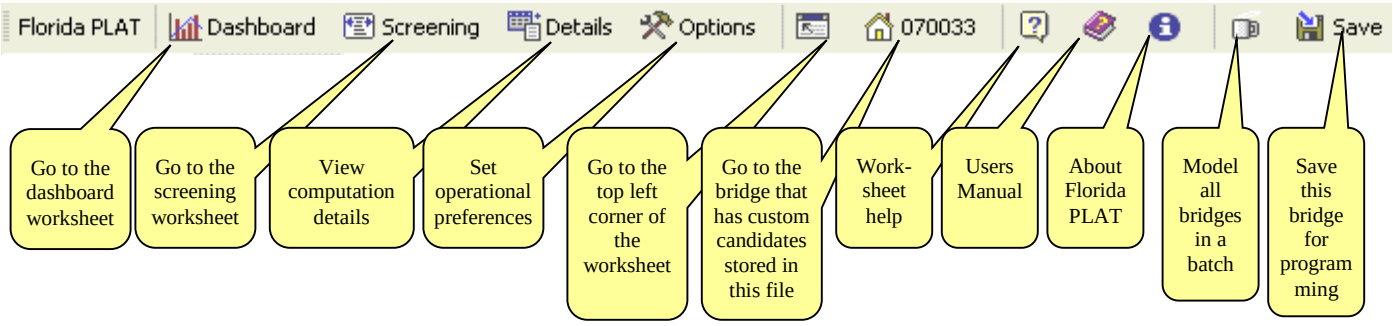
For most purposes you will need to use only three worksheets in the system:

Dashboard – the bridge-level instrument panel, that you will use most of the time. It comes up automatically whenever you create or open a workbook file.

Screening – a menu for sorting and selecting bridges. The analysis gives performance indicators that help you visit bridges in order of urgency or priority.

Details – If you want to see the detailed computations behind the Dashboard, you can view this worksheet.

Most of the time you will navigate through the system using the toolbar, which looks like this:



The toolbar appears on the Add-Ins ribbon.

To learn how the life cycle cost analysis works, see Life Cycle Cost Framework. In particular, it is useful to understand the concept of Candidates and the various types of them. A set of quick lessons is provided to get you started in understanding and using the tool effectively:

- Viewing a Structure
- Understanding Life Cycle Cost
- Predicting Condition
- Understanding Candidates
- Understanding Timing
- Navigating to Other Structures
- Screening Structures
- Customizing Candidates – Cost Factors
- Customizing Candidates – Scope Items
- Managing Customized Structures
- Viewing Computation Details

We hope you will find the tool indispensable as you plan work on a bridge, especially during the gaming process each fall.

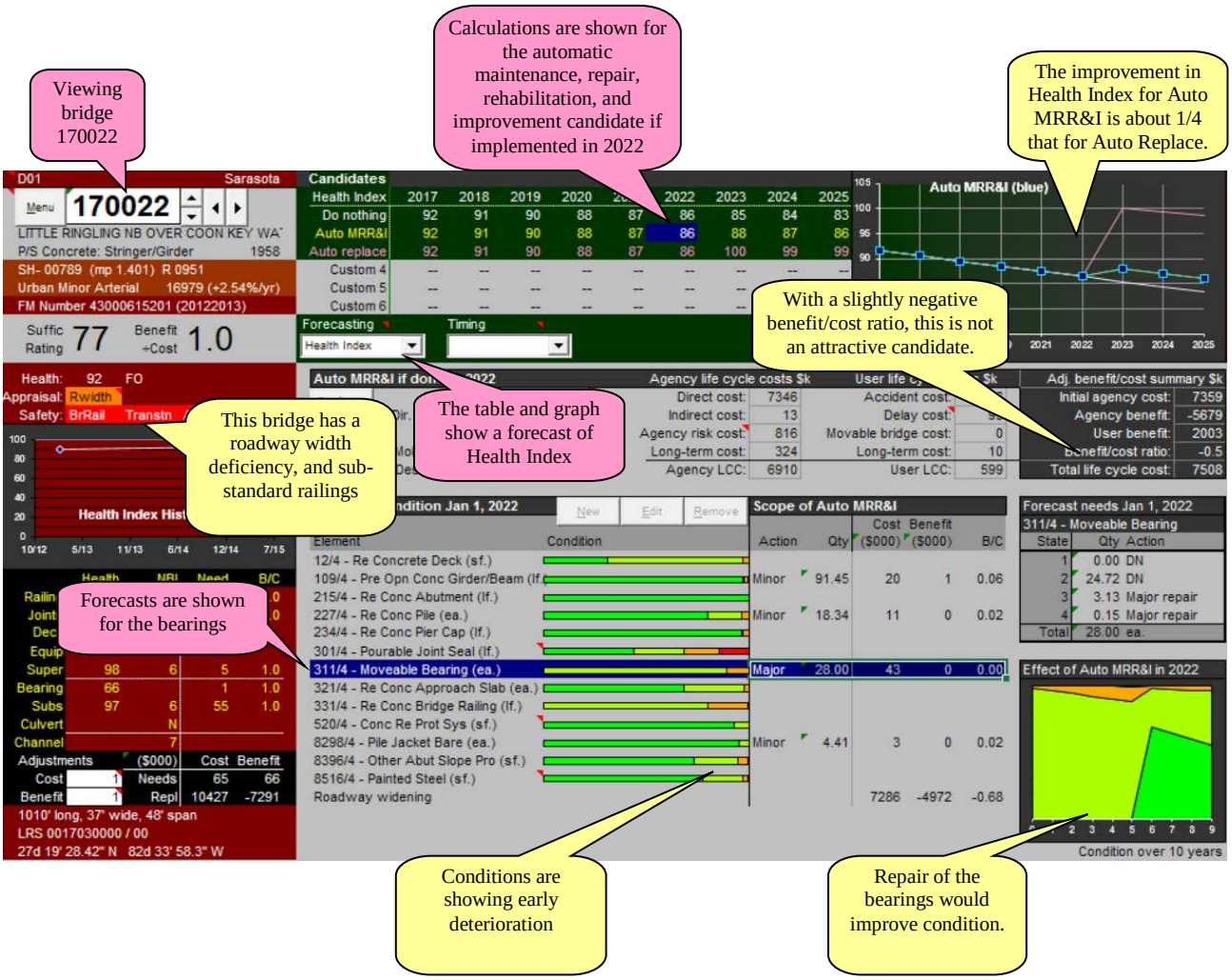
Viewing a Structure

To see the Dashboard, just double-click the Florida project level analysis tool icon in Windows. This is the first screen that will come up. (If you have macro protection turned on in Excel, you will be warned about macros; click the Enable Macros button.) You might see a different bridge and different results, but the screen layout is always the same.

The main controls for the system are indicated by red balloons below. You can choose what bridge to view, select one of the Candidates and implementation years (by clicking a cell in the upper table), and select a scope item for the candidate (by clicking a cell in the lower table). You decide what performance measure to tabulate and graph in the upper part of the screen by choosing from a pick list.

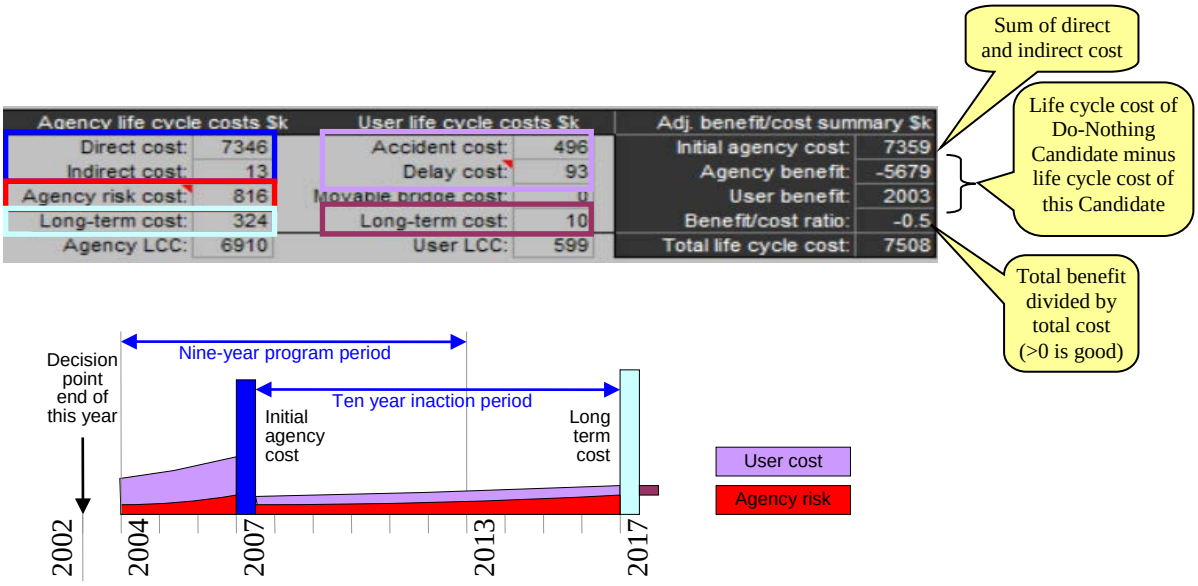
Some of the most interesting results on this particular screen are highlighted in yellow. In general, the reddish area on the left (Bridge Pane) has bridge inventory data and its current condition and needs, along with its Health Index history. The greenish area on top right (Candidate Pane) describes the scoping and timing options for the bridge. The gray area in the middle (Candidate Details Pane) provides detailed results for one selected Candidate and year. The lower half (Scope Pane) lists the elements, their forecast conditions, and projected needs. Details about one selected element are shown to the right of this (Element Forecast Pane).

In a few places around the worksheet, you will see tiny red triangles in the upper right corner of a worksheet cell. These are comments that give more information about an item, or that provide help information.



Understanding Life Cycle Cost

For each possible combination of Candidate and implementation year, the model computes a life cycle cost analysis. Its results are presented in the center section of the Dashboard.



The diagram above highlights the main cost components from the Dashboard, then shows them in matching colors in a timeline. Each cost is defined in the table below. If any Candidate is compared with the possibility of doing nothing, the operative question is: will the investment of initial costs (blue) be more than offset by savings in future costs (violet, red, light blue, and purple).

Agency life cycle costs		User life cycle costs	
Direct cost (blue)	Cost directly related to the quantity of scope items (not discounted)	Accident cost (violet)	Expected value of user costs due to excess accident risk, because of narrow bridge roadway (discounted)
Indirect cost (blue)	Maintenance of traffic, mobilization, and engineering costs (not discounted)	Delay cost (violet)	Expected value of user costs due to height or weight restrictions, and the delay/detour costs due to natural and man-made hazards
Agency risk cost (red)	Economic consequences to the agency of natural and man-made hazards	Movable bridge cost	Movable Bridge Cost, quantifying the user costs of movable bridge openings
Long-term cost (light blue)	Total life cycle costs beyond the end of the model, based on ending conditions (discounted)	Long-term cost (purple)	Remaining user costs beyond the end of the model (discounted)
Total agency LCC	Sum of the above, all discounted	Total user LCC	Sum of the above, all discounted

Since all of the costs occur at various times in the future, they are processed in a standard engineering procedure called net present value analysis. Each cost item is discounted (reduced in value) by an amount that depends on how far in the future it occurs. Naturally if a cost needs to be incurred, we prefer to put it off as long as possible, because then it matters less to us. The discount factor represents how much less it matters for each year that we can delay the cost.

The indicators on the right side of the Dashboard portion shown above, summarize the rest of the analysis. We want to select Candidates with high benefit/cost ratios. In particular, we want the ratio to be more than zero, indicating positive net benefits. In the rest of the analysis, we will use this concept to compare scoping and timing alternatives on each bridge.

Predicting Condition

The life cycle cost model depends to a great extent on the prediction of future conditions on each element of the bridge. This forecasting is performed by means of a deterioration model.

Instead of predicting an exact condition state in the future, which is beyond the current state-of-the-art, the model estimates the likelihood of each future condition state. This is done by means of transition probabilities, the odds of making a transition from one state to the next in one year.

A typical example of a deterioration model for concrete girders is shown in the table below. The left side shows the transition probability matrix. As an example of interpreting this table, if all the girders on a bridge are in new condition (state 1), then next year 96.6% of the length of the girders will still be in state 1, and 3.4% will have deteriorated to state 2. In the second year, 96.6% × 96.6% = 93.3% will still be in state 1. In fact, the conditions at the end of any year in the future can be predicted, in principle, by matrix multiplication. The table at right shows the result of ten years of multiplication.

Transition probabilities

		One year later	
From state	Transition time (yrs)	Same state	Next state
1	20	96.6%	3.4%
2	15	95.5%	4.5%
3	10	93.3%	6.7%
4		100.0%	0.0%

Predicted conditions

Year	State 1	State 2	State 3	State 4
1	100.0%	0.0%	0.0%	0.0%
2	96.6%	3.4%	0.0%	0.0%
3	93.3%	6.5%	0.2%	0.0%
4	90.1%	9.4%	0.4%	0.0%
5	87.1%	12.1%	0.8%	0.0%
6	84.1%	14.5%	1.3%	0.1%
7	81.2%	16.7%	1.9%	0.2%
8	78.5%	18.7%	2.5%	0.3%
9	75.8%	20.5%	3.2%	0.5%
10	73.2%	22.2%	3.9%	0.7%

Fortunately, this is a computation the computer can do very quickly. You can see the results for any element on a bridge in the lower right portion of the Dashboard, in the Element Forecast Pane.

This particular example shows a concrete girder that is to be repaired in 2006. At this point, deterioration is forecast to have progressed to where none of the element remains in state 1, 3388 feet are in state 2, 561 feet are in state 3, and 80 feet are in state 4.

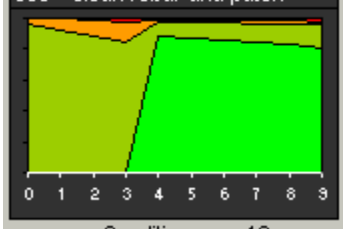
The upper table also shows the lowest life cycle cost actions for each condition state. The example analyzed here assumes that the repairs in states 2 and 3 are implemented.

In the lower part of the example is a graph of condition if this strategy is implemented. This is an area chart, whose full height represents 100% of the element. Bright green is state 1, and red is state 4. Most of the element is returned to state 1, with just a small portion remaining in other states. Deterioration proceeds normally after that year, as evidenced by the declining fraction of bright green as we move toward the right.

Forecast needs Jan 1, 2006
109/4 - P/S Conc Open Girder

State	Qty	Action
1	0.00	DN
2	3388	Seal&Patch
3	561.13	Cln&Patch
4	79.76	Replace
5		
Total	4029	(LF)

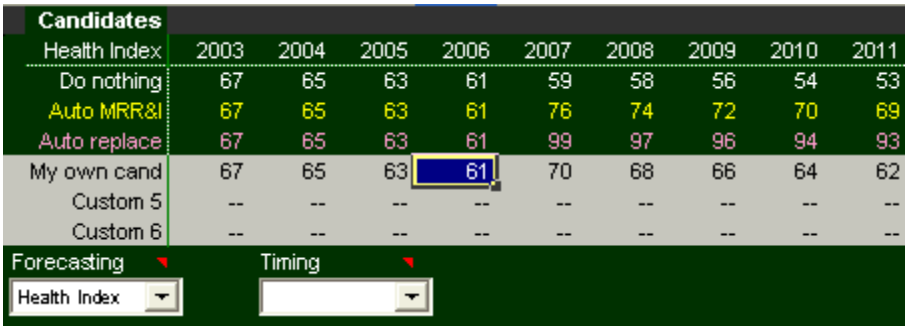
Effect of Auto MRR&I in 2006
303 - Clean rebar and patch



Condition over 10 years

Understanding Candidates

In order to describe the economic future of a bridge in a manageable way, the model uses the concept of Candidates. Each Candidate represents a different way of approaching the scoping of a possible project. The Candidate Pane of the Dashboard provides six slots in which Candidates may be defined. Three of these slots are provided automatically, while the other three can be created manually. The example below has one of these Custom Candidates.

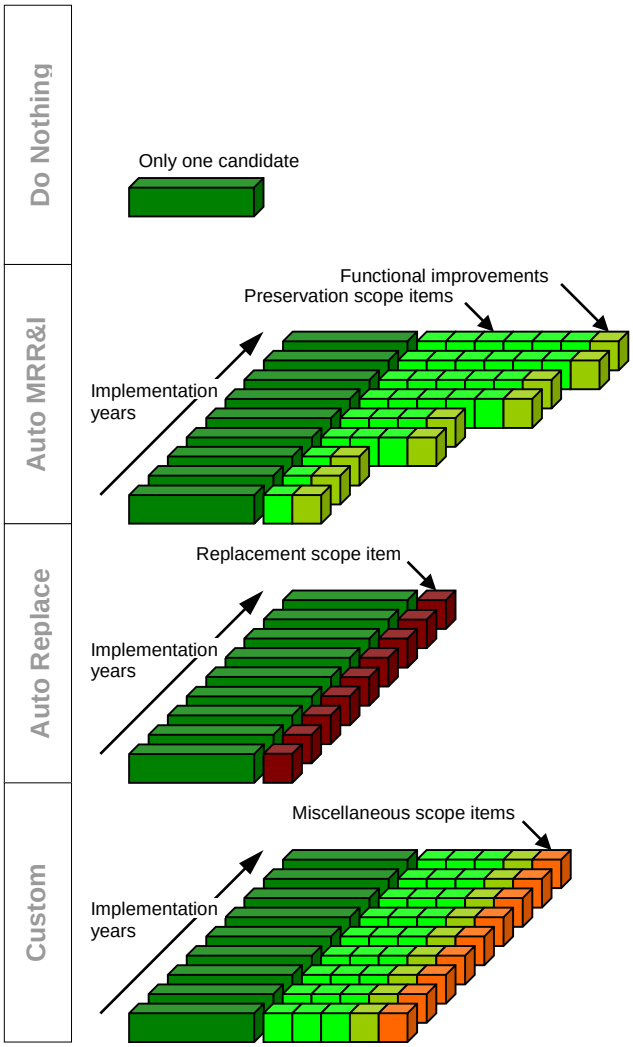


Candidates

Health Index	2003	2004	2005	2006	2007	2008	2009	2010	2011
Do nothing	67	65	63	61	59	58	56	54	53
Auto MRR&I	67	65	63	61	76	74	72	70	69
Auto replace	67	65	63	61	99	97	96	94	93
My own cand	67	65	63	61	70	68	66	64	62
Custom 5	--	--	--	--	--	--	--	--	--
Custom 6	--	--	--	--	--	--	--	--	--

Forecasting: Health Index

Timing:



Simplest in this group is the Do Nothing Candidate, which describes the life cycle of the bridge if nothing is done to it in any year of the program period.

Next is the Auto MRR&I (maintenance, repair, rehabilitation, and improvement) Candidate, providing scope items to address all the preservation and functional needs on the bridge. The scope can change depending on the implementation year: usually needs grow because of deterioration.

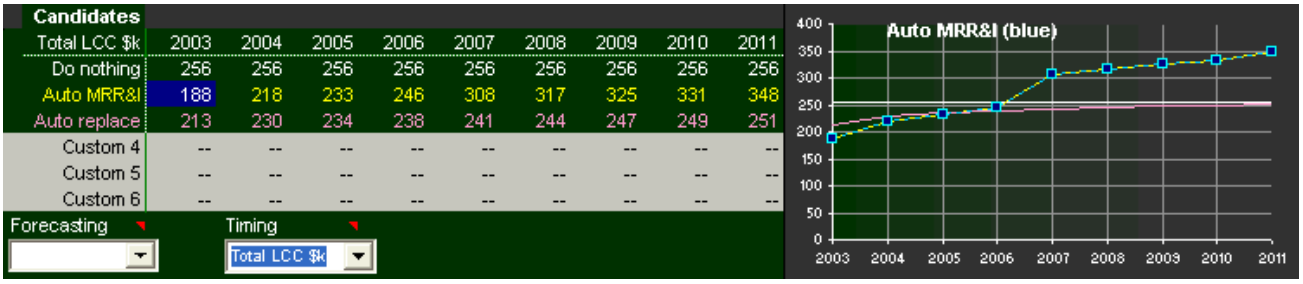
Third is Auto Replace, which estimates the life cycle cost if the bridge is simply replaced.

Finally, Custom Candidates let you define your own scope, which is the same each year. For example, you can decide to replace all the joints instead of just a few of them, or you can change the selection of action for girder repairs. You can add miscellaneous scope items where you specify the cost and benefit.

Each Candidate (except Do Nothing) is investigated for implementation in each of the nine years of the program period. This lets you simultaneously explore the possibilities of scoping and timing.

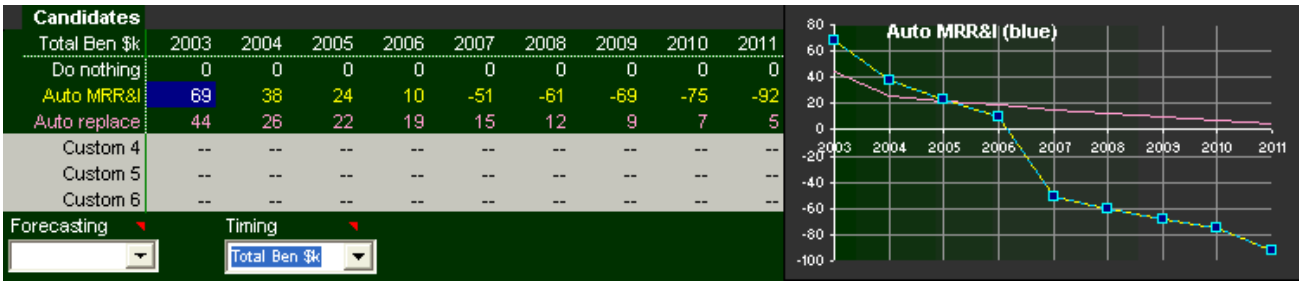
Understanding Timing

The key trade-off in the project level analysis can be described as a matter of timing. Each bridge is certain to need preservation, improvement, or replacement work at some point in the future, so the main question is "when?" In the life cycle cost analysis, it is assumed that either some sort of work is planned by the engineer during the program period, or the software generates a long-term set of work immediately following the end of the program period. A graphical representation of this is given in the Candidate Pane of the Dashboard worksheet.



Candidates									
Total LCC $k	2003	2004	2005	2006	2007	2008	2009	2010	2011
Do nothing	256	256	256	256	256	256	256	256	256
Auto MRR&I	188	218	233	246	308	317	325	331	348
Auto replace	213	230	234	238	241	244	247	249	251
Custom 4	--	--	--	--	--	--	--	--	--
Custom 5	--	--	--	--	--	--	--	--	--
Custom 6	--	--	--	--	--	--	--	--	--

The best way to see the effect of timing is to select Total LCC (above) or Total Benefit (below) from the **Timing pick list**. These graphs actually show the same information, except Total Benefit subtracts life cycle cost from the Do Nothing life cycle cost, making the differences easier to see.



Candidates									
Total Ben $k	2003	2004	2005	2006	2007	2008	2009	2010	2011
Do nothing	0	0	0	0	0	0	0	0	0
Auto MRR&I	69	38	24	10	-51	-61	-69	-75	-92
Auto replace	44	26	22	19	15	12	9	7	5
Custom 4	--	--	--	--	--	--	--	--	--
Custom 5	--	--	--	--	--	--	--	--	--
Custom 6	--	--	--	--	--	--	--	--	--

As a bridge deteriorates, its needs increase. If work is postponed, therefore, the initial cost of the work, and the advanced deterioration risk before the work is done, cause increasing life cycle cost. If a bridge has functional deficiencies, user costs will continue to be incurred, at a growing rate because of traffic growth. Offsetting this, the initial cost and long-term cost are discounted by a greater amount, thus reducing life cycle cost. Usually (but not always) the effect of deterioration and traffic growth are larger, and life cycle costs increase as the work is delayed.

In the graphs shown above, Auto MRR&I has a lower life cycle cost than Do Nothing in 2003-2006, so it is an economical solution in that time frame. Auto Replace begins to have a lower life cycle cost than either Auto MRR&I or Do Nothing starting in 2006 and continuing to the end of the program period.

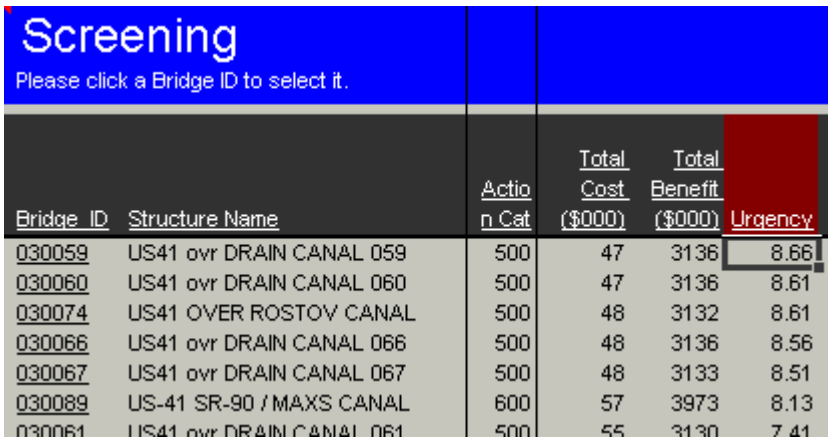
What this tells you is that this bridge has a good preventive maintenance opportunity, but only if the work is done by 2005. After that, the preventive maintenance opportunity is gone and replacement becomes the best approach.

Navigating to Other Structures

You will want to use the project-level analysis tool to scan through a group of bridges to see their economic health at a glance and compare one bridge with others. The software makes it easy to do this. All the tools you will need are clustered around the Bridge ID in the upper left corner of the Dashboard.

This area of the Dashboard shows the Bridge ID in the large box. Above it are the district (and owner and custodian, if not FDOT) and county. Below it are the structure name; structure type; year built (and year reconstructed, if applicable); route, milepost, and parallel structure designation; functional class; and total traffic and growth rate (combining roadways on and under the bridge). All of these help you to positively identify the structure.

You can visit any other bridge in the inventory (provided you have access rights to do so) by **typing its Bridge ID in the big box**, then pressing the Enter key.



Bridge ID	Structure Name	Action Cat	Total Cost ($000)	Total Benefit ($000)	Urgency
030059	US41 ovr DRAIN CANAL 059	500	47	3136	8.66
030060	US41 ovr DRAIN CANAL 060	500	47	3136	8.61
030074	US41 OVER ROSTOV CANAL	500	48	3132	8.61
030066	US41 ovr DRAIN CANAL 066	500	48	3136	8.56
030067	US41 ovr DRAIN CANAL 067	500	48	3133	8.51
030089	US-41 SR-90 / MAXS CANAL	600	57	3973	8.13
030061	US41 ovr DRAIN CANAL 061	500	55	3130	7.41

To help you navigate among bridges in a group, the software maintains a listing of bridges. You can select from this list by clicking the **Menu button**. A list of bridges is presented, allowing you to select one merely by clicking its Bridge ID. You will learn more about the capabilities of this menu in the next lesson.

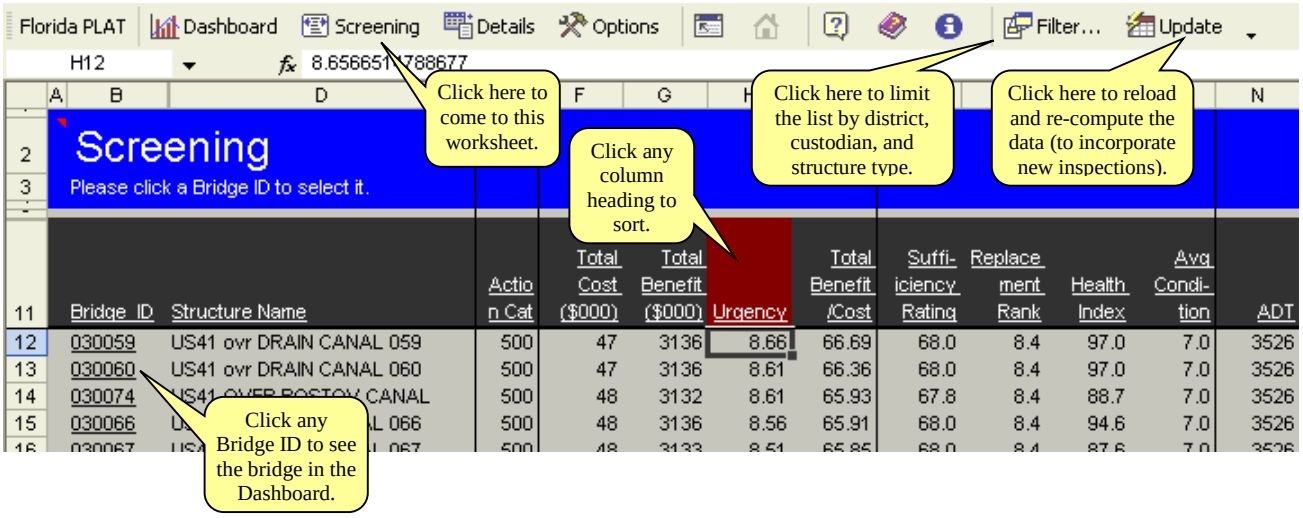
You can visit bridges in the order given in the menu, by clicking the **up or down arrow buttons**. This is the handiest way to quickly leaf through a list of structures. If you want to visit a bridge that is not in the list, you can still type its ID in the box.

You may want to compare a set of bridges that are not near each other in the menu. To do this, first visit each bridge by typing its Bridge ID in the large box, or using the Menu button to select it. Then click the **left and right arrow buttons** to move backward or ahead among the bridges you have just visited. The software maintains an internal list of the 100 bridges you have most recently visited since you opened the file.

Screening Structures

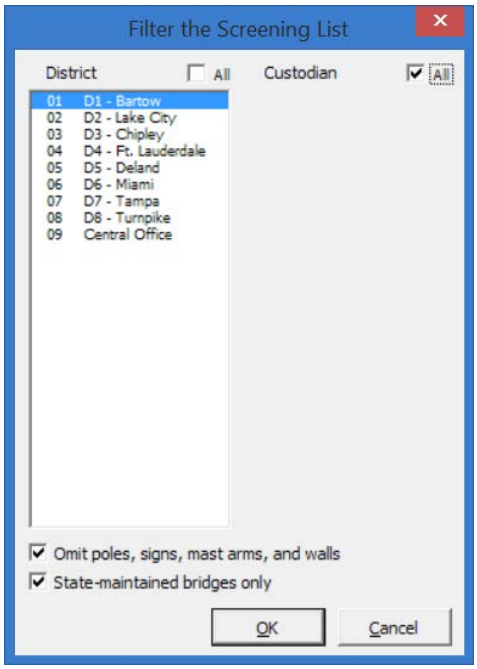
When you click the **Menu button** on the Dashboard, or the **Screening button** on the toolbar, you find a worksheet with powerful features for sorting and selecting structures. The Screening worksheet presents a list of structures, with identification and performance information. You can sort the list merely by **clicking a column heading**. For example, the list in the example below is sorted in descending order by Urgency (most urgent first). Click the column heading again to reverse the order.

Then **click any Bridge ID** in the list to see that bridge in the Dashboard.



A wide variety of data and performance measures are provided to help you with navigation. For example, Action Category (e.g. 600=replacement, 500=functional improvement, etc.) characterizes the candidate with lowest life cycle cost on each bridge; Urgency describes the improvement in life cycle cost if work is done in the first year rather than the second; and Health Index is a weighted average condition measure for the elements on the bridge, projected to today from the most recent inspection. See Screening Worksheet for more information about the contents.

Whenever you visit this worksheet, the toolbar extends to add two new buttons, Filter and Update. Use the **Filter button** to decide which bridges to show in the list. The example at right shows District 1 with all state-maintained structures, omitting poles, signs, mast arms, and walls. When you click the **OK button**, the software loads the bridges you requested into the list, and re-computes all the performance indicators. If you click **Cancel**, the filter settings are not changed and the data are not reloaded or re-calculated. (For example, you might do this just to see the current filter settings.)

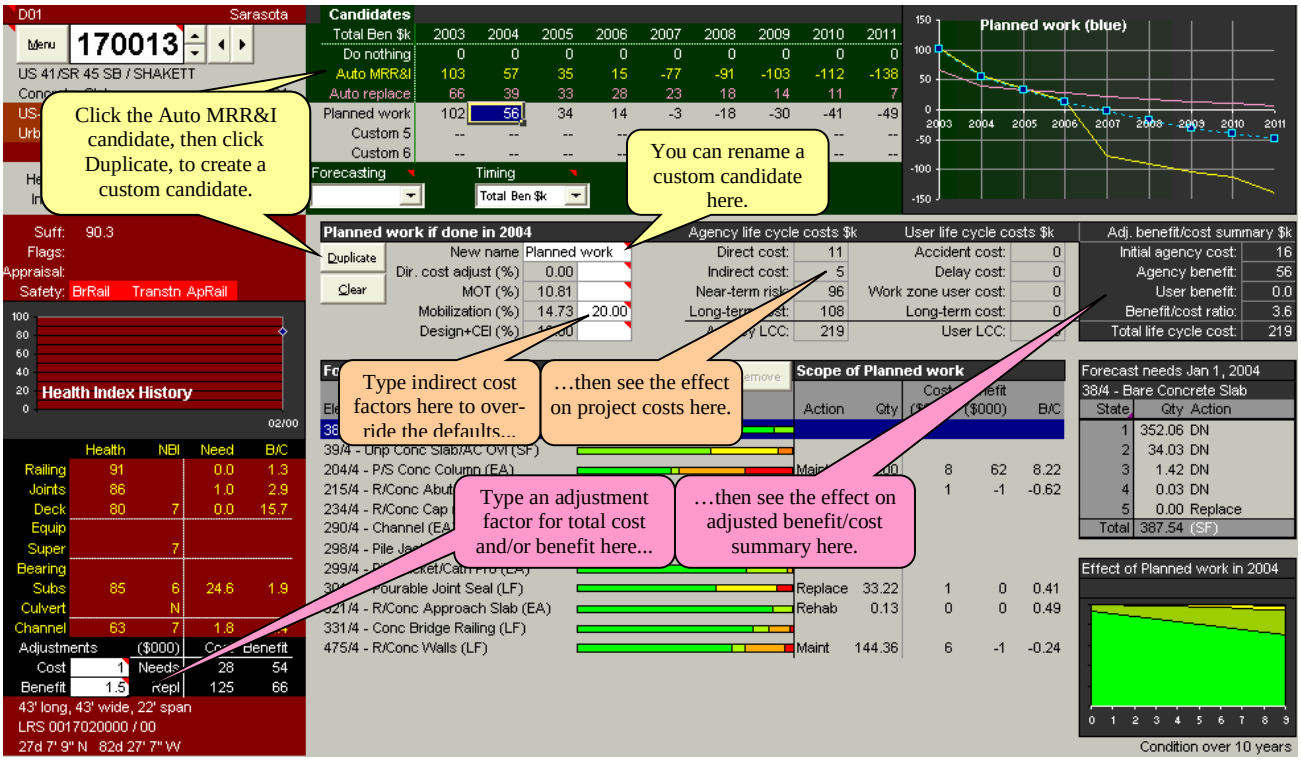


If you want to update the screening list without changing the filter settings, just click **Update** on the toolbar. Even if you never change the filter, you should click Update occasionally (e.g. daily or weekly) just to make sure you have the most recent inspection results. When you first visit the Screening worksheet after launching the project level analysis tool, the software asks you if you want to update now. This could take a minute or two depending on the number of bridges you want to see.

Customizing Candidates – Cost Factors

You can use the project level analysis tool to investigate alternative definitions of any project. For consistency, you will normally want to use the system's outcome prediction (e.g. deterioration, element-level preservation costs, and user costs) models as provided, without changing these inputs from one bridge to another. However, you may well want to change the initial costs or total benefits to reflect factors known to you but outside the domain of the analytical models. For example, a bridge with lead paint would have greater mobilization costs and greater overall costs than other bridges.

To customize the indirect costs or scope of work on a bridge, you must first create a Custom Candidate. You do this by first **clicking anywhere in the Auto MRR&I row** of the Candidate Pane (or on any existing Custom Candidate), then clicking the **Duplicate button**, as indicated with the yellow balloons in the example below. Your new candidate will be added to the table and graph as shown. Then **click in the row** of your new Custom Candidate if you want to modify it.



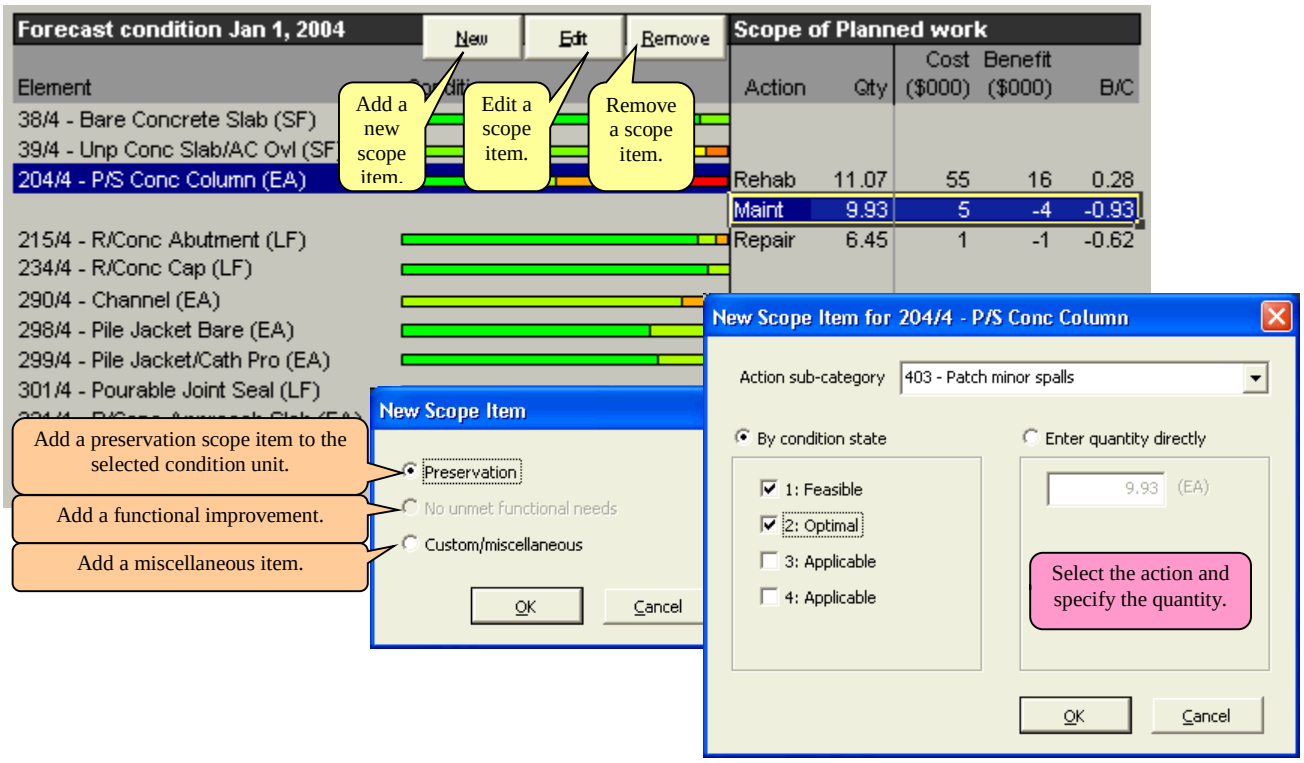
The project level models provide default indirect cost factors, but you can over-ride them by simply **typing a new value**. The resulting indirect cost is immediately shown (orange balloons in the example). This number is then used in all subsequent calculations of initial cost, life cycle cost, and benefit/cost ratio.

Another possible adjustment can be applied to the total cost and benefit of all candidates (not just Custom Candidates) on the bridge, by **typing adjustment factors** in the white boxes near the bottom of the Bridge Pane. These factors affect only the results reported in the dark gray section at the right of the Candidate Details Pane.

Customizing Candidates – Scope Items

After you have created a Custom Candidate (see preceding lesson), you can modify its scope, by making changes in the Scope Pane. You can add new scope items, change the action and/or quantity of an existing preservation scope item, or remove a scope item. The yellow balloons in the example below show the **buttons** for these purposes. First click the scope item you want to change, then click the button.

The Scope Pane always shows at least one row for each element, even when there are no scope items. An element may have more than one scope item, as is the case for element 204 in the example below.



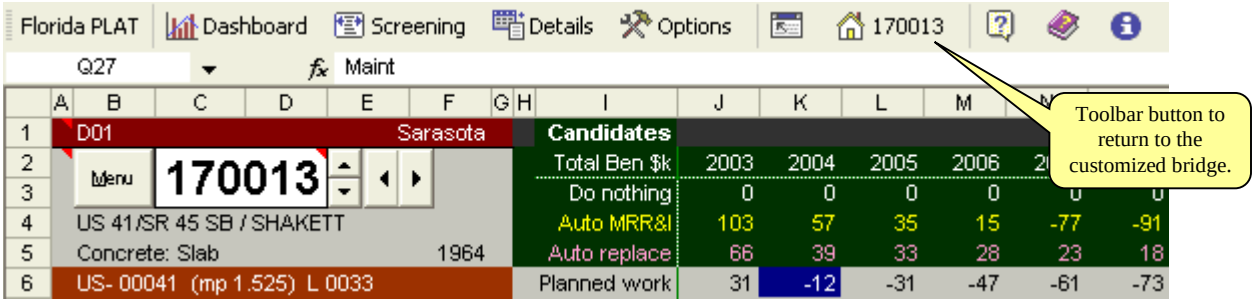
When you click the **New button** to add a scope item, you can choose the type of item to add. If you choose Preservation, the software will add a new preservation scope item to the element you have selected. The dialog for this purpose (far right) lets you select from the feasible actions, and specify a quantity by either clicking condition states, or typing the quantity directly.

If the bridge has any functional deficiencies, you can add a Functional Improvement scope item. This choice is disabled (as in the example) if there are no functional needs.

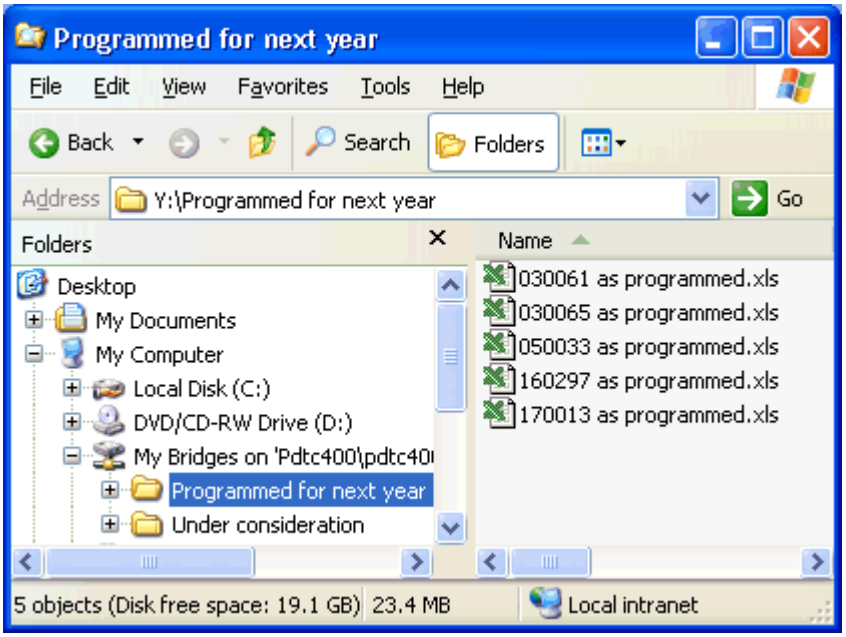
You can also add your own custom scope items that are not otherwise defined in the software. For each of these, you provide a name, cost, and benefit that are added directly to the project totals. For example, a bridge rehabilitation that includes repair of decorative portals might warrant a separate scope item for this.

Managing Customized Structures

When you use any of the customization features on a bridge, the information you enter is stored in an Excel workbook file. Each file can store the customizations for one bridge. The toolbar shows which bridge was customized, so you can return to that bridge with one click even if you have subsequently visited many other bridges.



If you customize a lot of bridges, you may want to create a directory on your hard drive to store them all. You can use the directory structure of Windows to separate different types of customizations. Each Excel workbook file should have a name that includes the Bridge ID, as in the example below. Use Excel's Save As feature to set the location and name of a file.



Viewing Computation Details

Every time you visit a bridge on the Dashboard, the software conducts a full life cycle cost analysis. Most of the time, the Dashboard shows all the results you will need. However, if you need more detail about any aspect of the computation, or if you just want to see a complete worked example of the analysis, click the **Details button** on the toolbar. The example below has most of the rows hidden so you can see the major headings within the worksheet.

Florida PLAT | Dashboard | Screening | Details | Options | 170013

U1326

Computation Detail for Project-Level Analysis

Analyzed on 11-18-2002 at 12:46:00
Based on 2000 inspection

Bridge 170013

US 41/SR 45 SB / SHAKETT

Candidate: Auto MRR&I in 2005

JUSTIFICATION PHASE: REPLACEMENT and FUNCTIONAL IMPROVEMENTS

JUSTIFICATION PHASE: NETWORK-LEVEL INPUTS and DETERIORATION OF ELEMENTS

SCOPING/COSTING PHASE: SCALE FEASIBILITY

SCOPING/COSTING PHASE: AUTO MRR&I CANDIDATE IN YEAR 2005

OUTPUT PREDICTION

CONSEQUENCE PHASE: PERFORMANCE BEFORE AND AFTER IMPLEMENTATION

CONSEQUENCE PHASE: FINAL SUMMARY STATISTICS

PREDICTED PERFORMANCE MEASURES

Year	HealthIx	PresNeed	Pres B/C	Acc Risk	UserCost
Base 2002	80.79	27,553	0.95	0.0000	0
2003	78.91	37,428	1.01	0.0000	0
2004	77.07	47,752	1.04	0.0000	0
2005	83.46	20,478	0.60	0.0000	0
2006	81.73	28,727	0.64	0.0000	0
2007	79.98	38,192	0.68	0.0000	0
2008	78.25	48,623	0.70	0.0000	0
2009	76.55	59,798	0.72	0.0000	0
2010	74.87	71,519	0.73	0.0000	0
2011	73.23	83,621	0.73	0.0000	0

Preservation data are shown at the end of the indicated year.
HealthIx = Health index of the bridge.
PresNeed = Total agency cost of the Pontis optimal actions summed over all elements (using network-level variable and fixed costs).
Pres B/C = Benefit/cost ratio of the Pontis optimal actions summed over all elements.
Functional deficiency data are totals for the indicated year.
Acc Risk = Number of excess accidents predicted because of a roadway width deficiency.
UserCost = Total of accident risk and truck detour user costs.

Highest action category	Replace	The most significant action category in this candidate project
Ending health index	73.23	Forecast for the end of the program horizon (end of 2011)

DIRECT AND INDIRECT COST FACTORS

Direct cost adjustment	0.000	Fraction of direct cost of preservation; default = 0.000
Maint of traffic	0.121	Fraction of adjusted direct cost of preservation; default = 0.121
Mobilization	0.143	Fraction of adjusted direct cost of preservation; default = 0.143
Engineering	0.100	Fraction of adjusted direct cost of preservation; default = 0.100

Note: Functional improvements, replacement, and custom scope items are treated as entirely direct costs.

AGENCY LIFE CYCLE COSTS

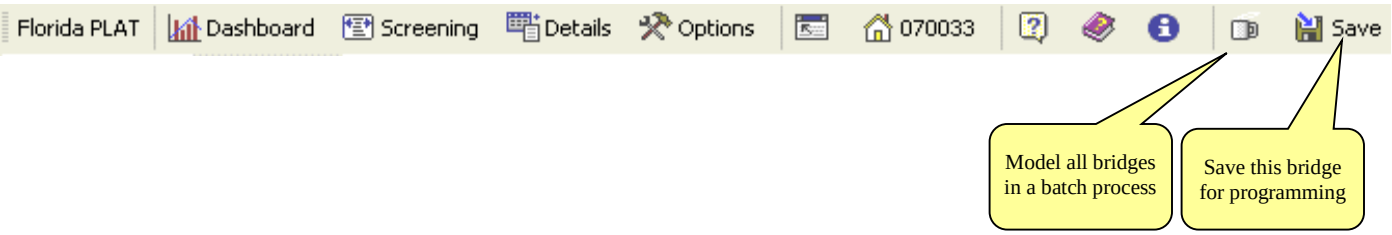
Direct cost ($)	7,628	Summed over all scope items, does not include preservation indirect costs (before discounting)
Indirect cost ($)	2,775	Computed based on preservation direct costs using the adjustments above (before discounting)
Near-term risk ($)	111,348	Failure risk in the years before an action is taken, using Pontis failure costs and probabilities, discounted
Long-term cost ($)	111,427	Residual life-cycle cost after the project, accounting for the probabilities of subsequent projects, discounted
Agency life-cycle cost ($)	232,763	Total of the life-cycle costs in this section, including discounted direct and indirect costs

Note: Discounted costs are present value (2002) using a real discount rate of 0.35000

USER LIFE CYCLE COSTS

Saving Results for Programming

A separate Excel model, the Network Analysis Tool (NAT) is available to develop programs and budgets using the results of the PLAT. You can send your PLAT results to the NAT by using the right-most toolbar buttons on the Dashboard (below).



The Batch Process button loads every bridge listed on the Screening worksheet, analyzes it using the PLAT models, then saves the results in the PLAT Results Database. This database is a Microsoft Access file separate from your BrM database. This process can take awhile, possibly six hours or more if you analyze the entire inventory. Fortunately, this is something you would normally do only once a year.

If you make changes to an individual bridge, such as adding custom candidates, and want those changes reflected immediately in the programming and budgeting analysis, click the Save button. This action writes the project information to the PLAT Results database, but does not save the Excel file on your hard drive. Use Excel's Save command to save the PLAT Excel file on your hard drive.

The toolbar buttons are not available if your PLAT workstation is not configured for access to the PLAT Results Database.

Worksheet Reference

The project level analysis tool consists of an Excel workbook file, containing 15 worksheets. Three of these worksheets are intended for use by the majority of users, while the rest provide storage for data in the background.

Presentation worksheets accessible from the toolbar:

- Dashboard
- Screening
- Trace (Computation Details)

Raw bridge data worksheets:

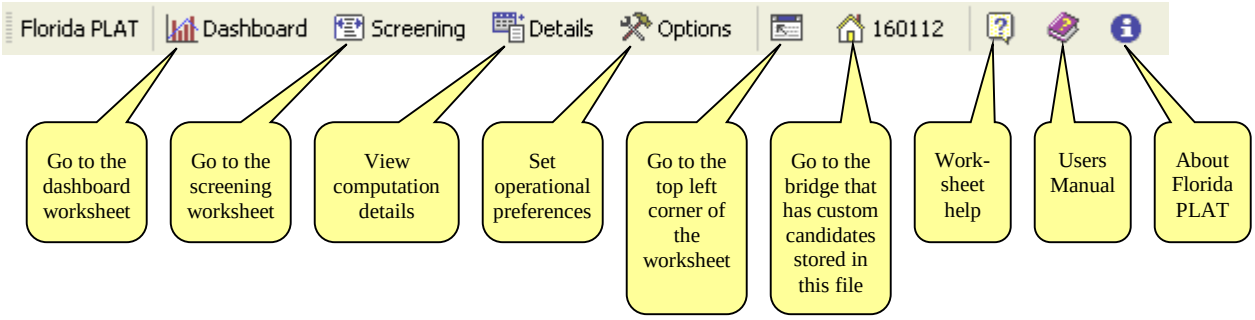
- Inventory
- Movable Bridge Model
- Candidates
- Scope Items

Definition and model worksheets:

- Element Definitions and Models
- Action Definitions and Models
- Action Sub-Categories
- Model Parameters
- Risk Parameters
- Code Tables

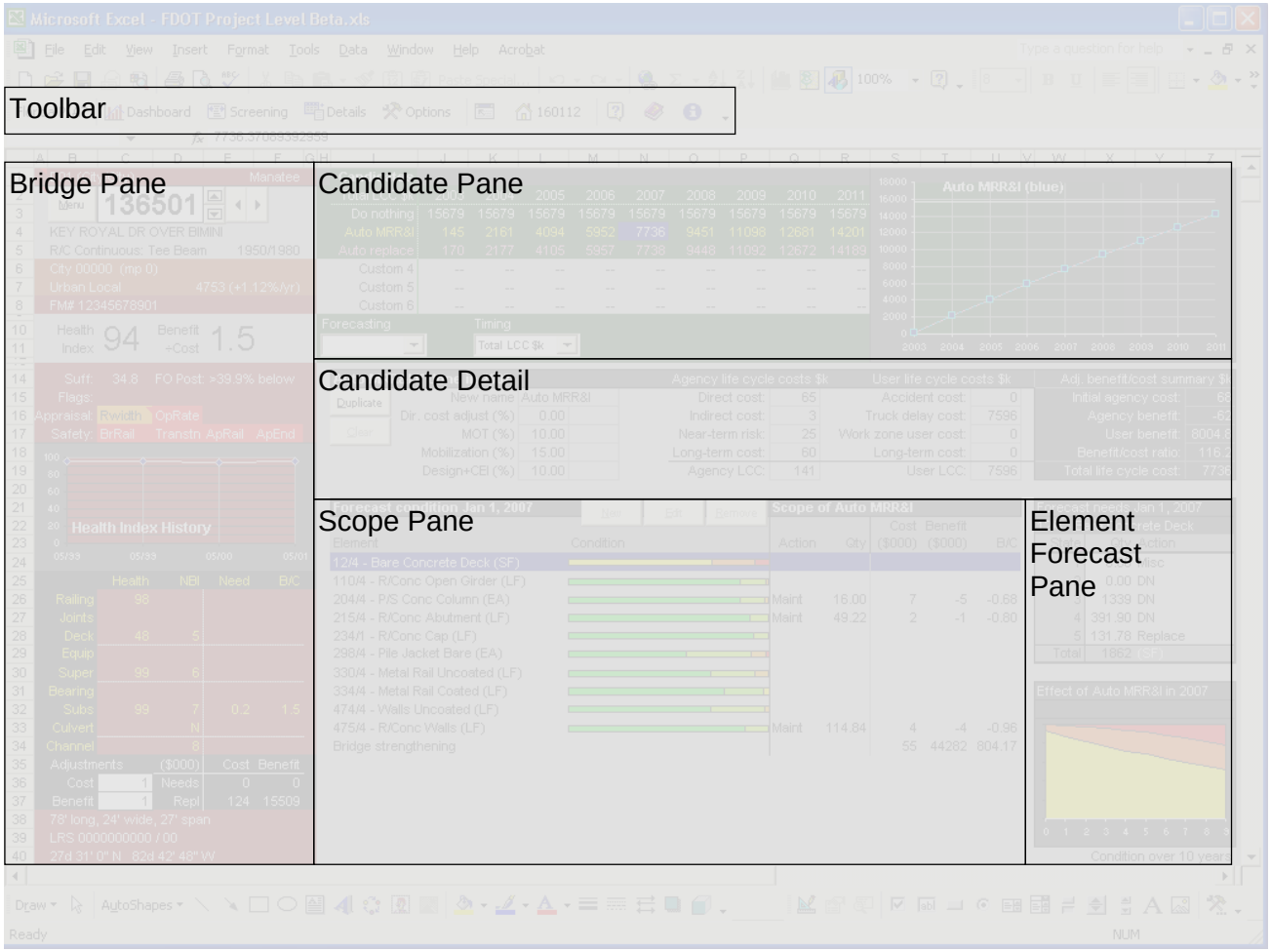
Configuration worksheet

One additional worksheet, Sensitivity, is for internal use by the software. Most of the time you will navigate through the system using the toolbar, which looks like this:



The toolbar may be found on the Add-Ins ribbon. Most of the worksheets in the file are hidden, by turning off the Excel worksheet tabs, since most users will not need them. However, if you do need access to any but the first three worksheets in the above list, you can activate the Excel worksheet tabs by clicking the Options button on the toolbar. This presents a window with configuration options governing the behavior of the software. If you check the first box (Advanced) and click OK, the Excel worksheet tabs will appear. You can follow the same procedure again to turn the tabs off.

Dashboard



The dashboard provides most of the controls and outputs of the system in one convenient layout. This makes it quick and easy to flip among bridges, or within a bridge among candidates and scope items. The diagram above shows the sections of the Dashboard worksheet, which are:

Toolbar – A set of buttons with which you can navigate among the main worksheets, and access other important items of functionality. In Excel 2007 and later this is part of the Add-Ins ribbon.

Bridge Pane – Inventory, appraisal, and condition data; and current needs on the bridge.

Candidate Pane – A table comparing candidates and implementation years. Various forecasting and timing results can be displayed in the table and the accompanying graph.

Candidate Detail –Performance measures about a selected candidate and implementation year.

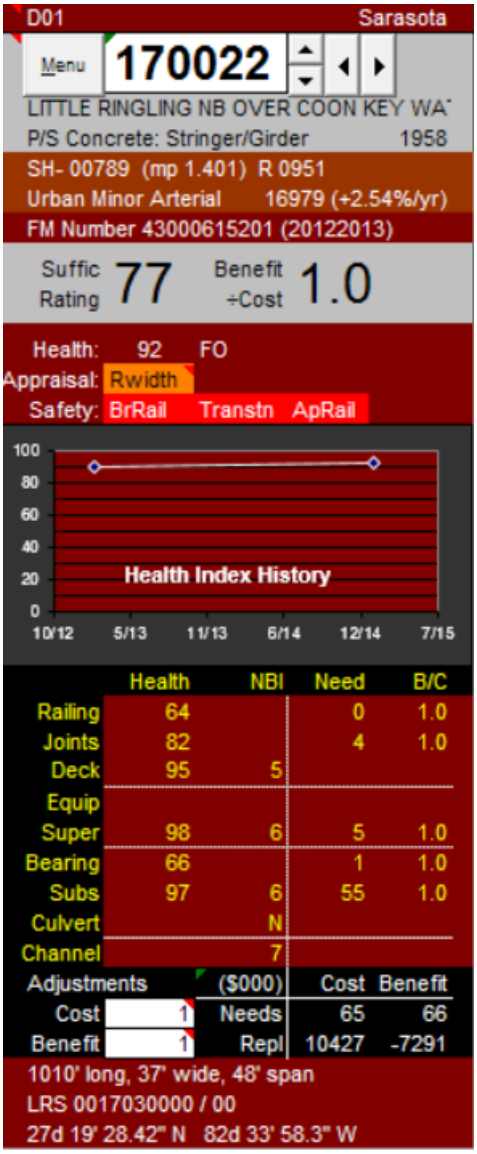
Scope Pane –Individual items of work within a selected candidate in the selected implementation year.

Element Forecast Pane – A table and graph showing the predicted condition of one element selected in the Scope Pane.

Risk Pane – A table located to the right of the Dashboard, reporting on all types of risks.

Also within the Dashboard are buttons to manage custom candidates and scope items. Click a link in the list for more information about the contents of each section of the Dashboard worksheet.

Bridge Pane



The Bridge Pane of the Dashboard is designed to allow you to quickly browse through a list of bridges to find the ones needing attention. It briefly summarizes the major identification information about the bridge as follows.

Row 1. The left side shows the district in which the bridge is located. If the bridge is not owned or maintained by FDOT, then abbreviations for the NBI owner or custodian categories (items 21 and 22) are shown also. The right side shows the county where the bridge is located.

Rows 2 and 3. Here is shown the bridge_id and buttons for navigating to other bridges. The **Menu button** brings up the Screening worksheet, presenting a prioritized list of bridges from which you may select. The **up and down arrow buttons** allow you to go from one bridge to another in the order given in the Screening worksheet. You may also select a bridge by typing its bridge_id in the box. As you visit a series of bridges, the software behind the scenes maintains a list of bridges visited. The **left and right arrow** buttons allow you to navigate through this list in the order visited. This makes it possible, for example, to compare any two or more bridges by switching back and forth among them, even if they are not adjacent to each other in the Screening list.

Row 4 is the bridge strucname. In the FDOT inventory this usually is a combination of the facility carried and feature intersected.

Row 5 gives the structure type of the main span (NBI 43) and the year built (NBI 27). If the bridge was reconstructed, the year built includes a slash mark and the year reconstructed.

Row 6 describes the bridge location along a principal route (roadway-on). It is a combination of NBI items 5, 11 (milepost), 101 (left/right parallel structure), and the parallel bridge sequence number.

Row 7 gives the functional class of the roadway on the structure and the total traffic volume of all routes on and under the bridge. The average traffic growth rate is in parentheses. Traffic volume is estimated as of the current system date based on the past and future traffic counts given in the inventory.

Row 8 shows the financial management system ID number and year, if the bridge is listed in that system.

Rows 10 and 11 emphasize the current condition of the bridge. Sufficiency Rating describes overall physical condition and functional adequacy, while Benefit/Cost describes the priority of current MR&R needs. A high sufficiency rating with high benefit/cost ratio indicates a bridge in good condition where there are attractive preventive maintenance opportunities. A bridge with low sufficiency rating and low benefit/cost ratio indicates that, even though the bridge is in worse condition, it can be allowed to deteriorate further without a large escalation in needs.

All condition and needs information (except NBI data) on the Control Panel are projected to the current date using the deterioration model. This means the information will be different from the most recent inspection if the inspection was conducted more than a year earlier.

Row 14 gives the forecast health index at the beginning of the analysis period using the deterioration model. If the bridge is functionally obsolete or structurally deficient according to NBI criteria, this is indicated, along with the posting status.

Flags. Rows 15-16 in the bridge pane present "flags", the method of notifying you of functional deficiencies. The color reflects the severity of the flag, with red the worst. If you hold the mouse arrow over a flag, a pop-up window shows more information about it. The following list shows the types of flags that may appear:

Row 15: Appraisal flags. These appear if there is a functional deficiency, or a low NBI appraisal value for any of the following:

Roadway width
Operating Rating
Vertical Clearance
Underclearance appraisal (NBI 69)
Waterway adequacy (NBI 71)
Approach alignment (NBI 72)

Row 16: Safety features. These flags show the four parts of NBI item 36.

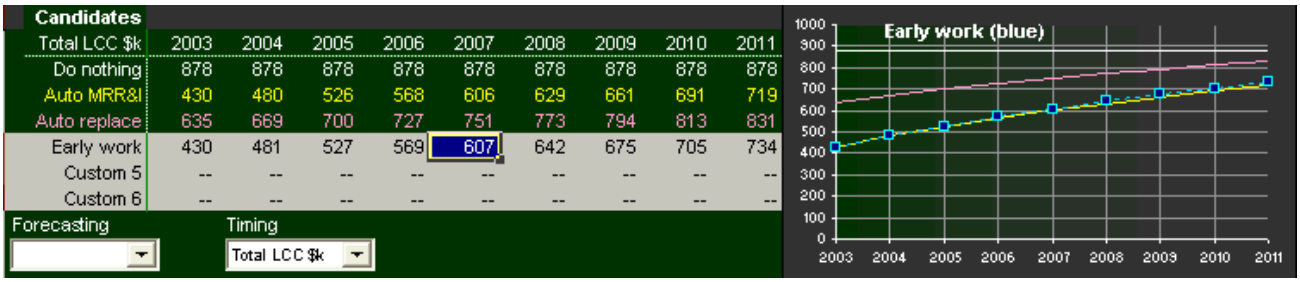
History. The graph in rows 17-24 shows historical condition of the bridge, using the Health Index.

Element category condition. Rows 25-34 present a table showing current conditions and needs by element category. The Health Index and NBI condition rating (NBI 58, 59, 60, and 62) are shown whenever available. The cost and benefit/cost ratio of needs are given based on the life cycle cost model. This gives an initial idea of the size and urgency of MR&R needs.

Cost and benefit of needs. Rows 35-37 provide the total cost and benefit of needs. You can provide an adjustment factor for costs and benefits, to reflect unique attributes of the bridge that would cause its costs and/or benefits to be higher or lower than normal. In the case of costs, this could be heavy traffic, poor access, or lead paint, for example. The adjustments are used for all Candidate total cost and benefit calculations, the rightmost column in the Candidate Detail Pane.

Miscellaneous geometry and location. Rows 38-40 provide some useful information on geometry and location of the structure.

Candidate Pane



The Candidate Pane of the Dashboard worksheet addresses two major issues in project-level analysis:

- Deciding on a general scoping approach, such as deciding whether to completely replace a bridge, to address all the needs individually, to address just certain types of needs, or do nothing at all.
- Deciding on the timing of work. Because needs change over time due to deterioration and traffic growth, the timing also affects the scope of certain kinds of projects.

Since the two decisions are linked, the Candidate Pane presents the alternatives in a two-dimensional format allowing you to see the full range of choices at once. The project level analysis tool generates three automatic candidates (graph colors shown in parentheses):

- Do Nothing (white) - no action in any year of the planning period;
- Auto MRR&I (yellow) - do a reasonable set of actions in response to all maintenance, repair, rehabilitation, and improvement needs on the bridge, in one year of the period (a separate life cycle activity profile is generated for each of 9 possible implementation years);
- Auto Replace (pink) - replace the bridge in one year (again a separate definition for each of the 9 years).

In addition, you may create up to three Custom Candidates, and analyze each one in any implementation year. “Early work” is a Custom Candidate in the example above; it is selected in the table and shown in blue in the chart. Any time you move to a different bridge, change any of the model inputs, or modify the scope of a Custom Candidate, the table and graph update themselves automatically.

You choose what data item is tabulated and plotted by selecting a performance measure from either the **Forecasting pick list** or the **Timing pick list**. Any time you select from one of these, the other one is cleared. If you choose from the Timing pick list, the years in the program horizon are treated as alternative implementation years. Scope, costs, and benefits can vary depending on the year in which the Candidate is implemented. If you choose from the Forecast pick list, the years describe a time series of future values of the performance measure, for the candidate and year you select.

To select a candidate and implementation year, simply **click any cell in the table**. Dark blue shading indicates which cell is selected (Early work in 2007, in the example above). The software automatically updates the table and graph (if a forecasting performance measure was selected), as well as the Candidate Details, Scope Pane, and Element Forecast. In the graph, blue boxes highlight the selected candidate. You can “animate” the deterioration of elements and the change in scope over time by using the arrow keys to move the selection left and right through the table.

Candidate Details

Early work if done in 2022				Agency life cycle costs $k		User life cycle costs $k		Adj. benefit/cost summary $k	
Duplicate	New name	Early work		Direct cost:	7346	Accident cost:	496	Initial agency cost:	7359
	Dir. $ adjust (%)	0.00		Indirect cost:	13	Delay cost:	93	Agency benefit:	-5681
Clear	MOT (%)	2.99		Agency risk cost:	816	Movable bridge cost:	0	User benefit:	2000
	Mobilization (%)	19.13		Long-term cost:	326	Long-term cost:	13	Benefit/cost ratio:	-0.5
	Design+CEI (%)	0.11		Agency LCC:	6912	User LCC:	602	Total life cycle cost:	7514

The Candidate Details Pane of the Dashboard worksheet provides a set of performance measures for a selected candidate and implementation year. The example above is for a Custom Candidate called "Early work" if implemented in 2022. Its detailed results are as follows:

New name – You can rename a Custom Candidate by typing the new name in this box. Automatic candidates cannot be renamed.

Direct cost adjustment – This factor is a positive or negative percent adjustment applied to direct preservation costs, before any of the indirect cost factors are applied. It can be modified by typing a new value in the white box, only in Custom Candidates.

Maintenance of traffic; Mobilization; and Design, construction engineering, and inspection – These are positive cost factors, in percent, applied to adjusted direct cost of preservation scope items. They can be modified by typing new values in the white boxes, only in Custom Candidates.

Direct cost – The sum of all direct costs, including preservation, functional improvement, replacement, and miscellaneous scope items, not discounted, in thousands of dollars.

Indirect cost – The sum of maintenance of traffic, mobilization, and design + CEI, not discounted, in thousands. Note that replacement, functional improvements, and miscellaneous scope items do not contribute to this total, but are included entirely in the direct cost number.

Agency risk cost – The total discounted risk due to natural and man-made hazards, in thousands.

Long-term cost – Discounted present value of all preservation costs beyond the end of the 10-year hiatus (or beyond the program period for Do Nothing), in thousands.

Agency life cycle cost – Sum of the numbers above it, this is the total life cycle cost incurred by the agency, in thousands. All of the numbers are discounted for this calculation.

Accident cost – Discounted user cost, in thousands, due to excess accident risk. This is non-zero, as in the example, if the bridge has a roadway width deficiency either on or under the bridge.

Delay cost – Discounted user cost, in thousands, due to traffic delays from impaired vertical clearance, insufficient operating rating, and/or moveable bridge openings. User cost associated with risk is also included.

Movable Bridge Cost – the delay to road users due to movable bridge openings.

Long-term cost – Discounted present value of a perpetuity of user costs starting after the end of the program period, if the candidate does not remedy all functional deficiencies on the bridge. The calculation assumes that there is no further traffic growth, and caps the result at discounted replacement cost of the bridge.

User life cycle cost – Sum of the numbers above it, this is the total life cycle cost incurred by road users.

Initial agency cost – Sum of direct and indirect costs, in thousands, not discounted.

Agency benefit – Agency LCC of the Do Nothing candidate, minus Agency LCC of the subject candidate, in thousands.

User benefit – User LCC of the Do Nothing candidate, minus User LCC of the subject candidate, in thousands.

Benefit/cost ratio – The sum of Agency benefit and User benefit, divided by Initial agency cost. Any result greater than zero indicates a desirable candidate, as in the example.

Total life cycle cost – The sum of Agency LCC and User LCC, in thousands.

The two buttons on the left side of the pane are concerned with managing Custom Candidates:

Duplicate – Make a copy of the currently-selected candidate, and put it into one of the Custom Candidate slots. This is available only if Auto MRR&I or a Custom Candidate are selected.

Clear – Remove the current Custom Candidate from its slot. This is available only if a Custom Candidate is selected.

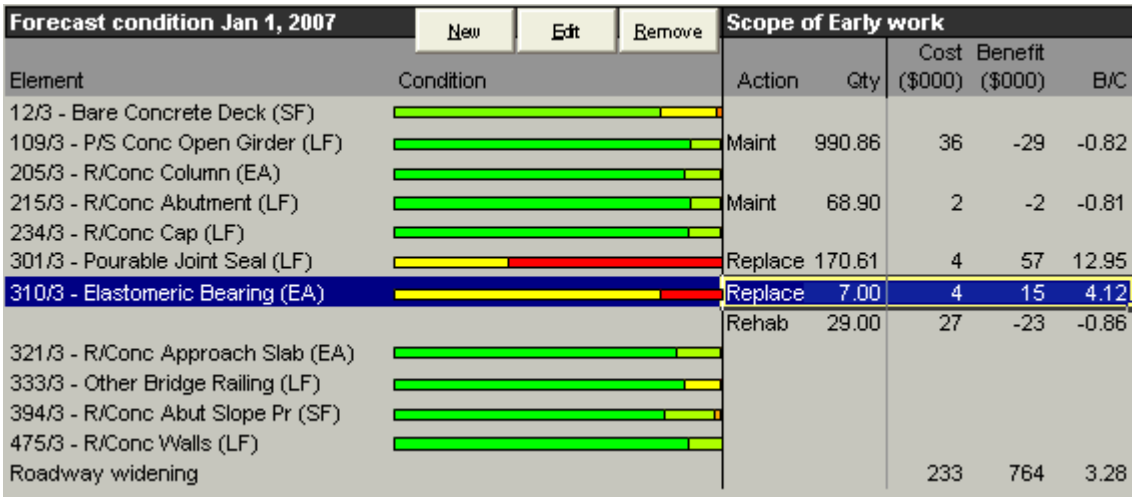
See Managing Candidates for more information on Custom Candidates.

A breakdown of hazard-related costs from the risk analysis can be found to the right of the Dashboard.

Risk analysis for structure '010076' in 2014

	Hurricane	Tornado	Wildfire	Flood	Vessel	Height	Weight	Crash	Decay	Fatigue	Total
Hazard prob (%)	8.45	0.62	15.31	1.00	0.00	0.00	0.00	0.31	1.45	0.00	27.13
Agency cost ($k)	0.02	0.01	0.05	0.00	0.00	0.00	0.00	0.02	21.83	0.00	21.93
…as % of repl cost	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.47
User cost ($k)	0.03	0.01	0.04	0.00	0.00	0.00	0.00	0.03	5.01	0.00	5.12
…minutes per car	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.09
Total risk ($k)	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.1	26.8	0.0	27.1

Scope Pane



The Scope Pane of the Dashboard worksheet lists the elements and functional deficiencies on the structure, and lists the scope items defined for each one in the currently-selected candidate and implementation year.

Each element is labeled with its element number and environment, followed by its name and measurement units for costing. It is possible that an element and environment could appear more than once in the list if it was inspected segmentally (e.g. a separate element inspection record for each span or structure unit), or for coating elements protecting more than one other element. The predicted condition at the beginning of the selected implementation year is shown as a bar graph with green as state 1 and red as state 4. You can see the information numerically by clicking one of the rows in the table and then looking at the Element Forecast Pane.

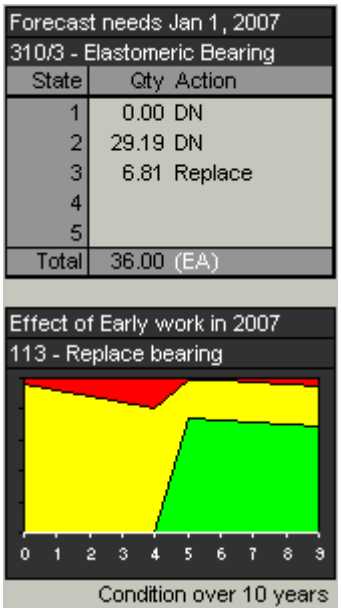
To the right of each element is a list of scope items, if any. This list shows the action category, quantity (in the element's US Customary units), cost (sum of variable and fixed costs), benefit (difference in long-term cost between the action and do-nothing), and benefit/cost ratio. To see more information about the action, click it and then look in the Element Forecast Pane. The sum of costs in this list will always agree with the Initial Agency Cost reported in the right-most column of the Candidate Details Pane. However, the benefit column is computed directly from element-level information and will not generally agree with the life cycle cost analysis reported in the Candidate Details Pane.

The example shows that it is common for a candidate to include scope items with negative benefit. This can happen if the project scope was expanded to include larger quantities than the life cycle cost optimum, as a way of avoiding further needs during the subsequent 10 years.

It is possible to have more than one scope item per element. In the example, the bridge has 36 elastomeric bearings, of which 7 are to be replaced and the remainder rehabbed.

Below the list of elements is a list of functional improvement and miscellaneous scope items. Functional improvements appear only if there are functional deficiencies to be corrected. The buttons at the top of the pane are for managing scope items in Custom Candidates. You can create a **new** scope item, **edit** an existing scope item, or **remove** a scope item, all by clicking a scope item in the list and then clicking one of the buttons. These buttons are active only if a Custom Candidate is selected.

Element Forecast



The Element Forecast pane on the Dashboard worksheet provides detailed information about one element and scope item selected in the Scope Pane.

The upper portion of the pane shows the predicted condition of the selected element at the beginning of the selected year, before the selected candidate is implemented. The action column is the action with lowest life cycle cost for each condition state.

The bottom portion is a graph of predicted condition over the entire program period, before and after the candidate is implemented. It is an area chart where the vertical axis ranges from 0 to 100% of the total element quantity. Year 0 is just before the first program year, and year 9 is at the end of the final program year. This example is the same one used for the Scope Pane, where 7 bearings were replaced and the rest were rehabbed in 2007.

Managing Candidates

The project level analysis tool allows you to create up to three Custom Candidates on the Dashboard. This is done by making a copy of another candidate, either Auto MRR&I or another Custom Candidate, in a particular implementation year. Custom candidates have the same scope items in every implementation year, but the life cycle cost analysis still varies depending on when the work is implemented. You would perform this analysis when the scope of work and initial cost are being firmed up for program development, and later when you want to see what effect a schedule change might have on a candidate that is already firmly scoped and costed.

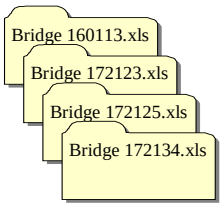
Each Excel file stores custom candidate data for one bridge. These data items include:

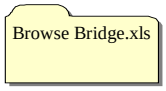
- Bridge cost and benefit adjustment factors (lines 36 and 37 of the Bridge Pane).
- Candidate name, direct cost adjustment, and indirect cost factors (Candidate Detail Pane).
- Scope item type, name, corresponding element or functional need, action sub-category, quantity, cost, and benefit (Scope Pane).

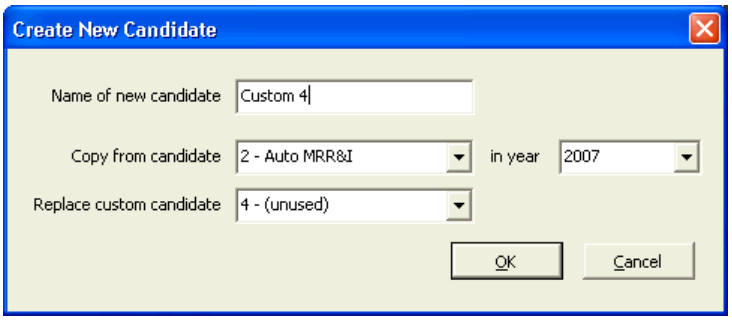
When you enter or change any of this information, the system stores it on the Candidates and Scope Items worksheets. You can then use the Dashboard to visit any other bridge without losing this information. The **Home button** on the toolbar indicates which bridge has custom data stored in the file: if you click it, you are returned to that bridge and the custom information is displayed. The Home button is dimmed if there is no custom candidate data in the file.

If you attempt to enter any custom data on a bridge, when a different bridge is already stored in the file, a warning message will appear asking whether you want to discard the custom data on the earlier bridge.

If you would like to permanently store your custom candidate data, it is recommended that you use the Excel Save As feature, and name the file in a way that identifies the bridge (e.g. use the Bridge ID in the file name). Use a different copy of the file, without a Bridge ID in its name, when you are merely browsing among bridges and not customizing them.







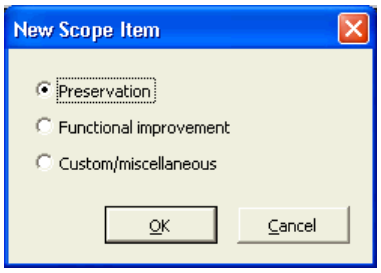
To create a new candidate, click the Auto MRR&I candidate or any Custom Candidate in the Candidate Pane, then click the **Duplicate button**. A dialog box (above right) lets you name the candidate; specify the candidate and year from which the scope items should be copied; and designate which of the three custom slots should receive the new candidate. If you already have three custom candidates, you will need to over-write one of them, since only three slots are available. Then click OK if you want to proceed.

To delete a Custom Candidate, click it in the Candidate Pane, then click the **Clear button**. The system will ask you to confirm before clearing the slot.

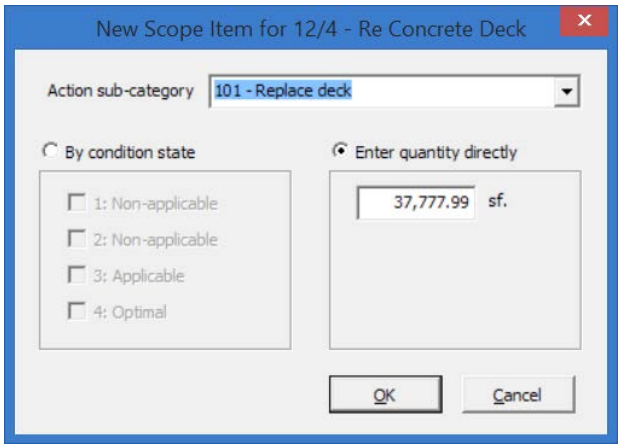
Managing Scope Items

The Dashboard has features to create, edit, and delete scope items in any Custom Candidate. You cannot modify the scope list in any of the Auto Candidates. If you would like to modify the Auto MRR&I candidate, first create a new Custom Candidate as a copy of it, then modify the custom candidate. Preservation scope items may be added to any element, even if it already has scope items. Functional scope items may be added for each functional deficiency present on the bridge, if a corresponding scope item is not already present (i.e., if you previously deleted one). You can add as many miscellaneous scope items as you like.

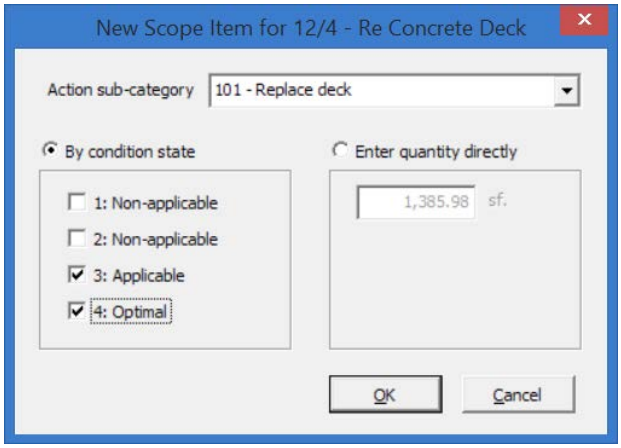
To add a preservation scope item, first click the element to which you would like to add it. Then, to add any kind of scope item, click the **New button**. The first dialog that appears, shown at right, asks what type of scope item you would like to create. The Preservation button may be dimmed if you did not first select an element. The Functional improvement button may be dimmed if all of the needed improvements are already provided in the candidate, or if there are no functional deficiencies on the bridge.



What you see next depends on which type of scope item you selected. If you chose a preservation scope item, the dialog shown at right appears. The Action sub-category pick list shows all the feasible actions defined for all condition states of the selected element. You must select one of these. Note that you cannot select do-nothing, but you can delete scope items as described below.

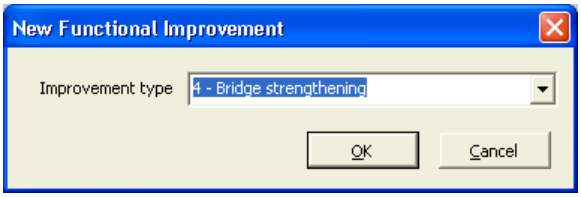


You can enter the quantity of work in the scope item directly, if you click the "Enter quantity directly" radio button as in the top example. Alternatively, you can click the "By condition state" radio button and then click the checkbox next to each condition state that you would like to include, as in the bottom example. The system then calculates the quantity automatically, and provides this in the box on the right. If you would like to see the quantity in each condition state, merely move the dialog box (if necessary) by dragging its title bar, so you can see the Dashboard's Element Forecast Pane underneath.

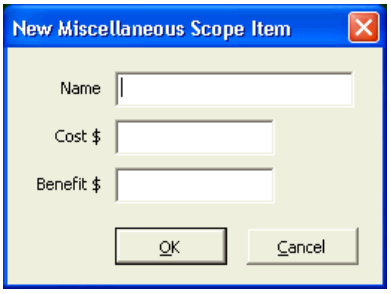


Next to each condition state checkbox on the left side of the dialog is an indication of the suitability of the selected action for that condition state. This may be Optimal, Feasible, Applicable, or Non-Applicable. This is for guidance only, as you are free to check any of the boxes or enter any quantity. The preservation output model works out the most appropriate life cycle cost behavior for any quantity you choose.

If you chose to add a functional improvement scope item, you will see the dialog box at right. The pick list contains all functional improvements that are needed on the bridge but not currently present in the candidate.



If you chose to add a miscellaneous scope item, you will see the dialog shown at right. You can enter any name for the item, and provide your own cost and benefit. The cost will be included in the "Direct cost" field of the Candidate Details Pane, and the benefit will be discounted (because of the future implementation year) and then included in the "Agency benefit" field.



To edit any scope item in a Custom Candidate, select it and then click the **Edit button**. The dialogs for editing are the same as those shown above for new scope items.

To delete a scope item, select it and then click the **Remove button**. Even if it has no scope items, every element on the bridge is always shown in the Scope Pane.

Screening

Screening

Please click a Bridge ID to select it.

Bridge ID	Structure Name	Custodian	District	Facility Carried	Feature Intersected
136501	KEY ROYAL DR OVER BIMINI	4	01	KEY ROYALE DRIVE	BIMINI BAY
164137	ROCKRIDGE RD OVER GATOR	2	01	ROCKRIDGE ROAD	GATOR CREEK
030059	US41 ovr DRAIN CANAL 059	1	01	US41	DRAINAGE CANAL 059

Action Cat	Total Cost ($000)	Urgency	Sufficiency Rating	Replacement Rank	Health Index	Avg Condition	Deck (58)	Super (59)	Sub (60)	Chan (61)	Culv (62)	Struc Eval (67)	Deck Geom (68)	Under Clr (69)	Posting (70)
500	65	31.17	34.8	5.0	94.1	6.5	5	6	7	8	N	4	2	N	0
600	84	9.41	38.2	5.7	87.7	6.8	7	6	7	7	N	4	4	N	0
500	47	8.66	68.0	8.4	97.0	7.0	7	7	7	7	N	6	4	N	5

Water Way (71)	Appr Align (72)	ADT	Grow Rate	Lanes	Byp Len	Total Benefit ($000)	Agency Benefit ($000)	User Benefit ($000)	Total Benefit /Cost	Agency Benefit /Cost	User Benefit /Cost	Main Sub-Cat	Total Re-coat	Deck Repl
7	7	543	0.61	1	24	615	-92	708	5.62	-0.84	6.47	503		Yes
7	7	11934	3.78	2	5	28	28	0	0.38	0.38	0	101		Yes
8	9	26686	0.87	2	19	1162	1162	0	2.48	2.48	0	403	Yes	

The Screening worksheet acts as a menu of bridges in a defined subset of the BrM inventory. You reach the worksheet by clicking the Menu button on the Dashboard, or by clicking the Screening button on the toolbar. The bridge currently selected on the Dashboard will also appear selected on the Screening list, if it is present there. When you click the up and down arrow buttons on the Dashboard, you will visit bridges in the same order as they are shown on the Screening list.

There is a lot of flexibility in how you use this list. You can:

- **Click a bridge ID** to go directly to that bridge on the Dashboard;
- **Click a column heading** to sort the list on that column; click it again to reverse the order;
- Click the **Filter button** on the toolbar to set filter conditions, to determine what bridges appear in the list;
- Click the **Update button** on the toolbar to reload the data from BrM and re-calculate all the results shown in the list;
- Use any functionality of Excel to manipulate and analyze the list;
- Add, move, or remove data items to be retrieved from the database whenever the list is updated.

The list can easily hold all of the more than 30,000 structures in the FDOT BrM inventory, though it takes a minute to load so many. Usually you will want to work with smaller groups, such as the state-maintained bridges in one district.

When you first visit the Screening worksheet, it will ask you if you want to update the list. If you click Yes, this reloads all the filtered bridges from BrM and computes an abbreviated form of the project-level analysis on all of them, to produce the numbers shown in the list. If you click No, the list will remain the same as the last time you used it, and it is possible that some of the information will be out-of-date if new inspections

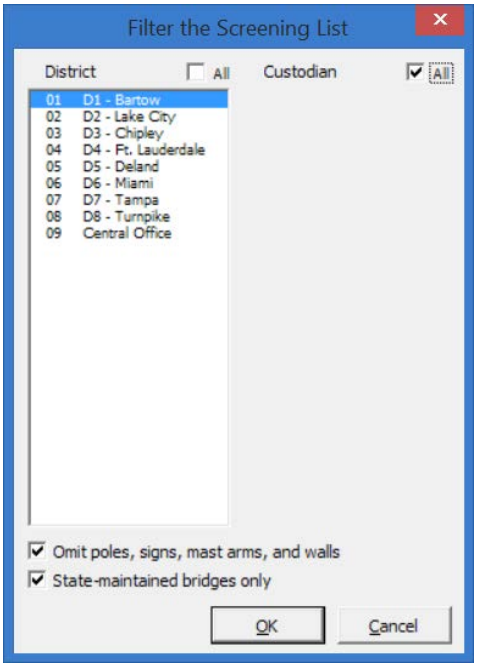
have occurred in the meantime. Information on the Dashboard, however, is always up-to-date with the BrM database, even if the Screening worksheet is not.

Above are shown the columns that are normally included in the list. Most of these are NBI data items and are self-explanatory. However, the software also provides a number of performance measures, computed by performing the project-level analysis on all bridges in the list, and using the Candidate that provides the lowest life cycle cost in the first year of the program.

Name	Description
health	Health index estimated as of this year
paint	Health index for painted steel elements
hicat	Highest action category
hisubcat	Largest (in cost) action sub-category
recoat	Yes if the Candidate includes total recoating
overlay	Yes if includes wearing surface replacement
deckrepl	Yes if the Candidate includes deck replacement
totalcost	Total initial cost
totalben	Total benefit
agcyben	Agency benefit
userben	User benefit
totbencost	Total benefit/cost ratio
agcybencost	Agency benefit/cost ratio
userbencost	User benefit/cost ratio
urgency	Urgency of Candidate
replrank	Replacement rank
mincond	Minimum NBI condition rating
avcond	Average NBI condition
adt	Average daily traffic estimated this year
growth	Average growth rate

One of the columns you will use often is Urgency, a benefit/cost ratio describing the increase in life cycle costs if work needed in the first year is delayed to the second year. Bridges with high Urgency numbers are the ones most in need of immediate attention, from an economic standpoint. This is not the same as economic priority: it is possible for a work candidate to have large life cycle cost savings but low urgency if its potential savings are equally large in the second year. The Total Benefit/Cost ratio is more of an indication of priority, though for certain purposes several of the other performance indicators could be valid indicators of priority as well.

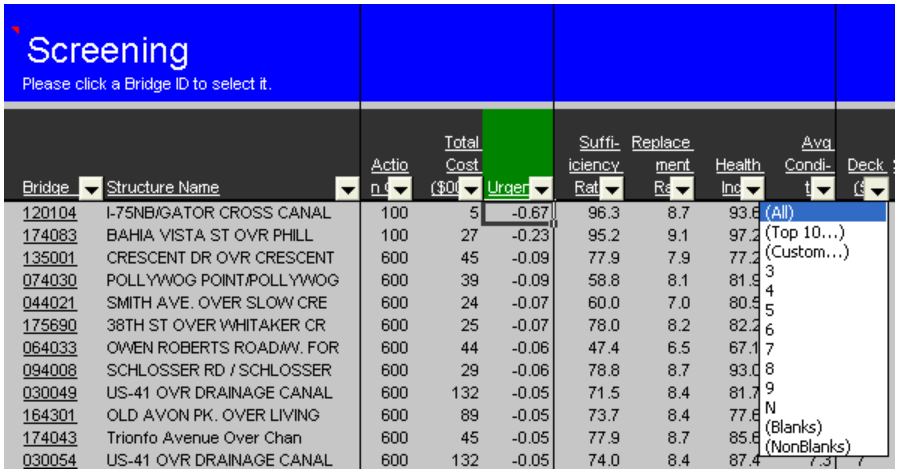
Filter



If you click the Filter button on the toolbar while in the Screening worksheet, you will see the dialog box at left. This is the Filter dialog. You can click any one or more districts and/or custodians in these lists. Click the All checkbox to select all the items in the list. If you check the "Omit poles, signs, mast arms, and walls" box, the filter accepts only bridges with numeric values of bridge.servtypon (service type on bridge).

After you click OK, the software will load all the selected bridges and perform the project level analysis on all of them, to update the Screening worksheet. This can take from several seconds to a couple of minutes depending on the number of bridges selected.

In addition to this feature, you can take advantage of filtering features built into Excel. For example, if you choose Excel's Data – Filter – AutoFilter command, Excel will provide drop-down arrows next to each column heading, as shown below. Click one of these arrows (e.g. Deck rating in the example) to see a list of all the values that occur in the column, as well as other features for subdividing the list.



Computation Details

The Trace, or Computation Details, worksheet is an annotated log of all the calculations performed during the project level analysis of the bridge shown on the Dashboard. It shows intermediate results, branches in the logic, and an explanation of all the final results. You can print this from Excel as a report if desired. You can also use the tables in the worksheet as a starting point for your own Excel models to further analyze the bridge.

Raw Bridge Data Worksheets

Three worksheets, normally hidden, provide behind-the-scenes storage of raw bridge data presented on the Dashboard and used in the project level analysis. They are not accessible from the toolbar.

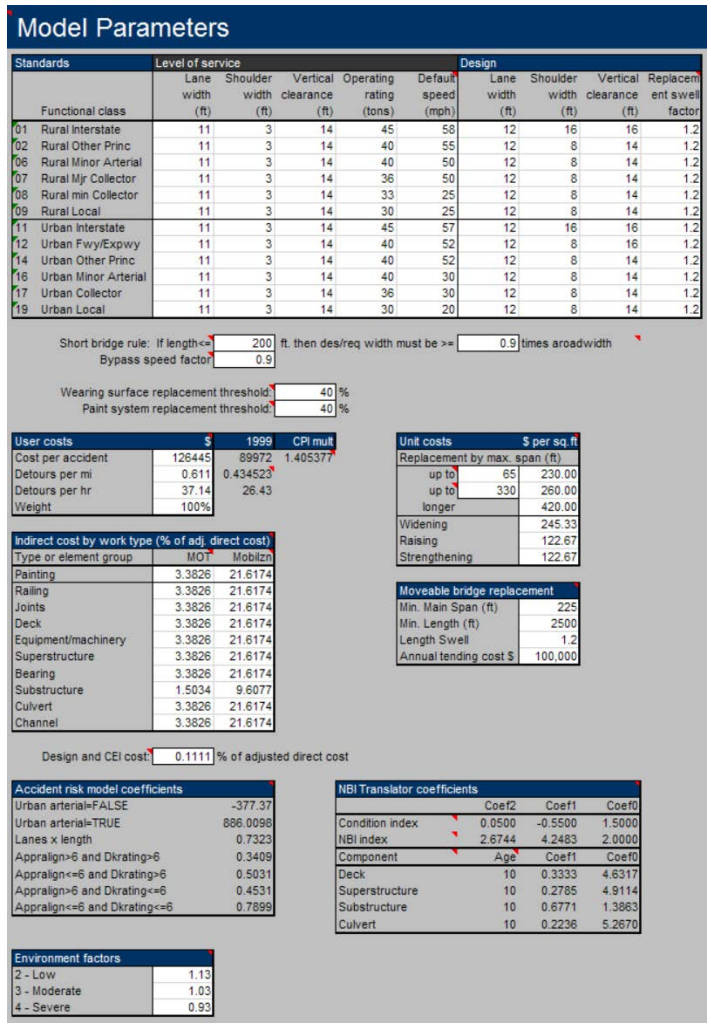
- Inventory – Each time you visit a new bridge, data about that bridge are loaded into this worksheet. From there, the information is presented on the Dashboard using Excel formulas. This worksheet can be customized if necessary.
- Candidates – If you create Custom Candidates, the system saves information about them on this worksheet. This information includes the Candidate name and cost factors.
- Scope Items – If you create Custom Candidates, the system saves their lists of scope items in this worksheet.

Unless you are an advanced user wanting to customize the system, you probably will never need to visit these worksheets.

Definition and Model Worksheets

Many of the worksheets in the system hold modeling input data, which should be updated periodically by the system administrator as part of an annual process.

- Parameters – Miscellaneous modeling parameters (right) used throughout the analysis. Each item on this worksheet has an Excel comment explaining it. This worksheet is meant to be updated manually once a year.
- Code tables – This worksheet consists of lists of NBI codes and more readable labels representing them. These are assumed to be nearly static, so they are reviewed and updated manually each year.
- Element definitions and models – Element characteristics such as their names, units, and protective system associations; plus additional modeling parameters, updated manually, for the deterioration model, the NBI Translator, and do-nothing life cycle costs.
- Action definitions and models – Includes action names, sub-categories, effectiveness, unit costs, and life cycle costs.
- Action sub-categories – Additional modeling parameters for the scale feasibility and deck replacement models. These are updated manually.
- Risk – A worksheet which provides all of the many parameters affecting the risk analysis.



Model Parameters

Standards	Level of service					Design			
Functional class	Lane width (ft)	Shoulder width (ft)	Vertical clearance (ft)	Operating rating (tons)	Default speed (mph)	Lane width (ft)	Shoulder width (ft)	Vertical clearance (ft)	Replacement swell factor
01 Rural Interstate	11	3	14	45	58	12	16	16	1.2
02 Rural Other Princ	11	3	14	40	55	12	8	14	1.2
06 Rural Minor Arterial	11	3	14	40	50	12	8	14	1.2
07 Rural Mjr Collector	11	3	14	36	50	12	8	14	1.2
08 Rural min Collector	11	3	14	33	25	12	8	14	1.2
09 Rural Local	11	3	14	30	25	12	8	14	1.2
11 Urban Interstate	11	3	14	45	57	12	16	16	1.2
12 Urban Fwy/Expwy	11	3	14	40	52	12	8	16	1.2
14 Urban Other Princ	11	3	14	40	52	12	8	14	1.2
16 Urban Minor Arterial	11	3	14	40	30	12	8	14	1.2
17 Urban Collector	11	3	14	36	30	12	8	14	1.2
19 Urban Local	11	3	14	30	20	12	8	14	1.2

Short bridge rule: If length<= 200 ft. then des/req width must be >= 0.9 times aroadwidth

Bypass speed factor 0.9

Wearing surface replacement threshold: 40 %

Paint system replacement threshold: 40 %

User costs	$	1999	CPI mult
Cost per accident	126445	89972	1.405377
Detours per mi	0.611	0.434523	
Detours per hr	37.14	26.43	
Weight	100%		

Unit costs		$ per sq.ft
Replacement by max. span (ft)		
up to	65	230.00
up to	330	260.00
longer		420.00
Widening		245.33
Raising		122.67
Strengthening		122.67

Indirect cost by work type (% of adj. direct cost)		
Type or element group	MOT	Mobilzn
Painting	3.3826	21.6174
Railing	3.3826	21.6174
Joints	3.3826	21.6174
Deck	3.3826	21.6174
Equipment/machinery	3.3826	21.6174
Superstructure	3.3826	21.6174
Bearing	3.3826	21.6174
Substructure	1.5034	9.6077
Culvert	3.3826	21.6174
Channel	3.3826	21.6174

Moveable bridge replacement	
Min. Main Span (ft)	225
Min. Length (ft)	2500
Length Swell	1.2
Annual tending cost $	100,000

Design and CEI cost: 0.1111 % of adjusted direct cost

Accident risk model coefficients	
Urban arterial=FALSE	-377.37
Urban arterial=TRUE	886.0098
Lanes x length	0.7323
Appralign>6 and Dkrating>6	0.3409
Appralign<=6 and Dkrating>6	0.5031
Appralign>6 and Dkrating<=6	0.4531
Appralign<=6 and Dkrating<=6	0.7899

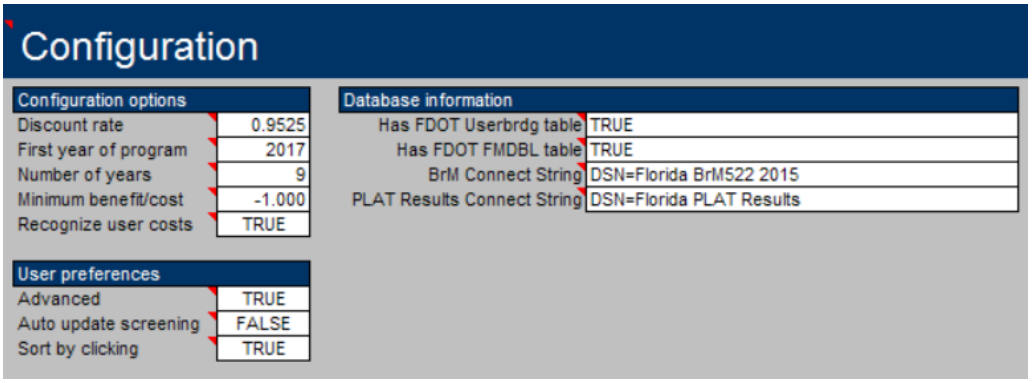
NBI Translator coefficients			
	Coef2	Coef1	Coef0
Condition index	0.0500	-0.5500	1.5000
NBI index	2.6744	4.2483	2.0000
Component	Age	Coef1	Coef0
Deck	10	0.3333	4.6317
Superstructure	10	0.2785	4.9114
Substructure	10	0.6771	1.3863
Culvert	10	0.2236	5.2670

Environment factors	
2 - Low	1.13
3 - Moderate	1.03
4 - Severe	0.93

Unless you are an administrator, you will probably never need to visit these worksheets, and they are not accessible from the toolbar. For any given bridge, the modeling inputs used in the project level analysis are given in the Computational Details worksheet.

Configuration Worksheet

This worksheet is important to the system administrator when preparing the model for use each year. It contains fundamental parameters controlling the behavior of the software, including the connection to the BrM database. It also provides storage for the items on the Options dialog.



Normally you will not need to visit this worksheet unless you are the system administrator, and it is not accessible from the toolbar. If you have trouble connecting to the BrM database, your administrator may recommend changes to the Connect String.

You can set a minimum benefit/cost ratio to determine which interventions generated by the PLAT are carried over into the Network Analysis Tool (NAT) for programming and budgeting. Normally you should use 0, which saves all interventions having non-negative benefits. If you leave it blank, all interventions are carried over, even those with negative benefits.

Florida DOT has special tables in its BrM database to support scour analysis and financial management, among other purposes. Certain data items from these tables appear on the Dashboard and Screening worksheets. If you do not use the Florida DOT database, you should indicate FALSE in the field “Has FDOT UserBrdg & FMDBL”.

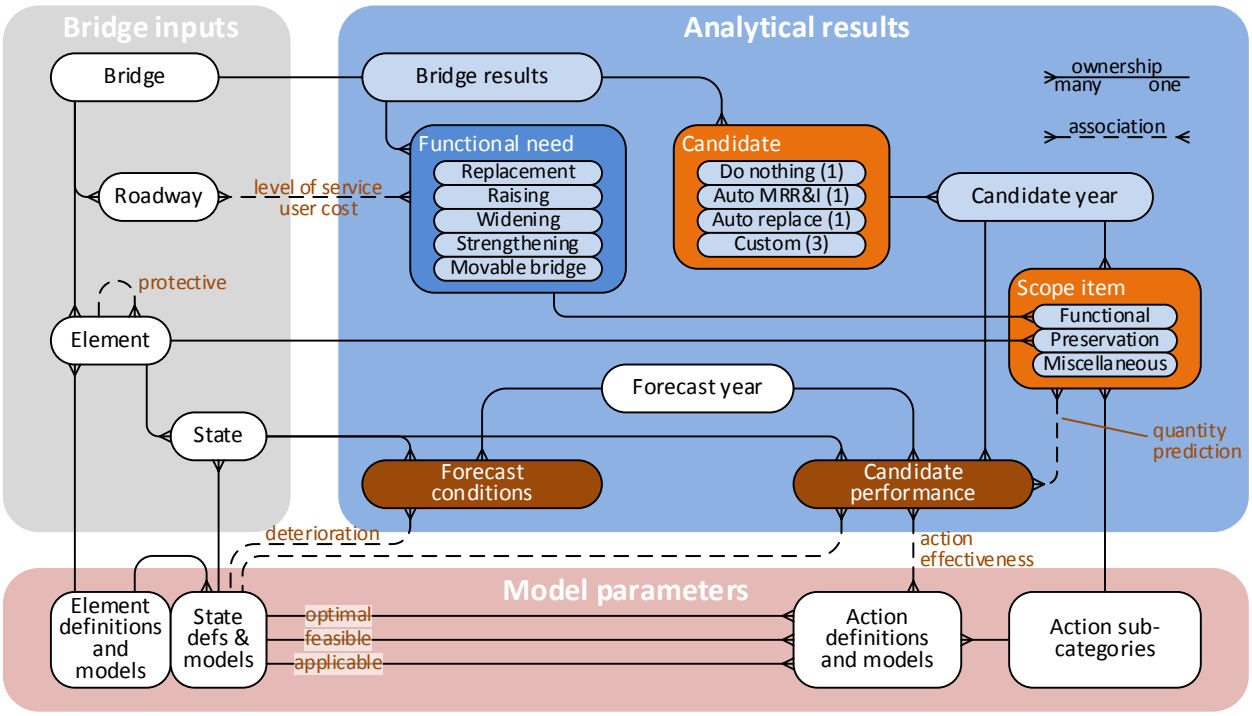
The PLAT Results database is a Microsoft Access database separate from BrM, which serves to convey PLAT analysis results from PLAT to NAT. To use it, create an ODBC profile for the PLAT Results database in the same manner as you would for BrM, and enter its connect string. Leave the connect string blank if you will not be saving to the PLAT Results database.

Analytical Framework

The project level analysis tool is essentially a life cycle cost model, that performs a net present value analysis of the costs likely to occur over a bridge's life. To give it decision support power, the model provides its greatest level of detail during a program period of 9 years, when a bridge project may take place, and less detail during a subsequent period of indefinite length. The tool compares alternative definitions of a project, called Candidates, and alternative implementation years, to aid the engineer in planning the work. The tool is purely a predictive model – not an optimization – which outputs performance measures for decision-making.

The following diagram summarizes the objects and relationships that participate in the analysis. The primary analytical results come in the form of Candidates, which are alternative patterns for scoping of a project. There are three types of automatically-generated candidates, and engineers may also create three Custom Candidates. Most Candidates (other than Do Nothing) are evaluated separately for each possible implementation year, each Candidate-Year having a different list of Scope Items.

Roadway data from BrM feed into a functional needs analysis, resulting in functional scope items that reduce future user costs. Element data combine with element-level preservation models, to form preservation scope items that reduce future agency costs. Engineers may also add their own miscellaneous scope items with user-defined costs and benefits.

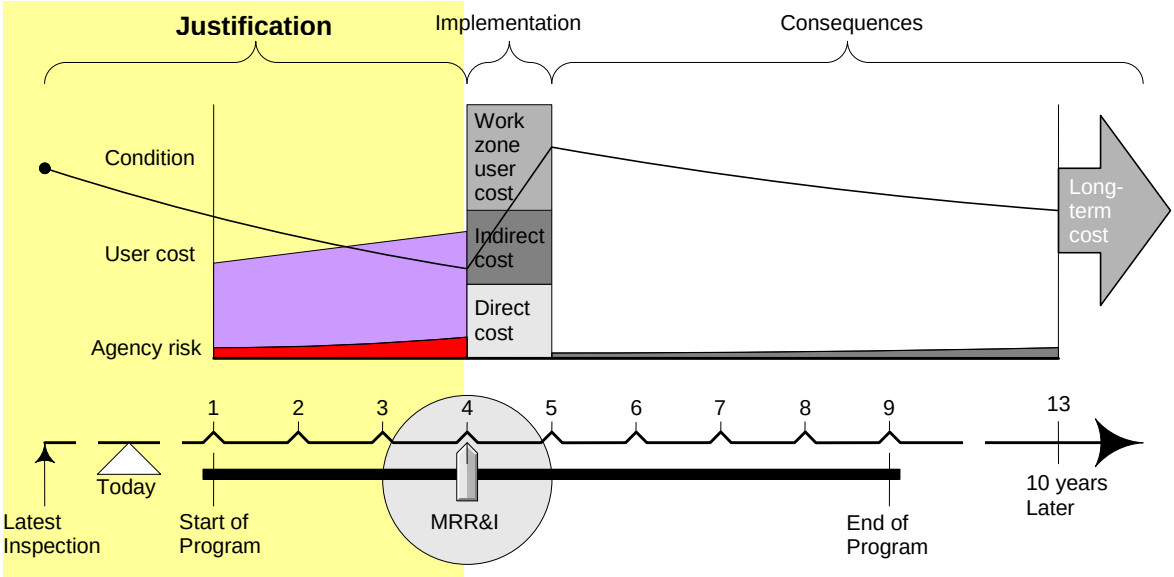


Each candidate type has its own characteristic life cycle cost profile, consisting of three phases:

- Justification phase, which predicts deterioration and user costs from the latest inspection up to the year in which a candidate is being considered.
- Implementation phase, where predicted needs at the investigated point in time are converted to a definition of a realistic candidate project with a scope and initial cost.
- Consequence phase, predicting the long-term outcome resulting from the considered project.

Follow the links for more information about all the components of the life cycle cost analysis.

Justification Phase



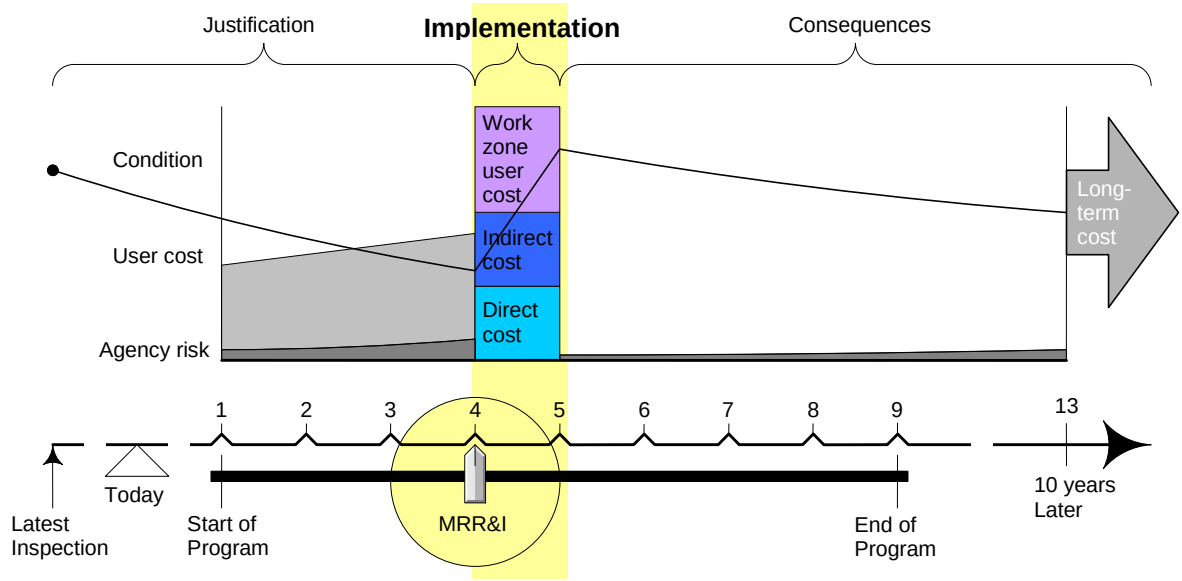
The justification phase of the analysis is the build-up of needs that occurs in the years before a candidate is implemented. The FDOT project-level analysis tool estimates the following cost components:

- Agency risk. This is the sum of all agency and user costs associated with the vulnerability of the bridge to natural and man-made hazards.
- User cost of functional deficiencies. This includes the cost of excess accident risk and truck detours, according to the FDOT user cost model.
- User cost of moveable bridge openings. This includes the delay to all road users caused by frequent opening of moveable bridges to allow passage of ships.

To calculate these quantities as well as those needed for subsequent phases, the model simulates the deterioration of each bridge element from the most recent inspection to the year in which a candidate project is contemplated, using the same Markovian transition probabilities used in BrM. When a portion of the element reaches states 3 or 4, it is assigned a risk penalty. By convention, the risk penalty is recognized at the end of a year based on conditions forecast at the end of the preceding year.

Certain bridge elements, namely coatings, wearing surfaces, cathodic protection, expansion joint seals, and drainage systems, exist primarily to slow the deterioration of other elements. During the simulated deterioration, this effect is modeled by adjusting the deterioration rate of protected elements (most superstructure and substructure elements), according to the predicted condition of protector elements on the same bridge.

Implementation Phase



The project level analysis tool is not meant to generate optimal projects, but it does have a convenient method to create reasonable first-cut candidates, based on life cycle cost minimization and respecting certain constraints on realism of candidate definitions. These provide a reasonable measure of need, project urgency, and economic merit for the life cycle model. The engineer is encouraged to revise the scope of the project, by creating Custom Candidates, based on his or her own knowledge of the bridge.

Three candidate types are always generated automatically:

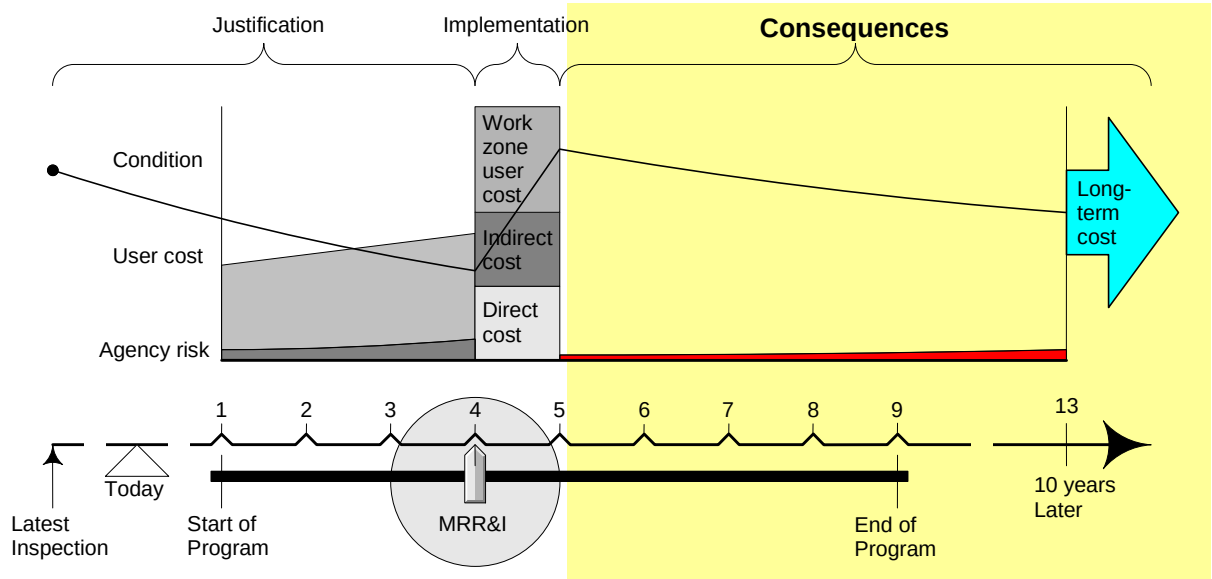
- Do Nothing - no action in any year of the planning period;
- Auto MRR&I - do a reasonable set of actions in response to all maintenance, repair, rehabilitation, and improvement needs on the bridge, in one year of the period (a separate life cycle activity profile is generated for each of 9 possible implementation years);
- Auto Replace - replace the bridge in one year (again a separate definition for each of the 9 years).

In addition, the engineer may specify up to three additional candidate scopes, and analyze each one in any implementation year.

The process for generating the Auto MRR&I candidates uses least-life-cycle-cost criteria to identify preservation actions on each element, and uses level-of-service standards to identify functional improvements. A few refinements are imposed on this process to generate realistic project candidates.

A cost model estimates the direct and indirect costs of each candidate. Indirect costs include maintenance of traffic, mobilization, and engineering. The preservation costs developed in the earlier FDOT agency cost study were divided into direct and indirect components, based on rules of thumb that depend on the type of element.

Consequence Phase



In the idealized life cycle cost analysis, costs of a candidate project are assumed to occur on the first day of its implementation year, followed by a 10-year hiatus, period of inactivity when the bridge is allowed to deteriorate. User costs may occur during this period if any functional needs are left uncorrected, and appropriate risk costs also continue.

At the end of the hiatus period, it is not necessary to plan specific projects, but it remains necessary to estimate residual life cycle costs. Such an estimate must be sensitive to the ending condition of each element: if work is done during the program period, ending conditions will be relatively good, and further needs will be relatively small, compared with the do-nothing case. The model assumes that deterioration continues to occur for 10 years following the action, and that long-term residual preservation costs occur after that.

If any functional needs are uncorrected, they are either assumed to continue indefinitely beyond the 10-year period, or a bridge replacement cost is incurred, whichever gives the lowest life cycle costs. In the former case, traffic growth is assumed to stop.

Discounting and Present Value

Net present value analysis is used to compare costs occurring at different times in the bridge life cycle. Cash flows that occur in the future are discounted to a lower value when compared with cash flows that occur today, to reflect the fact that cash received today is more valuable — less risky — than cash in the future. There is no standard value for discount rate: what is most important is to select a reasonable rate consistent with agency policy, and use it consistently across all asset types managed by the agency.

The discount rate is based on the forecast real interest rate, i.e. the interest rate with inflation removed. It is calculated as follows:

Discount rate $$\alpha = \frac{1}{1 + \text{int}}$$

where: int is the real interest rate

Although it is not, in principle, required that inflation be removed from a life cycle cost analysis, this is normally done in the name of simplification. Inflation is less predictable than other economic inputs to the analysis, and it does not have a material effect on the results unless different cost factors are modeled to inflate at different rates. Including inflated unit costs at every point of input of economic data would complicate the models considerably. The project level analysis tool does not include such functionality.

Certain conventions in the life cycle cost analysis govern the length of discounting:

- Initial agency costs and long-term costs occur at the beginning of the implementation year.
- User costs and agency risk costs occur at the end of the year.
- All costs are discounted to the end of the year in which the model is run, as determined by the computer's system clock.

Here is an example of a discounted cash flow analysis:

	Today's date	10/28/02							
	Discount rate	0.95							
		End-of-year costs				Beginning-of-year costs			
Program year	Calendar year	User cost	Failure risk	Discount	Discount-ed sum	Initial cost	Long-term cost	Discount	Discount-ed sum
today	2002								
1	2003	30,789	4,443	0.950	33,470	0	0	1.000	0
2	2004	30,978	1,386	0.903	29,208	0	0	0.950	0
3	2005	31,167	1,425	0.857	27,944	0	0	0.903	0
4	2006	31,358	1,556	0.815	26,808	0	0	0.857	0
5	2007	0	0	0.774	0	109,425	0	0.815	89,128
6	2008	0	0	0.735	0	0	0	0.774	0
7	2009	0	0	0.698	0	0	0	0.735	0
8	2010	0	0	0.663	0	0	0	0.698	0
9	2011	0	0	0.630	0	0	0	0.663	0
long-term	2012	0	0	0.599	0	0	177,535	0.630	111,891
Total					117,431				201,019
	Life cycle cost	318,450							

Fundamental Models

All of the analytical models in the system are procedures written in Visual Basic for Applications and contained within the Excel workbook file. The framework consists of a collection of sub-models that work together to serve the analytical framework. Some of the models are used in more than one stage of life cycle costing. The main models are:

- Deterioration – Predicts future conditions of elements on a bridge, based on the most recent inspection and a possible candidate project implemented during the program period.
- Action cost and effectiveness – Predicts the outcome of a candidate by aggregating the effects of individual elements of a bridge.
- Candidate definition – Provides a reasonable, but not optimized, set of candidate projects to be compared in a life cycle cost analysis.
- Long-term cost – Estimates life cycle costs beyond the end of the program period, based on conditions predicted at the end of the period.
- Functional needs – Predicts the economic effect of functional deficiencies on road users.
- Risk analysis of natural and man-made hazards.

See Candidate Definition for information on how all these models are integrated to predict life cycle costs for each type of candidate.

Deterioration Model

As the primary cause of preservation needs in a bridge inventory, deterioration is the main driver of the life cycle cost analysis in the project level analysis tool. The system uses the same Markovian model as BrM.

A Markovian model assumes that the probability of making a transition from one condition state to another depends only on the initial state, and not on past conditions or any other information about the element. Thus, the model is expressed as a simple matrix of probabilities, which can be manipulated by matrix multiplication.

Analysis of historical Florida bridge inspection data revealed that the Markovian model overstates the rate of deterioration for bridges in excellent condition (Sobanjo and Thompson 2010). A new model was developed to alleviate this problem by more accurately describing the onset of deterioration. PLAT uses this model during every phase of the analysis.

At the project level, an important phenomenon to be modeled is the effect of protective elements, namely coatings, wearing surfaces, cathodic protection, joints and drainage systems, on the elements they protect (most superstructure and substructure elements). The system therefore has a set of deterioration refinements that quantify this effect.

Inspections and predicted conditions are all assumed to occur at the end of the year. The model predicts conditions described as “today” (the date the analysis is run) using the integer number of years from the inspection date to the computer’s system date. The base year given on the Configuration worksheet is the first year for which candidates are defined and programmed. These candidates are based on conditions at the end of the preceding year, which is usually the same as the “today” year.

To compute forecasts of NBI condition ratings, the program first uses the Markovian model as described here, then converts the forecast condition state probabilities into NBI ratings using a Translator algorithm .

Markov Transition Probabilities

A Markovian deterioration model assumes that the probability of making a transition from one condition state to another depends only on the initial state, and not on past conditions or any other information about the element. Thus, the model is expressed as a simple matrix of probabilities, which can be manipulated by matrix multiplication.

Transition probabilities			
		One year later	
From state	Transition time (yrs)	Same state	Next state
1	20	96.6%	3.4%
2	15	95.5%	4.5%
3	10	93.3%	6.7%
4		100.0%	0.0%

Predicted conditions				
Year	State 1	State 2	State 3	State 4
1	100.0%	0.0%	0.0%	0.0%
2	96.6%	3.4%	0.0%	0.0%
3	93.3%	6.5%	0.2%	0.0%
4	90.1%	9.4%	0.4%	0.0%
5	87.1%	12.1%	0.8%	0.0%
6	84.1%	14.5%	1.3%	0.1%
7	81.2%	16.7%	1.9%	0.2%
8	78.5%	18.7%	2.5%	0.3%
9	75.8%	20.5%	3.2%	0.5%
10	73.2%	22.2%	3.9%	0.7%

The table shows a typical transition probability matrix at left. The rows are condition states at the beginning of the year. The PLAT deterioration models are expressed as median transition times to deteriorate from one state to the next. The probability of remaining in the same state the next year can be computed from this transition time T using:

$$P = 0.5^{(1/T)}$$

So for example the table indicates that, for all units of the element starting the year in state 1, 96.6% will remain in state 1 after one year, and 3.4% will go to state 2. In the following year, out of those 3.4%, 4.5% will go on to state 3.

The rows of a transition probability matrix must always sum to 100%. Since the matrix describes the change in condition when no rehabilitation action is taken, the probabilities from any condition state to better states should always be zero. Once an element reaches the worst state, it is assumed to stay there.

Conditions at any future period can be predicted with a Markovian model by simple matrix multiplication. The table above right shows an example of how a starting position changes over 10 years. Note that the sum for each period must be 100%.

The Markov transition probabilities in PLAT were most recently updated in 2010 based entirely on Florida bridge inspection data (Sobanjo and Thompson 2010). They were further updated in 2015 to adjust for the changes in element condition state definitions.

Onset of deterioration

Previous research has noted that the Markovian models used in Pontis have fairly rapid initial deterioration. This creates a serious problem for multi-year programming models such as NAT, because it is difficult to configure such models to maintain a realistically high network condition level.

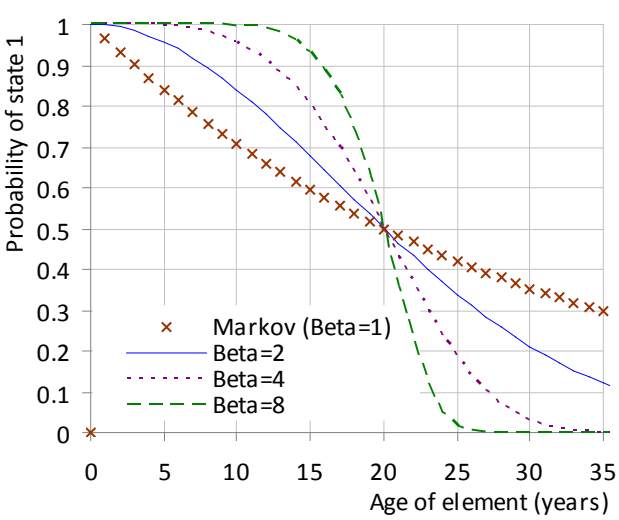
The solution in PLAT is to use a Weibull survival function to model the probability of remaining in condition state 1, as a function of age (Sobanjo and Thompson 2010). Subsequent transitions below state 2 are still modeled using Markovian models. A Markovian model has a constant probability of transitioning from state 1 to state 2, so the survival function is used as an enhancement, to make the transition probability variable. A new bridge will have a very high probability, approaching 1.0, of remaining in state 1 from year to year. As the bridge ages, the probability decreases. Once a portion of an element deteriorates to condition state 2, Markovian deterioration takes over for the remainder of the process.

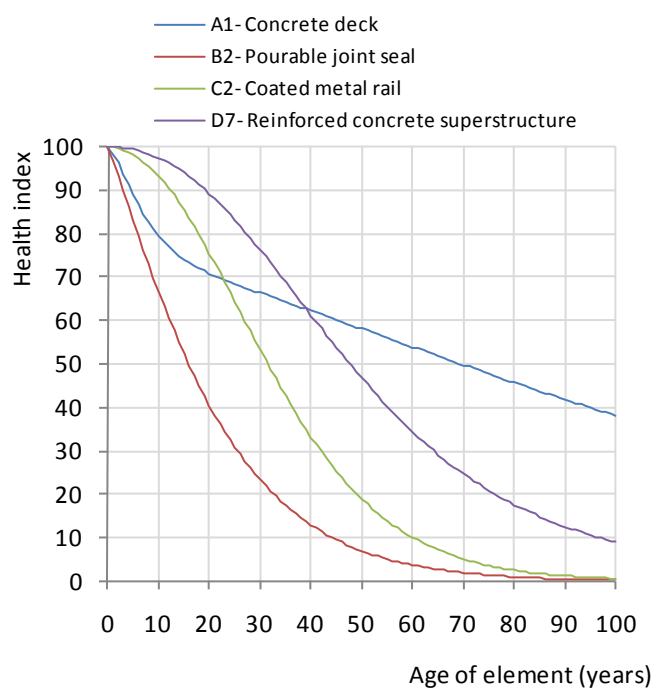
The Weibull curve has the following functional form:

$$y_{1g} = \exp\left(-\left(g/\alpha\right)^{\beta}\right) \qquad \alpha = \frac{t}{(\ln 2)^{1/\beta}}$$

where y_{1g} is the state probability of condition state 1 at age (year) g, if no intervening action is taken between year 0 and year g; β is the shaping parameter, which determines the initial slowing effect on deterioration; and α is the scaling parameter, calculated as above where t is the median transition time from state 1 to state 2, from the Markov model.

The graph below left shows the form of the Weibull curve, for four different values of the shaping parameter β, with t=20. A shaping parameter of 1 is mathematically equivalent to a Markov model, featuring the problematic rapid onset of deterioration. A shaping parameter of 2 introduces a delay, and higher values postpone significant deterioration even longer. At lower right is shown a sample of health index deterioration curves computed using the hybrid Markov/Weibull model.





Deterioration Refinements

Certain bridge elements, namely coatings, wearing surfaces, cathodic protection, expansion joint seals, and drainage systems, exist primarily to slow the deterioration of other elements. AASHTOWare Bridge Management adds a feature, known as the protection factor, which is meant to modify the deterioration model to represent the interaction among elements. The protection factor increases the median years to transition, thus slowing deterioration of a substrate element (such as a steel girder), if the protecting element (such as paint system) is partially or fully functional.

When forecasting deterioration for a specific element on a specific bridge, the transition time is computed as follows:

$$T'_j = f \times T_j^o$$

Where T_j^o = the transition time for state *j* for the given element if protective systems are absent and the element is in a Moderate environment

T'_j = the modified transition time

f = the protection factor, considering all characteristics of the bridge and element

The protection factor for a given element on a given bridge takes into account the various influences which can modify the transition time. It is calculated by multiplying together all the contributing factors as follows:

$$f = f^E \prod_e f_e^M$$

Where f^E = the Environment factor, reflecting climate and operating conditions of the element location

f_e^M = Modifier factors, the effects of each of the associated protective system elements *e*

The modifier factor for each protecting element depends on its condition, as follows:

$$f_e^M = pp_e^+ - \left(1 - (y_1 + \frac{2}{3}y_2 + \frac{1}{3}y_3)\right)(pp_e^+ - pp_e^-)$$

Where y_k = the forecast fraction of the protecting element in state *k*

pp_e^+ = the protection parameter for protecting element *e* for condition state 1

pp_e^- = the protection parameter for protecting element *e* for condition state 4

So if a deck in a Moderate environment is protected by a wearing surface with *f=1.2*, and a cathodic protection system with *f=2.0*, then the total protection factor is 1.2 ×2.0 = 2.4. If such element had not been protected by other elements (for example, a bare slab), its protection factor *f=1.0*. As a result, the rate of deterioration of a substrate element can vary over the life of a bridge as the protecting element deteriorates.

PLAT is configured to use the same protection factors as are provided in BrM release 5.2.2, as determined by the AASHTO Technical Review Team. Protection factors are used during all three phases of the analysis.

Preservation Actions

State key	Action key	Action name	Sub-category
2	1	Spot blast deck	319
2	2	Minor repair deck	302
3	1	Spot blast and minor repair deck	302
3	2	Spot blast and major repair deck	202
4	1	Spot blast and major repair deck	202
4	2	Replace deck	101

Each element and condition state has a set of feasible actions defined for it. Shown at right is an example of the feasible actions defined for a steel deck element on the MR&R Action Definitions worksheet. Each condition state has zero to four actions, one of which is always do-nothing. In the estimation of cost models, the 895 do-something feasible actions were grouped into 3 categories (Replace, Major, and Minor) and 54 sub-categories useful for cost estimation. This concept is used extensively in the system.

Within each condition state, the available actions have three levels of suitability as corrective measures to offset deterioration. These are:

- Optimal – The action has the lowest long-term cost, of all the feasible actions defined for the state.
- Feasible – The action is physically capable of being applied to the condition state, would be effective to some degree in correcting the deterioration, would be justifiable for that state in its own right, and has models defined for it.
- Applicable – The action is physically capable of being applied to the condition state, would be effective to some degree in correcting the deterioration, but would not be justifiable in its own right unless the same action is also applied to other states on the same bridge element where it is more suitable, as a part of an effort to capture economies of scale. Models are not defined for it.

The concept of applicability was developed for project level analysis to enable the engineer to define more realistic candidate projects. It is common to expand a project to encompass more condition states than would be considered feasible or optimal (usually states 2 and/or 3), as a way of forestalling the need to revisit the bridge any time soon.

Actions that are feasible for a given condition state are automatically also considered applicable. When an action is applicable but not feasible for a given state, then the predictive models of the system must look to another condition state, where the action is feasible, to find an appropriate set of models. This is done by the output prediction model.

Preservation Models

The project level analysis tool has a complete set of preservation models, including deterioration, action effectiveness, agency cost, long-term cost, preservation benefits, and the designation of optimal actions.

Here is an example of the preservation models.

ELEMENT 12 - Re Concrete Deck (Environment 3)

Quantity 27381.02 sf. Group 3

INPUTS BY CONDITION STATE AND ACTION

FromState		Action	Sub-category	Prob1	Prob2	Prob3	Prob4	Applicability	VarCost	FixCost	LTCost
1	>> 0	Do nothing	000-Do nothing	Unmodified transition time = 5.8 years				1234	0.00	0.00	0.91
2	>> 0	Do nothing	000-Do nothing	Unmodified transition time = 48.4 years				1234	0.00	0.00	1.31
	1	Minor repair	301-Repair of bridge deck	89.71	10.29	0.00	0.00	23	100.87	33.62	135.42
3	>> 0	Do nothing	000-Do nothing	Unmodified transition time = 50.9 years				1234	0.00	0.00	5.78
	1	Major repair	201-Major deck repairs	43.88	44.90	11.22	0.00	234	50.89	16.96	68.93
4	0	Do nothing	000-Do nothing	0.00	0.00	0.00	100.00	1234	0.00	0.00	56.67
	1	Major repair	201-Major deck repairs	43.88	44.90	11.22	0.00	234	50.89	16.96	68.93
	>> 2	Replace deck	101-Replace deck	100.00	0.00	0.00	0.00	34	40.39	13.46	53.85

Shaping parameter = 1.35

Health index weight = 25

Actions denoted by >> are optimal (lowest long-term cost) for the condition state.

The 'ProbN' columns are transition probabilities after the indicated action is taken, to each possible resulting state.

Applicability indicates the condition states to which each action may be applied.

VarCost is the variable (direct) unit cost of the action.

FixCost is the fixed (indirect) unit cost of the action.

LTCost is the long-term cost migrated from the Pontis network optimization.

The example shows the condition states and feasible actions defined for element 12. Each action has an action sub-category to which it belongs. The ProbN columns are the deterioration model and the action effectiveness model. Applicability indicates which condition states may receive the action.

VarCost and FixCost are variable and fixed (direct and indirect) components of the agency cost of each action. In principle, variable costs are directly proportional to the quantity of work, while fixed costs act as more of an overhead that does not necessarily vary linearly with quantity. The project-level analysis tool has a separate process for estimating indirect costs at the candidate level.

LTCost is the output of a network optimization. It represents the unit life cycle cost if the action is taken each time any of the element reaches the indicated state (assuming the optimal policy is followed for every other state). The action with lowest LTCost for each state is optimal for that state. For example, action 2 (Replace) is optimal for state 4 in the above example.

The unit benefit of any preservation action is calculated by subtracting the LTCost of the subject action from the LTCost of Do Nothing in the same state. If this difference is greater than zero, then performing the action has a lower life cycle cost than doing nothing, making it an attractive option.

Action Sub-Categories

With 895 separate actions defined for Florida elements, the MR&R (maintenance, repair, and rehabilitation) action scheme is rather unwieldy for many purposes in the project-level analysis. Therefore a simpler scheme with only 54 sub-categories was defined, as shown below. Each preservation action is associated with one sub-category, serving to group similar actions together.

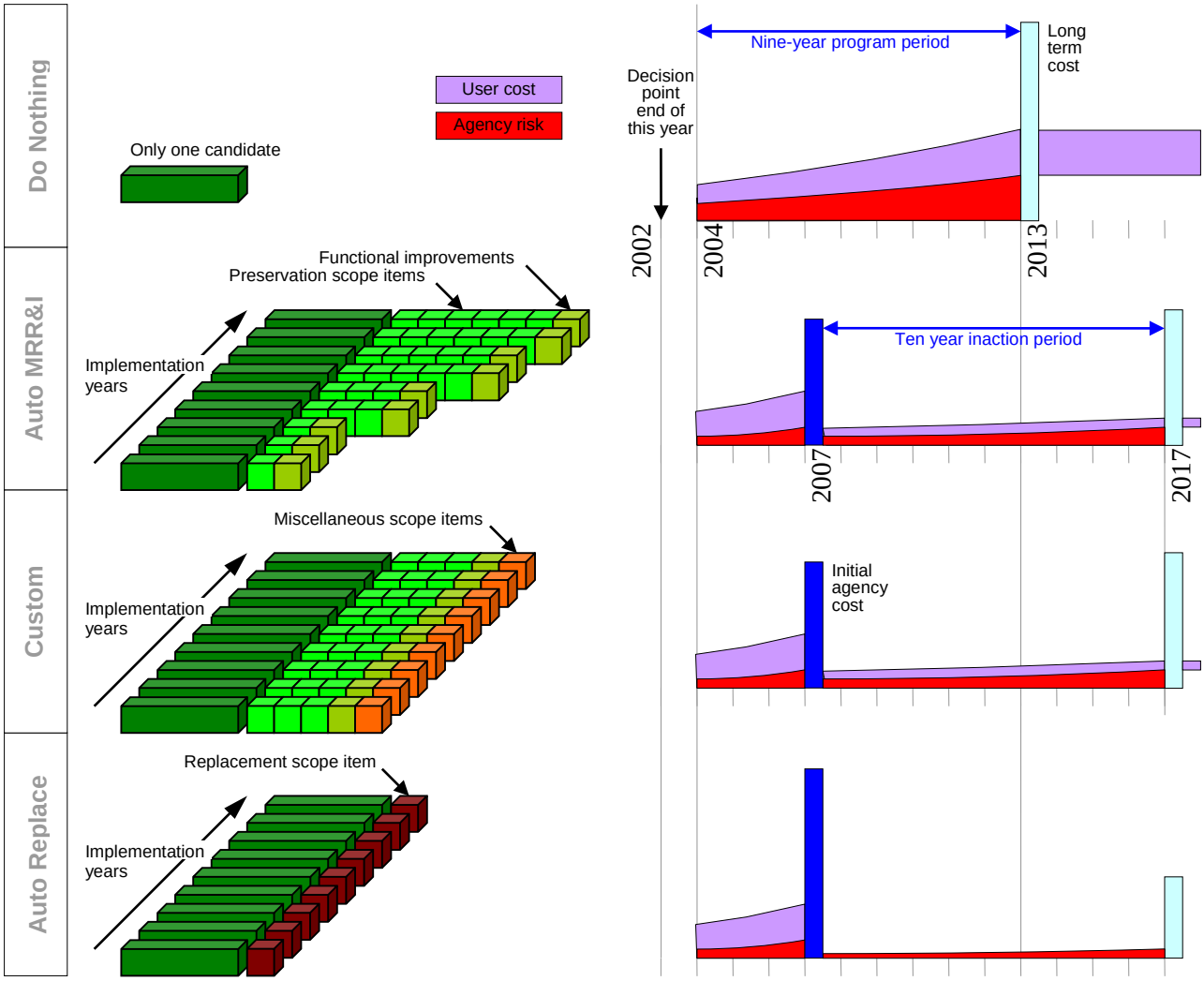
			Action Category		
		Object	100-Replace	200-Major repair	300-Minor repair
Materials	1	Deck	101	201	301
	2	Steel/metal		202	302
	3	Concrete		203	303
	4	Timber		204	304
	5	Masonry		205	305
	6	MSE		206	306
	7	Other material		207	307
	9	Wearing surface	109	209	309
Hi-Maint	10	Other element			
	11	Joint	111	211	311
	12	Joint seal	112		
	13	Bearing (incl p/h)	113	213	313
	14	Railing	114		
	19	Coatings	119	219	319
Drainage	21	Slope prot	121	221	
	22	Channel		222	322
	23	Drain sys	123	223	323
Machinery	31	Machinery (1)	131	231	331
	32	Cath prot	132	232	332
Major	41	Beam	141		
	42	Truss/arch/box	142		
	43	Cable	143	243	
	44	Substr elem (exc cap)	144 (2)		
	45	Culvert	145		
	46	Appr slab	146	246 (3)	
	47	Settlement/scour		247 (4)	
	48	Distortion		248 (5)	
Appurtenances	51	Pole/sign	151		

White cells represent valid sub-categories; numbers in parentheses refer to footnotes

Footnotes

1. Incl. elec, hydraulic, and mech elements
2. Incl. fenders, dolphins, and pile jackets
3. Mudjacking
4. Mitigate settlement or scour
5. Heat straightening and repair of distortion

Candidate Definition



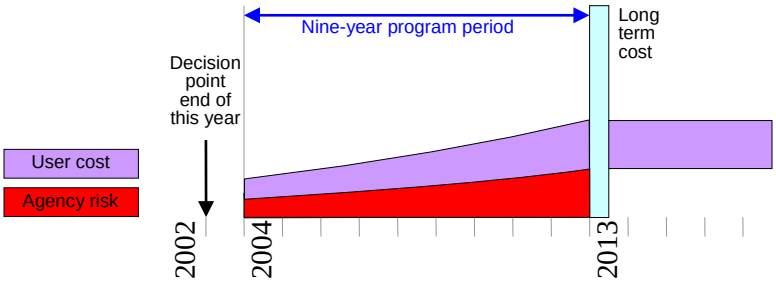
The project level analysis tool has four types of candidates, each with its own set of conventions for scoping and life cycle activity profiles, as illustrated above. Do Nothing has just one candidate, describing the case where no work is done in any year of the program period. Auto MRR&I, Custom, and Auto Replace each have nine candidates, representing implementation in each of the nine program years. Each of these has its own life cycle activity profile and its own total life cycle cost. Up to three sets of Custom candidates can be defined by the engineer.

Each candidate, except Do Nothing, may have scope items. Replacement candidates have only one scope item, replacement. Custom candidates have the same set of scope items for each year of the program, while Auto MRR&I candidates may have different scope items each year. Each scope item corresponds to one element and one action sub-category, or one functional improvement. It is possible for Auto MRR&I or Custom candidates to have more than one scope item for any given element.

In their life cycle activity profiles, the types of candidates differ in how they generate the four major cost components. Do Nothing recognizes a long-term cost immediately after the end of the program period. The other types have a ten-year period of inactivity following a candidate's implementation year, before long-term costs are recognized.

Do Nothing

Do Nothing represents the "base case" of the project level model, the scenario against which all other candidates are compared. The benefits of any candidate are computed by subtracting its life cycle cost from that of Do Nothing.



As the life cycle activity profile diagram shows, do nothing has three cost components:

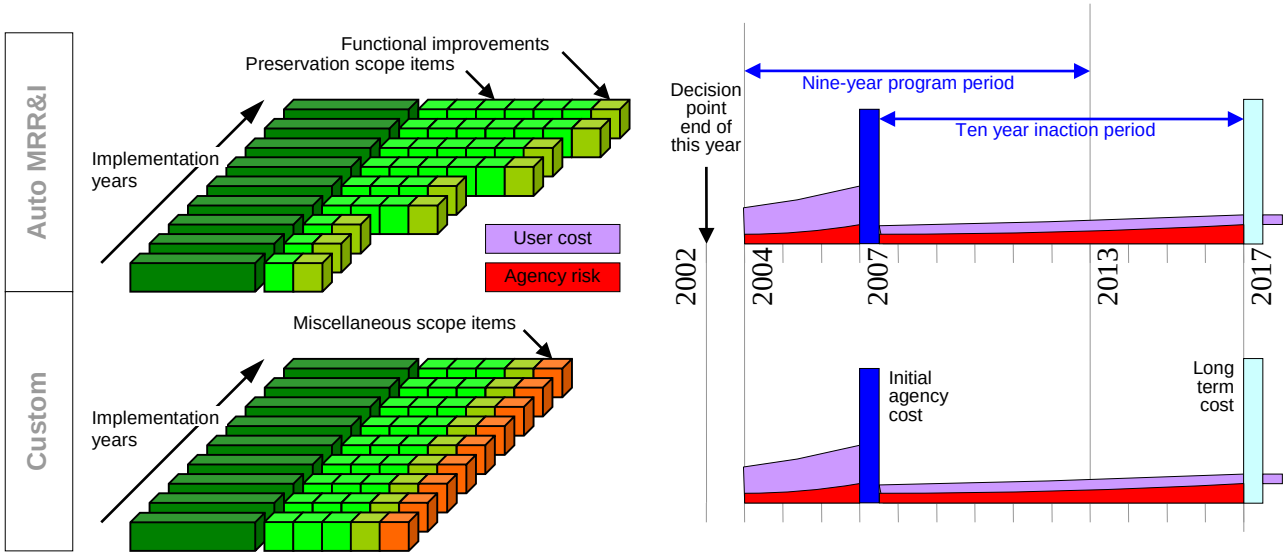
- Agency risk, representing the possibility of unplanned emergency repairs or replacement during the program period due to advanced deterioration and other hazards.
- User cost, recognized if there are any functional needs on the bridge, and also including the excess user costs due to natural and man-made hazards.
- Long-term cost, representing future costs after the program period, as a function of ending conditions.

The deterioration model and traffic growth model are the reasons why costs of the first two components increase over time. User cost continues, without further growth, after the end of the program period unless bridge replacement gives lower life cycle costs. Agency risk and the risk portion of user cost are assumed to end after the program period.

Auto MRR&I and Custom Candidates

Most of the analytical capability of the system is concerned with the Auto MRR&I (maintenance, repair, rehabilitation, and improvement) candidate, and Custom candidates created from it. The project level analysis tool has automated procedures to create a reasonable — but not optimized — first-cut project scope based on preservation and functional needs forecast for each year of the program.

The engineer is encouraged to create Custom candidates by making a copy of an Auto MRR&I candidate in a particular year, and then modifying it by adding, deleting, or editing scope items. Custom candidates can have any type of scope item other than replacement, including miscellaneous scope items with a user-defined cost and benefit. Preservation scope items can have a user-selected action and quantity, from which the model calculates the cost and benefit.



These candidates contain all of the major cost components.

- Agency risk, representing the possibility of unplanned emergency repairs or replacement during the program period due to advanced deterioration and other hazards. This occurs in the program years before implementation, and also occurs during the ten-year inaction period following implementation.
- User cost, recognized if there are any functional needs on the bridge, and also including the excess user costs due to natural and man-made hazards. If the candidate contains any functional improvement scope items, the user cost is reduced or eliminated from that year forward. (Only replacement is guaranteed to eliminate all excess user costs including risk costs.) If user cost is not completely eliminated, the portion related to functional deficiencies is assumed to continue without growth following the end of the program period. This present value of long-term user cost is capped at the discounted bridge replacement cost.
- Initial agency cost, the actual cost of the work to be done during the implementation year. This is assumed to occur at the start of the year. Custom candidates can have user-specified indirect cost factors. They can also have total cost and benefit adjustment factors.
- Long-term cost, representing future preservation costs after the 10-year inaction period, as a function of ending conditions.

The deterioration model and traffic growth model are the reasons why costs of the first two components increase over time. Risk and long-term cost in the consequence phase are calculated from the results of the preservation output model.

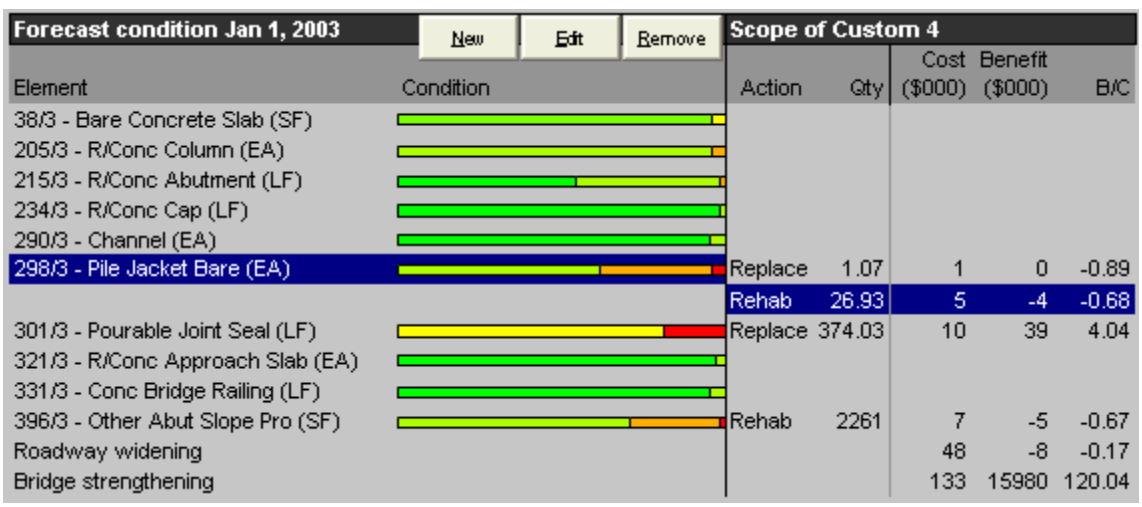
Preservation Scoping - Auto MRR&I

To generate a reasonable project scope for the Auto MRR&I candidate, the PLAT uses the network-optimal action for each condition state of each element where feasible. However, the model also imposes several refinements that modify the project to make it more realistic. The effect of the refinements is that the candidate is more practical, but might not be strictly optimal in a pure economic sense. The engineer can modify candidates, by creating Custom candidates, as a part of the gaming process. Regardless of whether a candidate is economically optimal, the model will provide valid feedback in the form of predicted conditions, life cycle costs, and other performance measures.

The following steps are executed as a part of generating an Auto MRR&I candidate for a given bridge and implementation year:

- Scale feasibility – The potential quantities of feasible actions are investigated to ensure that the implied quantity of work is in a practical range. This eliminates actions too small to be performed economically, and actions so large that a higher-type action (such as replacement) would normally be more appropriate.
- Total recoating or wearing surface replacement – A special variation on the scale feasibility model is evaluated to determine whether all coating or wearing surface elements on the bridge should be replaced, rather than localized repairs.
- Action selection and quantity prediction – From among the actions that are still feasible after the scale feasibility model, the one with lowest life cycle cost for each condition state is selected. This may or may not be the original optimal action. Certain actions may be expanded to encompass more condition states (usually states 2 and/or 3), as a way of forestalling the need to revisit the bridge any time soon.
- Deck replacement – If the deck is replaced, all barriers, wearing surfaces, joints, and drainage systems on the bridge are also replaced.

Each scope item corresponds to one element and one action sub-category, or one functional improvement. It is possible for Auto MRR&I or Custom candidates to have more than one scope item for any given element as in element 298 in the following example.



Scale Feasibility

Scale feasibility determines whether the amount of a particular type of need on a bridge is sufficient to affect the choice of action. This decision is not strictly limited to individual elements, because each bridge could have several elements with the same type of need: for example, girders, floor beams, and stringers may all need to be painted. The scale feasibility model is applied to all actions shown as optimal in the preservation model.

For each action sub-category, all the elements on the bridge that can use it, are grouped together. This is done by computing a weighted average percent in the states where the action is optimal. Weighting is according to the sum of fixed and variable costs if the action is applied to the entire element. The action is marked infeasible if the combined percentage is below a minimum threshold. It would be better to wait until the quantity becomes larger, to make the work more economical.

Thresholds are set on the Action Sub-Categories worksheet. It is recommended that these thresholds be set loosely. Their purpose is to improve the convenience of the tool by eliminating scope items that are obviously impractical, not to make scoping decisions on behalf of the engineer.

Here is an example application of the scale feasibility thresholds.

Check all the feasible actions to see which ones are within the window of feasible scale.
This narrows down the choices for the MRR&I candidate.

RESULTS BY CONDITION UNIT - Classification of action sub-categories

Elem/Envt	Feasible	Too small
215/3	303	144,203,247
226/3	303	144,203,247
234/3	303	141,203
306/3		111,211,311
310/3		113,213,313
321/3		146,201,246,301
331/3	303	114,203
510/3		109,209,309
8099/3		101,201,301
8396/3		121,221,247,307
8475/3	303	144,203,247

An action is too small to be cost-effective if the sum of all feasible actions in the same sub-category on the bridge doesn't reach the minimum threshold.
The threshold criterion is average percent in states where the action sub-category is optimal.
The average is weighted across elements by the cost of applying the action to each entire condition unit.

THRESHOLDS USED (%)

Action sub-category	Minimum	Actual
101 - Replace deck	20	0.02
109 - Replace wearing surface	20	0.02
114 - Replace railing	25	0.00
201 - Major deck repairs	10	3.54
203 - Major concrete repairs	15	1.70
211 - Major joint repairs	20	1.19
213 - Major bearing repairs	10	0.00
247 - Mitigation of setlement or scour	50	0.01
303 - Repair of concrete	10	65.71

Note: Minimum thresholds are applied to each sub-category as a whole.
Actual = The actual criterion for this candidate, used in checking the minimum threshold.

Coating System or Wearing Surface Replacement

Special scale feasibility models are provided to determine whether the bridge should be scoped as total coating system replacement and/or wearing surface replacement. This affects what scope items are created for the Auto MR&R Candidate. The engineer is still free to create Custom candidates that are scoped differently.

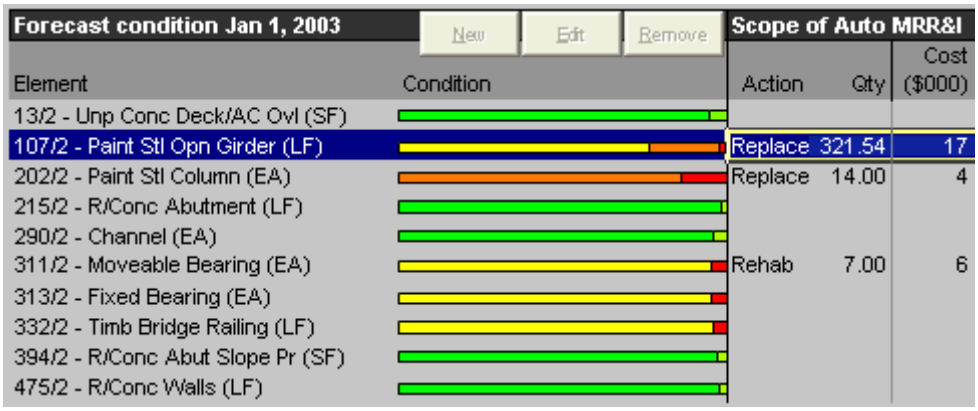
Coating system replacement is specified if both of the following conditions are met:

- A replacement action must be optimal and scale-feasible on at least one coating element.
- The weighted average percent in state 2 or worse among all coating elements must be above the threshold. Weighting is according to the total recoating cost of each element.

Separately, the wearing surface elements on a bridge are evaluated in the same way to determine the need for wearing surface replacement.

The replacement thresholds are set on the Model Parameters worksheet.

Here is an example of a candidate that satisfies these conditions. The girders and columns both have their entire quantities scoped for paint system replacement.



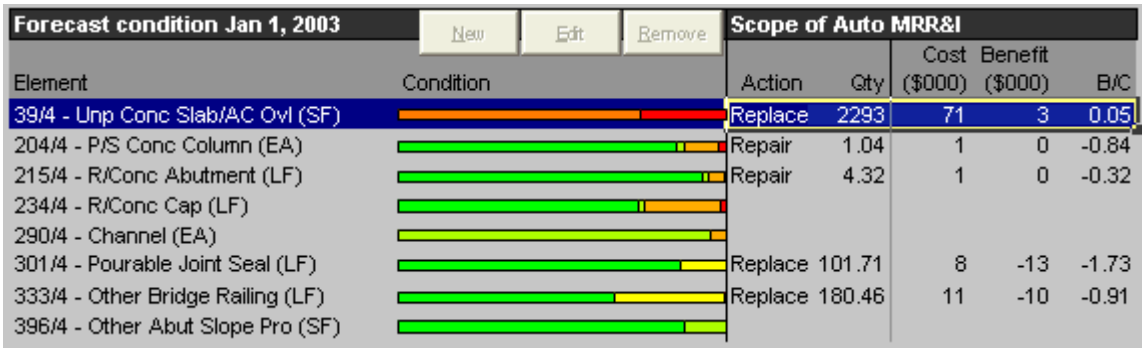
Deck Replacement

Deck replacement in PLAT is a unitary action; that is, it is always applied to the entire element. Florida does not use winter deicing chemicals and does not experience the same difficult deck maintenance issues common in other states, so deck replacement actions are relatively uncommon. Deck models optimized with Florida feasible actions, transition probabilities, and costs, tend to let the deck deteriorate to the worst condition state before a do-something action becomes optimal.

When transition probabilities are used for forecasting on a deck element, the predicted fraction in each condition state is interpreted as a probability that the entire deck will be in that state. The scale feasibility model uses these probabilities, so the minimum threshold is taken as the minimum probability that the deck will be in the investigated condition states. In the project level analysis for a given candidate and implementation year, the worst condition state that has a scale-feasible and optimal do-something action determines what action will be scoped for the entire deck.

Whenever the Auto MRR&I Candidate includes a deck replacement scope item, special handling in the model ensures that any additional deck elements, wearing surfaces, joints, barriers, and drainage systems on the bridge are also replaced. The engineer is still free to create Custom Candidates that are scoped differently.

Here is an example of a candidate scoped with deck replacement.



An interesting aspect of this example is that, even though deck replacement by itself has positive benefits, the combination of deck, joint, and railing replacement has negative benefits on this particular bridge.

Quantity Prediction and Applicability

After feasibility issues are settled, typically the actual quantity of work done in a bridge project is more than the quantity of deterioration that motivated the work. The primary reasons for this are:

- Certain types of work have significant economies of scale if performed on the entirety of an element rather than just a part of it. Deck replacement and paint system replacement are good examples.
- Often maintenance crews in the field discover additional problems not noticed in the inspection. This is especially true with hidden distresses such as concrete delamination.
- It is usually cost-effective, when visiting a structure to address a relatively poor condition state, to take advantage of the opportunity to address other deteriorated states on the same element, if this can be done with the same equipment and crew skills.

The project level model allows each action to apply to more condition states than those for which it is considered feasible, as long as the action is effective and not unreasonably expensive in addressing the deficiencies of the other condition states to which it is applied.

With the exceptions of decks, wearing surfaces, and coatings, element replacement is considered applicable for states 3 and 4; major repairs for states 2, 3, and 4; and minor repairs for states 2 and 3.

Calculation of quantities is done before the estimation of costs and condition outcomes. The application of each action to each condition state may have a different unit cost and effectiveness vector than the same action applied to other states. The means of deciding what unit costs and effectiveness vectors to use is determined in the preservation output model.

When an action does not address all deteriorated condition states of an element, it is possible that there could be more than one action on different parts of the same element. This would occur most often when a part of an element is replaced. The final scope of work of a model-generated project on a given element is determined from the following algorithm:

```
For each condition state of the element (starting with the worst)
    Find the feasible action with lowest long-term cost
        Apply the action to all the states to which it is applicable
        Calculate the action quantity as the sum of quantities in the applicable states
        Then skip to the next condition state that has not already been addressed
```

Preservation Output

In Auto MRR&I and Custom Candidates, it is common for the quantity of work in a particular scope item to differ from the quantity in the condition state for which the scope item's action is optimal according to life cycle cost minimization. In fact, in Custom candidates the quantity might not correspond exactly to any combination of condition states, since the engineer is free to enter any quantity at all. The project level analysis tool needs a reasonable way to match parts of a scope item with condition states, in order to use the most appropriate unit costs, action effectiveness vectors, and benefits.

The algorithm to do this examines the predicted probabilities in each condition state, starting with the worst. For each state, it examines the scope items (starting with the lowest action sub-category number, generally the most expensive) to find work most appropriate for that state. When it finds a match of actions, it matches quantities, and then deducts the matched quantity from running tallies of quantities in the condition state and scope item. The algorithm works in four stages, performing all possible matches at each stage for all condition states before proceeding to the next, stopping when all quantities of both condition states and scope items have been assigned. The stages are:

1. Optimal – A match occurs if the scope item's action subcategory agrees with the life cycle cost minimizing optimal action for the condition state.
2. Feasible – A match occurs if the scope item's action subcategory agrees with any feasible action for the condition state.
3. Applicable – A match occurs if the scope item's action subcategory is applicable to the condition state. This search is done by examining other condition states and their action lists, first in the direction of worse states, then in the direction of better states, until all states are examined or an action is found that matches the scope item's action sub-category and is applicable to the investigated condition state.
4. Non-Applicable – This is similar to the Applicable search except that the match is based only on action sub-category, without requiring that the action be applicable to the investigated condition state. This search occurs only toward states worse than the investigated state.

For any match that is found, the model uses the matched condition state and action to locate appropriate unit costs, long-term costs (for the benefit calculation), and action effectiveness vectors.

If any additional quantities are in deteriorated states, they are assumed to be unaffected by the project. They continue to deteriorate during the implementation year. For example, consider a steel girder element with 200 feet in state 5, and the rest in state 1. If a scope item is 100 feet of steel girder replacement (which could happen if the engineer manually reduced the quantity), then 100 feet are returned to state 1 and the rest remain in state 5.

If any additional unallocated quantity exists in a scope item, it has little or no effect. Its cost is included in the project but the effectiveness might be no better than the existing condition. In the example of the previous paragraph, if the scope item were increased to 300 feet of replacement, the project cost would reflect this but the benefit would only reflect the 200 feet, since the rest is already in state 1.

Cost Estimation

Each candidate has an initial cost that is assumed to occur at the beginning of the implementation year. For the Do Nothing candidate, the initial cost is always zero. For Auto MRR&I and Custom candidates, initial cost is made up of two components:

- Direct costs, which are always the sum of the direct costs of the scope items in the project.
- Indirect costs, consisting of maintenance of traffic (MOT), mobilization, and engineering (including design, construction engineering, and inspection).

The Replacement candidate combines direct and indirect costs into a single unit cost per square foot.

The first step of cost estimation for Auto MRR&I and Custom Candidates is a direct cost adjustment factor. This is always zero for Auto MRR&I, but may be set to a non-zero value (in percent, positive or negative) in Custom candidates. This gives the engineer a chance to raise or lower the direct cost to account for factors outside the model.

Following application of the direct cost adjustment factor, the indirect cost factors (in percent, positive or negative) are applied separately to the adjusted direct cost to calculate indirect costs. In the Auto MRR&I candidate, indirect cost factors depend on the types of elements present on the bridge, according to a table on the Model Parameters worksheet. The program computes a weighted average indirect cost factor, using the direct costs of scope items as weights. For painting scope items, the cost factors for painting are used instead of the cost factors by element type.

Indirect cost by work type (% of adj. direct cost)		
Type or element group	MOT	Mobilzn
Painting	3.3826	21.6174
Railing	3.3826	21.6174
Joints	3.3826	21.6174
Deck	3.3826	21.6174
Equipment/machinery	3.3826	21.6174
Superstructure	3.3826	21.6174
Bearing	3.3826	21.6174
Substructure	1.5034	9.6077
Culvert	3.3826	21.6174
Channel	3.3826	21.6174

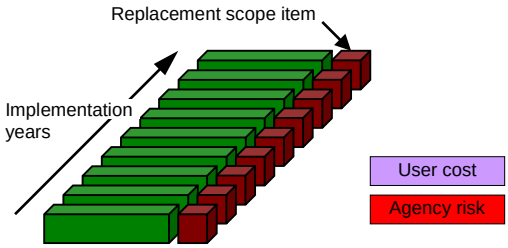
Preservation unit costs in PLAT were updated in 2016 based on Florida maintenance and contract data. They were divided into variable and fixed (direct and indirect) components according to the same factors found on the Model Parameters table. The scope item list on the Dashboard worksheet reports the total direct and indirect cost of each scope item, which will always agree with the sum of candidate direct and indirect costs in the Candidate Details pane for the Auto MRR&I candidate.

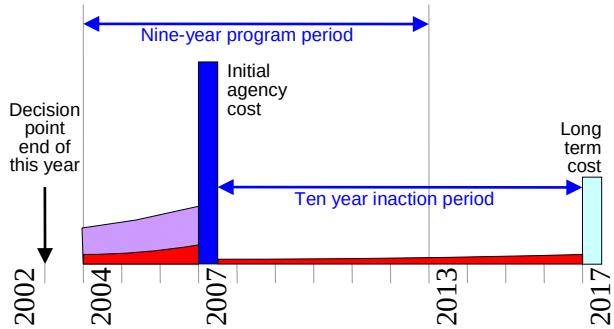
Custom candidates allow the engineer to modify the indirect cost factors. This changes the candidate indirect cost but does not change the scope items. In addition, the engineer may add cost items to a Custom candidate by using Miscellaneous scope items, which have user-specified costs and benefits.

As a final adjustment, the engineer may specify cost and benefit adjustment factors in the Bridge Pane of the Dashboard worksheet. The default values of each of these factors is 1.0. These factors affect the Initial agency cost, Agency benefit, and User benefit reported in the right-most column of the Candidate Details Pane, but they do not affect any other reported numbers. All candidates, including Do Nothing and Replacement, are affected by these factors.

Replacement

The Replacement candidate normally provides an upper bound on the cost and effectiveness of work that can be done on a bridge. Currently the project level analysis tool does not have features to analyze traffic requirements and their impact on the design of a replacement bridge. Therefore, the model is fairly simple. It computes initial costs from a swell factor (a multiplier reflecting the fact that replacement bridges are usually longer and wider than what they replace) and a unit cost per deck area (which varies according to maximum span length), both found on the Model Parameters worksheet. For other life cycle cost computations in the consequence phase, it is assumed that the replacement bridge has the same elements in the same quantities as the old bridge, starting in new condition. Other than the swell factor, no costs or benefits are recognized because of a larger or better-constructed bridge.





Replacement contains all of the major cost components.

- Agency risk, representing the possibility of unplanned emergency repairs or replacement during the program period due to advanced deterioration and other hazards. This occurs in the program years before implementation, and also occurs during the ten-year inaction period following implementation.
- User cost, recognized if there are any functional needs on the bridge, and also including the excess user costs due to natural and man-made hazards. Replacement is assumed always to remedy all functional needs and risks, so there are no excess user costs following replacement.
- Initial agency cost, the actual cost of the work to be done during the implementation year. This is assumed to occur at the start of the year.
- Long-term cost, representing future preservation costs after the 10-year inaction period, as a function of ending conditions.

The deterioration model and traffic growth model are the reasons why costs of the first two components increase over time.

Long-Term Cost

Each Candidate has a life cycle activity profile consisting of near-term and long-term costs. Near-term costs entail all costs within the program period incurred up to, and including, the year of implementation. These are the costs directly associated with decisions the engineer must make.

On each bridge, it is desired that the engineer be required to plan only the first programmed activity. Beyond this, further work is very far in the future and is subject to much uncertainty. Therefore, this subsequent work is treated as a predicted outcome, rather than as a decision variable. The essential piece of information we need about the future work is its contribution to life cycle cost. No work is done for a 10-year hiatus following the implementation year of the Candidate. At the end of the hiatus period, we recognize a residual long-term cost, which is the present value of all future work as described under optimal preservation policy.

Long term costs are computed at the element level, based on conditions at the end of the implementation year, forecast further through the hiatus period by the do-nothing deterioration model. They act as a penalty for leaving the element in less than perfect condition.

Long-Term Optimization and Residual Cost

PLAT uses the AASHTOWare Bridge Management (BrM) database: it no longer directly accesses a Pontis database and does not require Pontis to be installed. However, as an interim measure the life cycle cost factors and optimal actions were developed in 2016 by using an analysis of these costs that was performed using Pontis. Once the BrM 5.2.3 framework is more fully defined, the goal is to create a new life cycle cost analysis that is consistent with BrM definitions in order to estimate long-term costs for PLAT.

In Pontis, long-term cost is an estimate of life cycle cost over an infinite time horizon, calculated separately for each present condition state, assuming that a given policy is followed. It is calculated as follows:

Long-term cost $$L_{ia} = C_{ia} + \alpha \sum_j P_{aij} L_{j\bar{a}(j)}$$

where: C_{ia} is the unit cost of action *a* (fixed + variable) when the element is in state *i*

α is a discount rate for costs incurred one year in the future

P_{aij} is the transition probability of an element to be in state *j* in one year given state *i* and action *a* this year (Pontis deterioration model)

$\bar{a}(j)$ is the optimal action for state j (the action giving the lowest long-term cost)

$L_{j\bar{a}(j)}$ is the long-term cost which would be calculated next year if state *j* occurs and the optimal action for that state is selected (calculated recursively by the same equation)

The long-term cost equation is recursive, because it depends on a term which itself is calculated according to the same equation. It is not circular, however, because the long-term cost term on the right-hand side is for one year later than the left-hand side. When fully expanded, the equation is potentially an infinite series, because the time horizon of the analysis is not strictly limited. However, because of discounting, the contribution of each subsequent term is less than the previous one, approaching zero.

Pontis simplifies the problem by assuming that in the long-term, the equation reaches a steady-state, where the conditions and actions remain in the same proportions from one year to the next. The probability of any given state in year *t* is equal to the probability of the same state in year *t+1*. In other words, for each foot of girder moving out of a particular condition state, another foot moves in to replace it.

The project-level analysis tool assumes that, ten years after the implementation year of a candidate, the Pontis optimal policy starts to be followed, incurring the long-term cost as calculated above. Long-term costs increase with condition state, as in the rightmost column of the example below. If the candidate and its subsequent 10 years of deterioration leave a large fraction of an element in the worst state, then it is likely that further major work will be needed in the near future, and long-term costs will therefore be high.

ELEMENT 152 - Steel Floor Beam (Environment 4)											
Quantity 44055.00 lf. Group 5 Protectors: 301 8516											
	INPUTS BY CONDITION STATE AND ACTION										
FromState		Action	Sub-category	Prob1	Prob2	Prob3	Prob4	Applicability	VarCost	FixCost	LTCost
1	>> 0	Do nothing	000-Do nothing	Unmodified transition time = 9.4 years				1234	0.00	0.00	81.24
2	>> 0	Do nothing	000-Do nothing	Unmodified transition time = 29.7 years				1234	0.00	0.00	127.70
	1	Spot blast	319-Surface restoration of	70.85	29.15	0.00	0.00	23	110.96	36.99	202.89
	2	Spot blast and minor repai	302-Repair of steel	70.85	29.15	0.00	0.00	23	110.96	36.99	202.89
3	0	Do nothing	000-Do nothing	Unmodified transition time = 24.3 years				1234	0.00	0.00	203.56
	>> 1	Spot blast and minor repai	302-Repair of steel	70.85	29.15	0.00	0.00	23	110.96	36.99	202.89
	2	Spot blast and major repai	202-Major steel repairs	76.89	23.11	0.00	0.00	234	5,479.31	1,826.44	7,365.30
	3	Repair distortion	248-Repair of distortion	76.89	23.11	0.00	0.00	234	5,479.31	1,826.44	7,365.30
4	0	Do nothing	000-Do nothing	0.00	0.00	0.00	100.00	1234	0.00	0.00	1,099.82
	1	Spot blast and major repai	202-Major steel repairs	76.89	23.11	0.00	0.00	234	5,479.31	1,826.44	7,365.30
	2	Repair distortion	248-Repair of distortion	76.89	23.11	0.00	0.00	234	5,479.31	1,826.44	7,365.30
	>> 3	Replace unit	141-Replace beam	100.00	0.00	0.00	0.00	34	790.36	263.45	1,097.28

Functional Needs

Each bridge is examined for deficiencies that could affect the level of service provided to road users. When such deficiencies are found, the economic consequences, in terms of user costs, are estimated and added to the life cycle cost of the structure. Functional improvements may be undertaken to eliminate these user costs. Four types of functional needs are modeled:

- Deficient roadway width, which works together with deficient approach alignment to create excess accident risk, relative to a bridge constructed according to design standards. A width deficiency is recognized if the bridge roadway width is less than the required width. Required and design widths are calculated from:

  Required width = 2 × Design shoulder width + Number of lanes × Design lane width

  Design width = 2 × Design shoulder width + Number of lanes × Design lane width

  Bridges under a given length threshold have required and design widths based on the approach road width.

- Impaired vertical clearance, forcing certain trucks to find an alternate and presumably longer route. A deficiency is identified by comparing roadway vertical clearance with level-of-service standards.
- Inadequate load capacity, forcing certain trucks to find an alternate and presumably longer route. A deficiency is identified by comparing bridge operating rating with level-of-service standards.
- Moveable bridge openings, causing delays to highway traffic.

Level-of-service and design standards are determined from information given on the Model Parameters worksheet. A bridge may have any or all of the types of needs. Whenever a functional need is found, a flag appears in the Appraisal Flags portion of the Bridge Pane of the Dashboard worksheet, and a new scope item is created in the Scope Pane for the Auto MRR&I Candidate. Functional improvement scope items may also appear in custom Candidates.

A functional need is relieved by performing a functional improvement or replacement. The possible actions are:

- Widening – Relieves the width deficiency on the roadway on the bridge.
- Raising – Relieves the vertical clearance deficiency on all roadways under the bridge.
- Strengthening – Relieves the operating rating deficiency on the roadway on the bridge.
- Replacement – Relieves width deficiencies on and under the bridge, approach alignment deficiency, vertical clearance deficiency on and under the bridge, operating rating deficiency, and moveable bridge opening delays.

The initial agency costs of these actions are calculated from a unit cost per square foot of deck, as established on the Model Parameters worksheet.

Functional improvements reduce or eliminate excess user costs. The “excess” amount of user costs is determined by comparing the existing bridge with a replacement bridge constructed according to the design standards. Since replacement addresses more deficiencies than any of the other functional improvements (e.g. width deficiencies under the bridge), it is possible for a bridge to continue to have functional deficiencies and user costs even after functional improvements have been performed.

The Do Nothing Candidate allows no actions, including functional improvements, to occur during the program period. Its life cycle cost model assumes that either the excess user costs continue at a constant level forever after the end of the program period, or the structure is replaced just after the end of the period, whichever gives a lower life cycle cost. This is done to provide a consistent basis for comparing projects.

User Costs and Traffic Growth

When a functional deficiency is found to exist on a bridge, the effect on road users is represented as a user cost. This user cost is calculated for each year of the deficiency, discounted to present value, and added to life cycle cost. Functional improvements may eliminate certain user costs, so that they do not occur in any following years.

User costs are proportional to traffic volume, so they change each year because of traffic growth. In most cases, the model interpolates the traffic volume for any given year based on a constant growth rate between the most recent ADT and the future ADT provided in the roadway table of BrM. The complete formula is as follows:

Forecast average daily traffic $$V_{ry} = V_{r0} \times \left(\frac{V_{rn}}{V_{r0}} \right)^{\left(\frac{Y - Y_{r0}}{Y_{rn} - Y_{r0}} \right)}$$

Where: V_{r0} is the most recent actual traffic volume estimate (NBI item 29, adttotal in the roadway table)
Y_{r0} is the year of most recent traffic volume estimate (NBI item 30, adtyear in the roadway table)
V_{rn} is the forecast future traffic volume (NBI item 114, adtfuture in the roadway table)
Y_{rn} is the year of forecast traffic volume (NBI item 115, adtfutyear in the roadway table)
Y is the current year of the program simulation

If the most recent ADT is missing or zero, the effect is to turn off the entire user cost model. If any other variables needed for the traffic growth calculation are missing, the model uses the most recent ADT directly.

To provide a uniform basis for comparing candidates, the model adheres to the following conventions:

- User costs are discounted to present value (the end of the year when the model is calculated) under the assumption that they occur at the end of the year they are incurred.
- No user costs are recognized prior to the first year of the program (the base year).
- In the remaining years prior to the implementation year of a candidate, user costs are calculated based on existing functional deficiencies in the inventory. Level-of-service standards in this model are not dependent on traffic volume, so functional needs do not change from year to year if no action is taken.
- No user costs are recognized during the implementation year of the candidate. In the future, a work zone user cost will handle this case.
- After the implementation year, up to the last year of the program, user costs are based on any uncorrected functional deficiencies. Certain deficiencies (e.g. roadway width under a bridge) can be corrected only by replacement. Also, custom candidates can exclude needed improvements.
- After the end of the program period, the model assumes that either the remaining excess user costs continue at a constant level (without traffic growth) forever, or the structure is immediately replaced, whichever gives a lower life cycle cost.

The following types of user costs are recognized in the models: excess accident risk due to narrow bridge roadways; excess truck detours due to impaired vertical clearance; excess truck detours due to insufficient operating rating; and delays due to the opening of moveable bridges. In each case, the “excess” is computed by comparing the existing bridge with a bridge improved or replaced according to design standards.

A description of the detailed user cost computations on a bridge can be found on the Details worksheet (see example.)

Accident Risk

Accident risk costs occur if the bridge roadway width is deficient according to the level-of-service standards. The model for this cost was developed in Florida in 1998, based on a statewide bridge database and a statewide crash database. (Thompson et al 1999) Accident costs are calculated by:

$$\text{Weight\%} \times 365 \times \text{AADT} \times \text{AccCost} \times (\text{CurrRisk} - \text{ImprRisk})$$

Where: Weight% is the user cost weight given on the Model Parameters worksheet;
AADT is annual average daily traffic for the year analyzed;
AccCost is the unit cost per accident, on the Model Parameters worksheet;
CurrRisk is the current accident risk as described below;
ImprRisk is the improved accident risk as described below.

The Accident unit cost was derived from the results of a literature review conducted for Florida DOT in 1998, updated to 2016 using the Consumer Price Index. It is typical in public policy analysis for regulatory and investment purposes to use the "willingness-to-pay" approach, which includes the tangible costs of an accident such as medical care, property damage, insurance and legal expenses, employer costs, lost productivity, and travel delay; plus the intangible costs of pain & suffering, loss of enjoyment of life, inconvenience, and the premium associated with risk aversion. This methodology is well established in the safety literature.

Current and improved accident risk are calculated from a statistical regression model developed in Florida, based on bridge characteristics. Accident risk is calculated as:

$$(\text{Coef1} + \text{Coef2} \times \text{Lanes} \times \text{Length} + \text{Coef3} \times \text{Narrowness} \times \text{AADT}) \div 1000 \div \text{AADT}$$

Where: Coef1 is 886 for urban arterials and -377 (negative) for all other roads;
Coef2 is 0.7323;
Coef3 is determined from the table below;
Lanes is the number of lanes on the roadway (NBI 28, roadway.lanes);
Length is the length of the bridge (meters, NBI 49, bridge.length);
Narrowness is Lanes ÷ Traveled way width (meters, NBI 51, roadway.roadwidth);
AADT is annual average daily traffic for the year analyzed.

Determination of Coef3

Coef3	Good approach alignment (>6)	Bad approach alignment (<=6)
Good deck condition (>6)	0.3904	0.5031
Bad deck condition (<=6)	0.4531	0.7899

Deck condition here is NBI item 58, bridge.dkrating. Approach alignment is NBI item 72, inspevnt.appralign. Functional class (NBI 26, roadway.funcclass) is used in the determination of Coef1: values 14 and 16 are urban arterials. Note that these models were developed for metric data, so US Customary data coming into the model must be converted first.

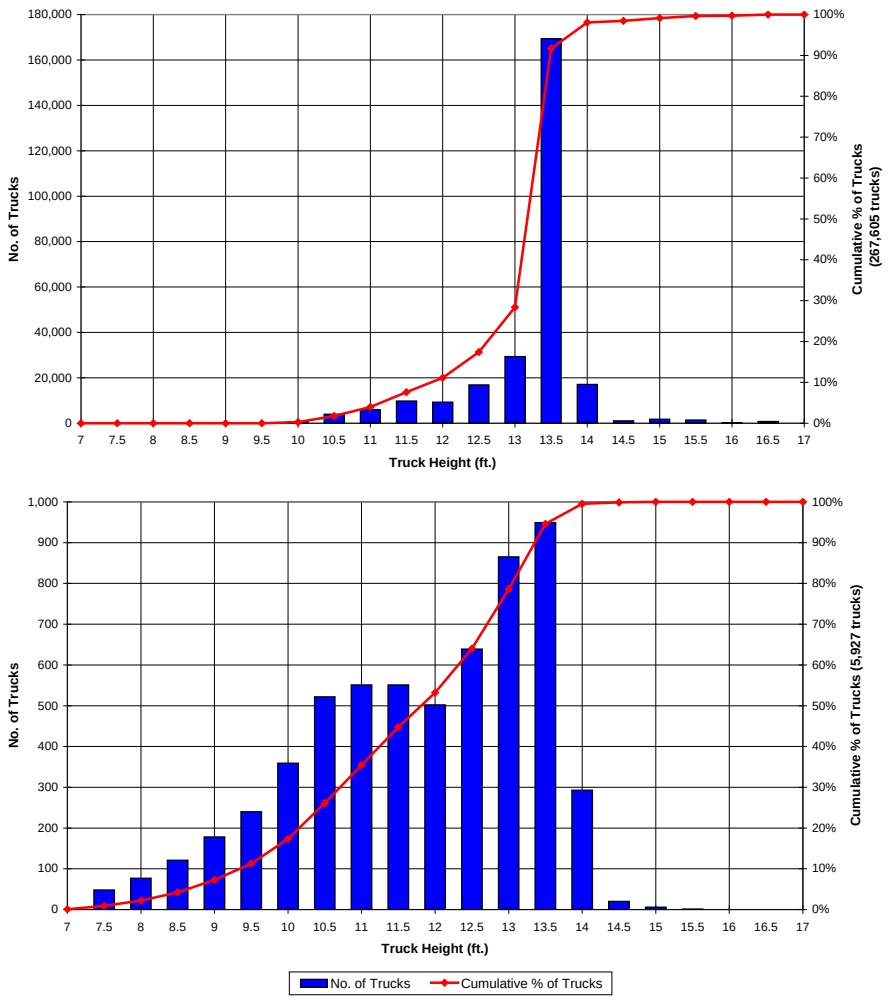
Vertical Clearance

Truck detour costs occur if the roadway vertical clearance (NBI 10, roadway.vclrinv) is deficient according to the level-of-service standards. Trucks too high to pass under the bridge are forced to detour, presumably on a longer route. The user cost of this is calculated by:

$$\text{Weight\%} \times 365 \times \text{AADT} \times \text{DetCost} \times \text{Truck\%} \times (\text{CurrDet\%} - \text{ImprDet\%})$$

Where: Weight% is the user cost weight given on the Model Parameters worksheet;
AADT is annual average daily traffic for the year analyzed;
DetCost is the detour cost per truck;
Truck% is the fraction of trucks in the AADT (NBI 109);
CurrDet% is the percent of trucks detoured by the current bridge;
ImprRisk is the percent of trucks detoured by the improved bridge.

To determine the percent of trucks detoured by any given vertical clearance restriction, a truck height histogram was developed (Sobanjo and Thompson 2004). Laser measuring equipment was installed at strategic locations on the Florida highway network to measure the full spectrum of vehicle heights. The following graphs show the results for Interstate (top) and non-Interstate roadways.



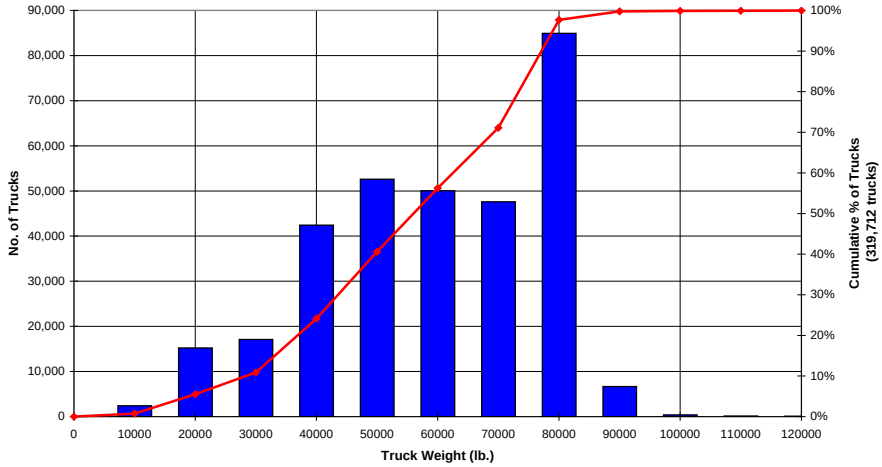
Load Capacity

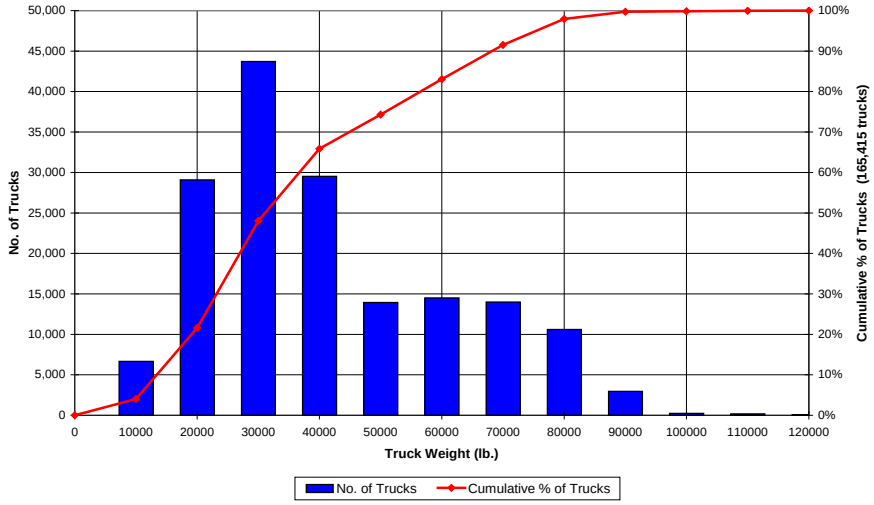
Truck detour costs occur if the bridge operating rating (NBI 64, bridge.orload) is deficient according to the level-of-service standards. Trucks too heavy to pass under the bridge are forced to detour, presumably on a longer route. The user cost of this is calculated by:

$$\text{Weight\%} \times 365 \times \text{AADT} \times \text{DetCost} \times \text{Truck\%} \times (\text{CurrDet\%} - \text{ImprDet\%})$$

Where: Weight% is the user cost weight given on the Model Parameters worksheet;
AADT is annual average daily traffic for the year analyzed;
DetCost is the detour cost per truck;
Truck% is the fraction of trucks in the AADT (NBI 109);
CurrDet% is the percent of trucks detoured by the current bridge;
ImprRisk is the percent of trucks detoured by the improved bridge.

To determine the percent of trucks detoured by any given operating rating restriction, a truck weight histogram was developed from Florida DOT weigh-in-motion data (Sobanjo and Thompson 2004). The following graphs show the results for Interstate (top) and non-Interstate roadways.





Truck detour cost

Each time a truck is detoured, it experiences vehicle operating costs associated with the added detour distance, and travel time costs associated with the added detour time. This cost is incurred for vertical clearance and load capacity deficiencies.

Detour cost per truck $\quad DetCost = VOC \times BypLen + TT \times BypLen/BypSpd$

Where:
- VOC is the unit vehicle operating cost per km of detour (Model Parameters worksheet)
- BypLen is the detour distance (km, NBI 19, roadway.bypasslen)
- TT is the unit travel time cost per hour of detour (Model Parameters worksheet)
- BypSpd is the speed on the detour route (kph, not in the NBI, roadway.det_speed)

FDOT collects detour speed information, but since this is not an NBI data item it may be missing in certain cases. When missing, the model estimates the detour speed by factoring the roadway speed (BrM roadway table), using the bypass speed factor on the Model Parameters worksheet. Since roadway speed also is not an NBI item, the model has a set of default speed values by functional class on the Model Parameters worksheet.

Economic parameters VOC and TT were developed in a literature review in Florida (Thompson et al 1999) and updated to 2016 using the Consumer Price Index.

Example Computation

WIDENING of roadway on the structure

INPUT DATA (all lengths in meters)

On_under:	On	DeckWidth:	10.000	FuncClass:	7	ApprAlign:	3
Length:	41.600	RoadWidth:	8.500	ADT (now):	6,485	DkRating:	7
Lanes:	2	ApprWidth:	3.800	Growth%	2.323		

This is a short bridge (<=60 m.)

Required width: ReqWidth = ApproachFrac*ARoadWidth = 0.3 * 3.800 = 8.820 m.

Design width: NewWidth = ApproachFrac*ARoadWidth = 0.3 * 3.800 = 8.820 m.

"" RoadWidth<ReqWidth and RoadWidth<NewWidth so roadway needs widening.

ACCIDENT COST PARAMETERS based on the FDOT accident risk model

Name	Coefficient	Description
Coef1	-377.3701	Constant (based on urban arterial functional class)
Coef2	0.7323	Coefficient for Lanes * Length
Coef3	0.3403	Coefficient for ADT * Lanes / RoadWidth (based on ApprAlign and DkRating)
AccCost	34,231	User cost per accident
Weight	1.0000	User cost weight

Accident risk = (Coef1 + Coef2*Lanes*Length + Coef3*ADT*Lanes/RoadWidth) / 1000

Excess cost = (Unimproved minus improved accident risk) * AccCost * Weight (but not less than zero)

Since ADT varies by year due to traffic growth, so does accident cost.

EXCESS ACCIDENT COST BY YEAR

Year	ADT	OldRisk	NewRisk	ExcessCost
2003	6,674	0.219	0.200	1,831
2004	6,870	0.235	0.215	1,885
2005	7,071	0.251	0.230	1,940
2006	7,278	0.267	0.246	1,997
2007	7,491	0.284	0.263	2,056
2008	7,711	0.302	0.280	2,116
2009	7,937	0.320	0.297	2,178
2010	8,169	0.339	0.315	2,242
2011	8,408	0.358	0.334	2,307

Long-term potential user cost (perpetuity with no growth) is $43,838 discounted to $26,247.

This is not yet capped at replacement cost.

Widening will add 75.712 sq.m of deck area and cost $48,456 ($640/sq.m).

RAISING to improve vertical clearance for roadways under the structure

There are no roadways under the structure.

STRENGTHENING to improve operating rating for the roadway on the structure

INPUT DATA (all lengths in meters, operating rating in metric tons)

On_under:	On	OpRating:	32.20	FuncClass:	7	Truck%	20
Length:	41.600	Bypass-km:	16.000	ADT (now):	6,485	Speed-kph:	51
DeckWidth:	10.000	Bypass-kph:	51	Growth%	2.323		

Level of service standard: 33 metric tons for this functional class.

OpRating<Standard, so operating rating needs to be strengthened.

Vehicle operating cost per detoured truck is bypass length * cost per km = 16.000*0.27 = $4.32

Travel time cost per detoured truck is bypass length / bypass speed * cost per hr = 16.000/51*26.43 = $8.29

Excess cost = Annual trucks detoured * cost per truck * user cost weight.

User cost weight is 100.00%.

The number of detours is calculated by ADT*Truck%*365*Percent detoured.

Since ADT varies by year due to traffic growth, so does the number of trucks detoured.

From the truck weight histogram, 11.246% of trucks are detoured.

EXCESS DETOUR COST BY YEAR

Year	ADT	Detours	VehOper$	TravTime$
2003	6,674	54,794	236,708	454,335
2004	6,870	56,398	243,641	467,641
2005	7,071	58,050	250,776	481,337
2006	7,278	59,750	258,120	495,434
2007	7,491	61,500	265,680	509,944
2008	7,711	63,301	273,461	524,878
2009	7,937	65,155	281,470	540,250
2010	8,169	67,063	289,713	556,073
2011	8,408	69,027	298,198	572,358

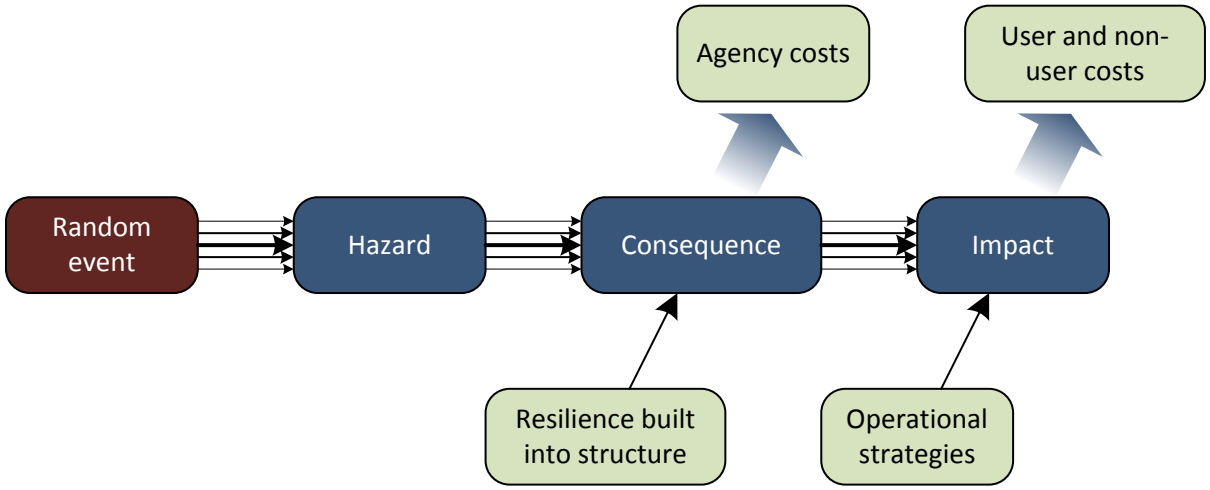
Long-term potential user cost (perpetuity with no growth) is $16,540,575 discounted to $9,903,453.

This is not yet capped at replacement cost.

Strengthening will cost $133,120 (416.000 sq.m at $320).

Risk

A variety of bad things can happen to good bridges in Florida: hurricanes, tornadoes, wildfires, floods, collisions, advanced deterioration, and fatigue (Sobanjo and Thompson 2013). The causes are, at least in part, outside agency control and subject to random external factors. They are considered to be hazards, which are quantified in terms of the likelihood of hazard occurrence. All of these hazards can cause a bridge to be damaged or destroyed, delivering a consequence to the agency (the cost to repair or replace the structure) and an impact on the public (disruption of transportation service and of the larger economy).



Hazards are modeled probabilistically. At a given bridge site, the hazard can strike with various levels of severity that can be forecast only with a broad concept of probability distribution. An F2 tornado 500 feet wide may touch down near a bridge, pass 1000 feet from the structure, and do no damage. The same tornado with stronger winds or a slight variation in its path, may destroy the same bridge. Tornadoes can happen anywhere in Florida, and do occasionally damage bridges. It is impossible to forecast future events on one given bridge, but it is possible to quantify a general level of risk based on regional records of tornado occurrence and statewide tornado damage.

Once a hazard strikes, the damage to the structure and impact on the public are also probabilistic, subject to a limited degree of agency control. A wildfire near a bridge may engulf and destroy the structure, or may cause varying levels of repairable damage, or may spare the structure and merely disrupt traffic with a pall of smoke. Efforts by emergency crews to save the structure or to minimize the impact on traffic have varying effectiveness, depending on random factors. When a hurricane strikes, the Department may close bridges pre-emptively to protect life, even if the bridge is not ultimately damaged.

For bridge management purposes, the main decision variable in the risk analysis is the selection and timing of programmed actions to increase the resilience of the Department's structures, thus indirectly influencing the social costs caused by hazards. The controllable costs of structure resilience and operational strategies, are combined with the more random future outputs of agency, user, and non-user costs due to hazards, to produce forecasts of life cycle costs.

If a project is delayed, this lengthens the period of higher risk costs, and thus increases LCC. The benefit of accelerating a project by one year is the one-year savings in life cycle cost. In a priority programming context where a limited budget must be allocated among projects each year, the best projects are those which would save the most in risk costs, relative to each dollar spent, if they are done this year rather than waiting another year.

Predicting risk on one bridge

In the Project Level Analysis Tool, the reason for predicting risk is to develop a reasonable and consistent basis for selecting and prioritizing projects. An FDOT research project developed an extensive set of risk models to do this (Sobanjo and Thompson 2013).

In any kind of forecasting model, it is important to separate long-term trends from short-term statistical noise. The fact that a tornado hit a specific bridge in the past, does not mean that particular bridge is more susceptible than the other bridges near it. Historical risk data are inherently "lumpy," and therefore must be smoothed geographically, over time, and within bridge types, in order to make reasonable forecasts. Smoothing can be done by classifying bridges into families or geographic groups, or by fitting statistical models to bridge characteristics.

Risk for one hazard on one bridge in one year is modeled as a social cost as follows:

$$C^{risk} = \sum_{s} \left(P_s^L \sum_{c} \left(P_{sc}^C D_{sc} (C^A + C^U) \right) \right)$$

Where P_s^L = Hazard likelihood probability of severity level *s*
P_{sc}^C = Consequence probability of class *c*, given severity level *s*
D_{sc} = Degree of damage in class *c*, given severity level *s*
C^A = Agency cost of recovery, per unit of D_{sc}, for class *c* and severity level *s*
C^U = User and non-user costs, per unit of D_{sc}, from class *c* and severity level *s*

This equation reflects the idea that a hazard may occur at various levels of severity, and each level of severity can produce a spectrum of consequences. The specifics of each event determine a quantity of damage to the bridge. This damage, in turn, produces agency and user/non-user costs in proportion to the quantity of damage.

The risk analysis divides up the social cost equation into three parts that can be analyzed separately. First, a unitless risk index that quantifies the combined effect of the probability distributions of severity and consequence, and their relative damage levels:

$$X = \sum_{s} \left(P_s^L \sum_{c} P_{sc}^C d_{sc} \right)$$

Next is the agency cost consequence of one unit of the risk index, which reflects the cost of repairing or replacing the bridge and recovering from an extreme event. This can be expressed as a function of bridge replacement cost as follows:

$$DC^A = Dc^A C^R$$

Where Dc^A = Recovery cost, as a multiple of replacement cost, for one unit of damage
C^R = Replacement cost of the bridge, in dollars

Here Dc^A is a scaling constant that is the same for every bridge. As would be expected, larger bridges are assigned more risk, because they cost more to repair or replace. Replacement cost is computed by multiplying bridge deck area by the average cost per square foot for bridge replacement.

Finally comes the user cost of one unit of the risk index, which reflects the inconvenience and harm to users and non-users of an extreme event. This can be expressed as a function of the maximum daily detour cost as follows:

$$DC^U = Dc^U C^D$$

Where Dc^U = User/non-user cost, as a multiple of one days' detour cost, for one unit of damage
C^D = User cost of detouring all traffic around the bridge for a day, in dollars

The daily detour cost is computed using the same methods PLAT already uses for its user cost model (Thompson et al 1999), based on traffic volume, detour distance, and detour speed. Bridges with higher volumes or longer detours are assigned more risk because the total amount of user inconvenience is greater, in the event of a service disruption. The formula for this cost is:

$$C^D = ADT(c^{VOC}BL + c^{TT}BL/BS)$$

Where ADT = Average daily traffic forecast for the year to be analyzed
c^{VOC} = Unit vehicle operating cost per mile
c^{TT} = Unit travel time cost per hour
BL = Bypass length in miles (NBI item 19, or roadway.bypasslen in BrM)
BS = Bypass speed in mph (roadway.det_speed in BrM)

With these substitutions, the risk cost can be computed as:

$$C^{risk} = XDC^A + XDC^U$$

Which is simply the expected value of agency cost plus the expected value of user cost.

Hurricanes

The hurricane likelihood model is prepared from geographic data on historical hurricane occurrence in the five categories on the Saffir-Simpson scale (Sobanjo and Thompson 2013). This data source is already geographically smoothed, and reflects the fact that wind speeds are typically much higher on the coast than inland. One of the primary hurricane damage processes, storm surge, is also a coastal phenomenon.

In each of the five wind categories, consequence estimates were prepared for each element on a 0-5 scale, with 5 being the most severe. Structure design types (NBI items 43A and 43B) were also given relative consequence scores. In addition, consequences were scaled according to bridge age and scour criticality. Together, these explanatory variables reflect several different damage processes and causes of vulnerability to winds and storm surge. The relative values were assigned judgmentally after extensive review of historical records, as discussed earlier in this report.

Taking the availability of data into account, the risk index is computed as follows:

$$X = \sum_{s} (P_s^L V_s^E) V^G V^S V^A$$

Where Ps^L = Likelihood probability for hurricane category *s*
V_s^E = Element vulnerability score, averaged over all elements on the bridge, for category *s*
V^G = General vulnerability score based on structure design and material (NBI item 43)
V^S = Vulnerability score based on scour criticality (NBI item 113)
V^A = Vulnerability score based on age of the bridge (computed from NBI item 27)

If Ps^L is missing for a given bridge, it is provided from district or statewide averages.

All of the vulnerability scores are statewide parameters that are assigned to each category or element using expert judgment, informed by a study of historical damage reports. In most cases they are initially assessed on a scale of 0 to 5, then scaled so they have a value of 1.0 for a “typical” bridge in the inventory, by adding 1 and dividing by 3. The correct score is then automatically assigned to each bridge or element based on the characteristics found in the inventory.

Age-based vulnerability is a linear function of bridge age, computed as follows:

$$V^A = (y - Y) * m + b$$

Where *y* = Base year, when the age-based vulnerability score is set to 1
Y = Year the bridge was built
m = Slope of the line
b = Vulnerability factor in the base year, which is 1.0

The parameters of this line are set using expert judgment to reflect the improvement in risk-based design methods over time.

Other natural hazards

Tornado likelihood was developed from historical records of tornado paths (Sobanjo and Thompson 2013). A bridge is associated with a particular tornado if the hazard passed within one mile of it. Even though tornadoes are common in Florida and can happen anywhere in the state, they are not common enough to produce a smooth probability distribution. Therefore, the historical incidence of tornadoes was accumulated by district in order to produce a more reasonable forecast of future tornado probability for any particular bridge.

Consequences of tornadoes were graded on a 0-5 scale by structure design type (NBI 43B) and by range of underclearance. Bridges with higher underclearances have been found to have an increased incidence of severe tornado damage in the historical record. Since design methods for wind loads have improved over the past few decades, age of each bridge was also used as a consideration in the risk allocation.

Wildfires were modeled in a manner quite similar to tornadoes. While they are very common across Florida, it was still necessary to smooth the historical data in order to have consistent predictions of future event likelihood.

Unlike many other states, most occurrences of scour in Florida are associated with hurricanes or flooding, and rarely occur independently of those extreme events. As a result, both categories of risk were combined and modeled as flooding events in this analysis. Floods are localized phenomena that occur in areas of low elevation, so the location of a bridge relative to a flood plain was the most significant factor in assessing hazard likelihood.

For a flood to damage a bridge by scour, it is necessary for a substructure unit to be in the water, at least during flood events. A bridge may also be damaged by changes in the river channel, which may erode the river bank and wash out the approach or expose the abutment foundation. Bridges may also be damaged by hydraulic pressure on the structure, or by impact of water-borne debris with the structure. Several available data items therefore contribute to the consequence assessment: superstructure design type, average span length, channel condition (NBI item 61), scour criticality (NBI item 113), and bridge age.

Vehicular damage

Although vessel collision is a very real concern in Florida, there is minimal data available about vessel traffic under bridges (Sobanjo and Thompson 2013). As a result, it was necessary to assign an equal risk likelihood to all bridges having navigable waterways and requiring pier protection. The pier protection data item (NBI item 111) and year of construction were used to distinguish consequences.

The hazard probability for truck overloads was assumed to be proportional to the fraction of trucks detoured due to operating rating limits. This fraction can be computed using a truck weight model developed in an earlier study with Florida weigh-in-motion data (Sobanjo and Thompson 2004). The percent of trucks detoured is:

For bridges carrying interstate highways:

OR<10000	100
OR<80000	102.24 - (8.982E-5)*OR - (1.4336E-8)*OR^2
OR<91000	18.976 - (2.083E-4)*OR
OR higher	0

For all other functional classes:

OR<3725	100
OR<85000	107.26 - (1.9743E-3)*OR + (6.5265E-9)*OR^2 + (2.2256E-14)*OR^3
OR higher	0

Where OR is the operating rating of the bridge, in pounds (NBI item 66).

This percentage is multiplied by average daily traffic and truck percent to yield an estimate of the number of trucks unable to use the bridge. It is assumed that some unknown fraction of these trucks will fail to detour, and an unknown fraction of those will overload the bridge, causing its damage or destruction. No effort is necessary to determine these fractions, since the calibration process includes an appropriate scale in the *D* parameter.

The consequence model for overloads considers the superstructure condition (NBI item 59) and bridge age as influential variables.

The hazard probability for over-height truck collisions was assumed to be proportional to the fraction of trucks detoured due to vertical clearance restrictions. This fraction can be computed using a truck height model developed in an earlier Florida study using laser truck counting equipment (Sobanjo and Thompson 2004). The percent of trucks detoured is:

For bridges carrying interstate highways:

VC<9.65	100
VC<13	855.91 - 223.43*VC + 22.199*VC^2 - 0.74236*VC^3
VC<14	(1.0956E+56)*VC^(-48.683)
VC<16.1	14.567 - 0.9046*VC
VC higher	0

For all other functional classes:

VC<7.3	100
VC<13.5	-26.275 + 34.692*VC - 2.3894*VC^2
VC<14	138.86 - 9.886*VC
VC higher	0

Where VC is the vertical clearance over the roadway, in feet (NBI item 10). This can apply to roadways under a bridge or on it, if vertical clearance is restricted.

This percentage is multiplied by average daily traffic and truck percent to yield an estimate of the number of trucks unable to use the bridge. It is assumed that some unknown fraction of these trucks will fail to detour, and an unknown fraction of those will strike the bridge, causing its damage or destruction. No effort is

necessary to determine these fractions, since the calibration process will include an appropriate scale in the *D* parameter.

A bridge can be damaged by other types of truck collisions on or under the bridge. This is especially a problem with fuel tanker trucks, which can ignite and damage the bridge by fire. The hazard probability for truck collisions is assumed to be proportional to the truck accident risk computed by the FDOT accident risk model (Thompson et al 1999). This model, developed using a regression analysis of bridge characteristics and crash statistics, computes accident risk as follows:

Expected truck accidents per year = Truck percent * (Term1 + Term2 + Term3)/1000, where:

Term1 = 886.0098 for urban arterials (functional class 14 or 16), or -377.3701 otherwise
Term2 = 0.7323*lanes*length
Term3 = coef3*lanes/roadwidth*adt

Where “length” is the structure length in meters (NBI item 49) and “lanes” is the number of lanes (NBI item 28). For roadways under the bridge, “length” is the bridge deck width (NBI item 52) in meters. “Roadwidth” is the traveled way width in meters (NBI item 51) and “adt” is the average daily traffic forecast for the year being analyzed. The coefficient on term3 takes the following values based on approach alignment and deck condition:

If approach <= “6” and deck <=”6”	0.7899
If approach <= “6” and deck >”6”	0.5031
If approach > “6” and deck <=”6”	0.4531
If approach > “6” and deck >”6”	0.3904

Note that this model was developed for metric data so proper conversions are performed.

For the consequence model, bridge age and structure type (NBI 43A and 43B) are considered significant, since newer bridges have more fire protection (such as standoff barriers), and certain structure types and materials are more resistant to fires.

Advanced deterioration

The hazard likelihood for advanced deterioration is estimated from forecast condition, using the following formula (Sobanjo and Thompson 2013):

$$P^L = \frac{a\varphi\left(\frac{ln(D)-\mu}{\sigma}\right)}{\sigma D\left(1-\Phi\left(\frac{\ln(D)-\mu}{\sigma}\right)\right)} + bD + c$$

where:

D	= decay index as computed below
ln(D)	= natural logarithm of the decay index
μ	= mean of *ln(D)* (table below)
σ	= standard deviation of *ln(D)* (table below)
$\varphi((ln(D)-\mu)/\sigma)$	= probability density function of the normal distribution
	= NORMDIST(ln(D),μ,σ,FALSE) in Excel
$\Phi((ln(D)-\mu)/\sigma)$	= cumulative distribution function of the normal distribution
	= NORMDIST(ln(D),μ,σ,TRUE) in Excel
a,b,c	= regression coefficients (table below)

Coefficients and distribution parameters for the hazard model

	Coefficients			Distribution	
Material	a	b	c	μ	σ
Concrete – prestressed	3000	0.00199	0	15.461	3.982
Concrete – reinforced	3000	0.00047	0	15.385	3.928
Steel	3000	0.00196	0	15.545	3.998
Timber	3000	0.00539	0	15.077	3.902

The regression coefficients and statistical distribution parameters in the model vary by NBI item 43A, main unit structure material type.

The decay index is similar to the health index (Shepard and Johnson 2001), but focuses on the worst two condition states of each element. The rationale and development process for it are described in the Final Report of this study. It is computed from current or forecast element-level condition as follows:

$$D = 100\sum_c \frac{W_c}{TEV_c}\left(\sum_s w_{cs}CEV_{cs}\right)$$

$$CEV_{cs} = \sum_{e\in c}(P_{es}Q_eC_e)$$

$$TEV_c = \sum_{e\in c}(Q_eC_e)$$

Where P_{es} = Fraction of element *e* observed or forecast to be in condition state *s*
Q_e = Quantity of element *e* on the bridge

C_e = Unit replacement cost of element e
W_c = Relative weight (importance) of component c (table below)
w_{cs} = Relative weight (importance) of condition state s of component c

This equation is organized into three components, deck, superstructure, and substructure. The three components are combined as a weighted average, using W_c as the weight. The equation considers two condition states for each element. The worst condition state is always given full weight, w_{c1}=1.0. The second-worst state is tabulated below. The coefficients vary by NBI main unit material (item 43A).

The consequence measure for advanced deterioration is structure replacement, rehabilitation, or posting. From the historical record, approximately 55 bridges per year are replaced due to advanced deterioration (statewide, including local bridges); 39 are rehabilitated, and 13 are posted. Using average agency and user costs as described earlier, this represents a total agency cost of $283 million and a total user cost of $331 million. These results are used in the risk allocation process to determine the appropriate scaling constants for the model.

Coefficients for the decay index

	Component weights W_c			2nd-worst state w_{cs}		
Material	Deck	Super	Substr	Deck	Super	Substr
Concrete – prestressed	20%	40%	40%	50%	50%	50%
Concrete – reinforced	20%	40%	40%	50%	50%	50%
Steel	20%	40%	40%	50%	50%	50%
Timber	40%	40%	20%	10%	50%	50%

Fatigue

The fatigue model, like the advanced deterioration model, directly estimates the probability of damage to a bridge (Sobanjo and Thompson 2013). As a result, it is not necessary to use a risk allocation process. Fatigue is included in the risk analysis if any of the following are true:

- Main unit material (NBI 43A) is 3 or 4 (steel superstructure) and design type (NBI 43b) is between 2 and 17 inclusive;
- Approach unit material (NBI 44A) is 3 or 4 (steel superstructure) and design type (NBI 44b) is between 2 and 17 inclusive;
- Fracture critical inspections are required on the bridge (NBI 92AA)

The bridge is excluded from the analysis if it was built during or after the year 1980, or if key traffic and truck data are missing or zero. The social cost of the risk is computed from:

$$C^{risk} = P^L C^{FR} + P^L C^{FD}$$

Where P^L = Probability of fatigue cracking
C^{FR} = Repair cost when a crack is found
C^{FD} = User cost when a crack is found

The probability of cracking is estimated using an adaptation of the AASHTO fatigue life model, using a lognormal distribution with respect to age of the bridge. It is computed as:

$$P^L = LOGNORMDIST\left(\frac{A}{A_M}, 0, ln\left(\frac{A_M}{A_E}\right)\right)$$

$$P^L = 0 \; if \; \frac{R_\gamma^M K_\gamma (g-1)}{T_1 C S^3} + 1 \leq 0$$

$$A_M = \frac{R_\gamma^M K_\gamma}{C T_1 S^3} \; if \; g = 1$$

$$A_M = \frac{\log\left(\frac{R_\gamma^M K_\gamma (g-1)}{T_1 C S^3} + 1\right)}{\log(g)} \; for \; any \; other \; g$$

$$A_E = \frac{R_\gamma^E K_\gamma}{C T_1 S^3} \; if \; g = 1$$

$$A_E = \frac{\log\left(\frac{R_\gamma^E K_\gamma (g-1)}{T_1 C S^3} + 1\right)}{\log(g)} \; for \; any \; other \; g$$

Where A = Age of the bridge in the year being analyzed
A_M = Mean age at the onset of cracking (years)

A_E = Evaluation fatigue life (one standard deviation sooner than A_M)
R_γ^M = Resistance factor (unitless) for fatigue category γ and mean life (table below)
R_γ^E = Resistance factor (unitless) for fatigue category γ and evaluation life (table below)
K_γ = Empirical fatigue constant (ksi^3) for fatigue category γ (table below)
C = Number of stress range cycles per truck passage
1.0 if maximum span length (bridge.maxspan)>12m
2.0 otherwise
S = Effective stress range (ksi) at the critical detail
T_1 = Single-lane truck volume in the first year of the bridge's life (explained below)
g = Traffic growth factor (explained below)

For this analysis, the appropriate fatigue detail category and stress range for the critical detail can be specified individually for each bridge. By default, the model assumes category D with a conservative stress range of 5 ksi.

Fatigue model parameters

Fatigue Category	R_γ^M	R_γ^E	K_γ (ksi^3)
A	2.8	1.7	2.50 E+10
B	2.0	1.4	1.20 E+10
B'	2.4	1.5	6.10 E+09
C	1.3	1.2	4.39 E+09
C'	1.3	1.2	4.39 E+09
D	1.6	1.3	2.20 E+09
E	1.6	1.3	1.10 E+09
E'	2.5	1.6	3.90 E+08

The growth factor g can be determined from BrM data, as follows:

$$g = \left(\frac{adtfuture}{adttotal}\right)^{\frac{1}{adtfutyear - adtyear}}$$

where all of the symbols are fields in the BrM roadway table. If adttotal is zero or missing, the bridge should not be included in the fatigue analysis. If any of the other variables are zero or missing, a growth factor of g=1.0 can be assumed.

The first-year truck volume is determined from the latest traffic count and the growth factor, and adjusted to estimate the maximum single-lane volume:

$$T_1 = 365 \times \frac{adttotal}{g^{(adtyear - yearbuilt)}} \times \frac{truckpct}{100} \times SLF$$

where adttotal, adtyear, and truckpct are in the BrM roadway table, and yearbuilt is in the BrM bridge table. If truckpct is missing, the AASHTO LRFD spec provides the following default values:

Functional class 01 (rural interstate)	20
Functional classes 02-11 (all other rural, and urban interstate)	15
Functional classes 12-19 (all other urban)	10

If any other fields are missing, the bridge should be excluded from the analysis. SLF is the single-lane factor, as follows:

If trafficdir=3 or lanes=1	1.000
If trafficdir=1 and lanes=2	0.850
If trafficdir=1 and lanes>2	0.800
If trafficdir=2 and lanes=2 or 3	0.500
If trafficdir=2 and lanes=4 or 5	0.425
If trafficdir=2 and lanes>5	0.400

where trafficdir and lanes are in the BrM roadway table. If either of these database fields are missing or zero, the bridge should be excluded from the analysis.

Agency consequences of fatigue are estimated from typical crack repair costs. Total agency cost (dollars) of repair of all fatigue cracks on a bridge in a year, given that at least one crack has been observed, is computed from this formula:

$$C^{FR} = \sum_{u} M_u N_u \left(F_{\gamma u} U_{\gamma u} + I\right)$$

where: u = Bridge unit (main or approach)
M_u = Span multiplier, cracks per span in a typical fatigue repair, default value = 0.2
N_u = Number of spans in unit u
$F_{\gamma u}$ = Cost impact factor (unitless) for category γ (see below)
$U_{\gamma u}$ = Agency cost, in dollars, of repairing one typical crack (see below)
I = Indirect cost, dollars per crack (traffic control, access, and mobilization) = $1500

The research described earlier in this report found an appropriate costing methodology in NCHRP Report 495 (Fu et al 2003) and updated the metrics. The recommended cost impact factors are as follows:

For trusses with fatigue detail category D:

Up to 120 feet in span	0.75
Up to 200 feet in span	1.00
Greater spans	1.20

For non-trusses with fatigue detail category D:

Up to 65 feet in span	0.51
Up to 100 feet in span	1.00
Up to 120 feet in span	1.33
Up to 140 feet in span	1.70
Up to 160 feet in span	2.16
Greater spans	2.70

For trusses or non-trusses with fatigue detail category E or E':

Up to 100 feet in span	0.75
Up to 120 feet in span	1.00
Up to 140 feet in span	1.28
Up to 160 feet in span	1.63
Greater spans	2.03

The unit costs recommended for 2013 dollars are as follows:

Trusses or non-trusses, category D	$2000
Non-trusses, category E or E'	4400
Trusses, category E or E'	5200

The user impact of fatigue cracking is estimated to entail the detour of all trucks for an average of 8 days, based on Department experience. Thus the formula is:

$$C^{FD} = C^{D}T \times 8\ days$$

where: C^{D} = Maximum daily detour cost, from equation above
T = Truck percent in the traffic stream

Performance Measures

Some of the most important outputs from the project level analysis tool are performance measures. These are used on the Dashboard worksheet to compare candidates with each other, and to evaluate project timing. On the Screening worksheet, they are used to prioritize bridges for planning attention.

Outside the system, performance measures can be used in network-level analysis in procedures to maximize the effectiveness of the bridge program subject to funding constraints. They can also be used in more general asset management, to compare bridge investments with other uses of Department funds.

The following table lists the performance measures used in the project level analysis tool, and tells how they are used. Follow the links for more information about how the measures are computed.

Measure	Dashboard Forecasting	Dashboard Timing	Screening	Derivation
NBI deck condition	Yes			See NBI Condition Ratings
NBI superstructure condition	Yes			See NBI Condition Ratings
NBI substructure condition	Yes			See NBI Condition Ratings
NBI culvert condition	Yes			See NBI Condition Ratings
Worst NBI condition	Yes			See NBI Condition Ratings
Health index	Yes		Yes	See Health Index
Paint health index	Yes		Yes	See Health Index
Cost of needs	Yes			See Needs
Benefit/cost of needs	Yes			See Needs
User cost	Yes			See User Costs
Accident risk	Yes			See Accident Risk
Life cycle cost		Yes		Agency, user, or total. See Analytical Framework
Action category		Yes	Yes	See Action Sub-Categories
Candidate initial cost		Yes	Yes	See Cost Estimation
Candidate benefit		Yes	Yes	Agency, user, or total. See Benefit
Candidate benefit/cost		Yes	Yes	Agency, user, or total. See Benefit
Urgency			Yes	See Urgency
Sufficiency rating			Yes	See FHWA 1994.
Replacement rank			Yes	See Wang 1991.
Avg NBI condition			Yes	See NBI Condition Ratings

Dashboard Forecasting — Can be forecast and graphed over the program period on the Dashboard worksheet, for any Candidate Year
Dashboard Timing — Can be analyzed and graphed as a function of Candidate timing
Screening — Can be sorted in the Screening worksheet

Health Index

The Health Index was first proposed by the California Department of Transportation as a type of weighted average condition measure for a bridge or any subset of an inventory. It includes all condition states, weighting each element by its failure cost or by some other appropriate weight. This gives emphasis to elements that have the biggest economic impact on bridge functionality. Prioritization by health index gives the same results as "worst-first" prioritization, which understates the importance of preventive maintenance on the better condition states. As a measure of current inventory condition, however, the Health Index is a consistent way to reduce the voluminous data in an element inspection into a simpler quantity that can be compared across bridges and over time. The Health Index is computed as follows:

Health index

$$HI = \frac{CEV}{TEV} \times 100$$

Current element value

$$CEV = \sum_{e} W_e \left(P_{e1} + \frac{2}{3} P_{e2} + \frac{1}{3} P_{e3} \right)$$

Total element value

$$TEV = \sum_{e} W_e$$

where W_e is the health index weight for element e
P_{ei} is the fraction of element e in condition state i

This index can be computed for an individual element, for a group of elements, a whole bridge, or any group of bridges. The Dashboard worksheet shows current health index for element groups and for the bridge as a whole. It plots historical health index values for past element inspections, and forecasts future health index values for any implementation year of any candidate. It does the same for the health index of painted steel elements. Current health index and paint health index is also available in the Screening worksheet for sorting of bridges.

Needs

Needs are actions that would be most cost-effective to perform right away on a bridge, if funding and project readiness are not considered. In the project level analysis tool, Needs are used as an economic condition measure. As the condition of an element declines, its needs grow. Since this quantity is expressed in dollars, the Needs on a bridge can be computed as an unweighted sum over its elements.

To determine needs on an element, the system uses the long-term cost minimizing optimal action for each condition state. The unit cost of this action is multiplied by the quantity in the condition state, then the result is summed over all condition states.

If there is a do-something action that gives a lower long-term cost than the Do Nothing action, then the unit cost of Needs will be greater than zero. The benefit of this work is computed as the long-term cost of Do Nothing, minus the long-term cost of the do-something action.

Therefore, any non-zero preservation needs will have a cost, benefit, and a benefit/cost ratio. All of these are used as performance measures on the Dashboard worksheet. For current conditions, Needs are reported for the bridge as a whole and for element groups. The Dashboard also forecasts future needs for any implementation year of any candidate.

Benefit

In the project level analysis tool, the term “benefit” is always used to denote a savings in life cycle costs of doing something, relative to doing nothing. Therefore it is always an economic quantity.

For candidate projects, agency benefit is the total agency life cycle cost of the Do Nothing candidate, minus the agency life cycle cost of the candidate in question. Similarly, user benefit is the total user cost of the Do Nothing candidate, minus the user cost of the candidate in question. In most cases the Dashboard and Screening worksheets report these benefits separately, as well as added together as total benefit.

A benefit/cost ratio is also computed. Keep in mind that benefits in the numerator of this ratio are computed from life cycle costs, where all costs are discounted according to how far in the future they occur. Costs in the denominator of the benefit/cost ratio are not discounted.

The Dashboard worksheet uses benefits and benefit/cost ratios to compare candidates with each other, and to evaluate changes in the implementation year of a candidate. The Screening worksheet uses these measures to sort bridges for planning attention.

Urgency

Urgency is an economic criterion to prioritize bridges for immediate attention in the Screening worksheet. It is calculated on each bridge from life cycle costs as follows:

1. Identify the candidate with the lowest total life cycle cost in the first implementation year.
2. Identify the candidate with the lowest total life cycle cost in the second implementation year.
3. Compute the difference in life cycle costs between (1) and (2), then divide by the cost of (1).

This measure is therefore a benefit/cost ratio of doing work in the first year rather than the second year, assuming that in either case you would choose the candidate with the lowest life cycle cost. If bridges are sorted in descending order by urgency, then the top bridges on the list are the ones most in need of immediate attention.

NBI Condition Ratings

An improved translation algorithm was developed in the 2010 project to convert element inspection data, arising either from inspections or from Markovian model forecasts, into NBI condition ratings (Sobanjo and Thompson 2010). Compared to the official FHWA translator, the new model is much more effective, especially when used with the output of deterioration models. This helps to make forecasts of NBI condition ratings more suitable for use as a performance measure.

The translation algorithm operates in the following steps:

1. Calculate an element condition index as a weighted average of the observed or forecast condition state probabilities for each element. The methodology is similar to the health index computation, but performed separately for each element. A polynomial regression model, which differs based on the number of defined condition states, adjusts the results to improve the correlation between element inspection data and field-gathered NBI condition ratings.
2. Convert each element condition index into an element-level NBI-style (0-9) condition rating, using another polynomial regression model.
3. For each NBI component (deck, superstructure, substructure, culvert), combine the relevant element condition indexes into a weighted average NBI condition rating. Weights are established separately for each element on the Element Definitions and Models worksheet. Slab elements are counted in both the deck and superstructure components. Non-bridge elements (such as sign structures) and movable bridge elements are not included in the NBI ratings.
4. For each component having one or more relevant smart flags, adjust the NBI condition rating by multiplying by the smart flag condition index. If there is more than one relevant smart flag, use the one with the worst condition index.
5. For bridges over 10 years old, apply a final adjustment model, which further improves the correlation between the translated NBI condition rating and field-collected NBI condition ratings. This adjustment is not applied to bridges after replacement actions.

It should be emphasized that the Florida translator results are not FHWA-approved. FDOT continues to gather NBI condition ratings during its routine inspections, for reporting to FHWA and for use in characterizing the current condition of the bridge inventory. However, the translated NBI ratings are used in PLAT analysis results to provide the best possible forecast of future NBI condition ratings as a consequence of evaluated investment candidates.

In addition to the NBI condition ratings, PLAT also computes the simple average and minimum of all available NBI condition ratings for a bridge. It is used in the Screening worksheet as a way of prioritizing bridges for attention. The NBI items considered are:

- Deck condition (58)
- Superstructure condition (59)
- Substructure condition (60)
- Culvert rating (62)

Any of these items that lack numeric (0-9) ratings are skipped in computing the average or minimum.

It should be emphasized that the translator was developed for the element and condition state definitions that were in effect in 2010. It does not reflect the changes in definitions that were made in 2015.

Administration

It is recommended that the Excel workbook be administered as a custom reporting program for purposes of deployment and security. It reads from the BrM database and produces results to be read or printed by the end-user. It does not write anything back to the BrM database, but may store results upon request in the PLAT Results database.

A small amount of data (mainly Custom Candidates) are created within the workbook and may be saved by the end-user in an Excel .XLS file in the local file system. These data have a lifespan of about a year, before they are likely to become outdated because of new inspections. Like most Excel files, these should have a normal level of security, protected by the local machine's Windows login procedure and regular backups.

It is important to note that it is not necessary to save the Excel file if no project customization has been performed. Bridge inventory and inspection data are always refreshed from the BrM database as a part of loading the workbook file.

Deployment is recommended to occur once per year. The most convenient way, for administrative purposes, is to provide an Excel template .XLT file in a centralized location accessible to all the users. Each user should launch the system by first launching Excel, then using File – New to create the Excel workbook from the template. If desired, a Windows short-cut to the template can be provided, to ensure that a fresh copy of the system is always loaded. If the user attempts to use File-Save to save changes to the file, Excel automatically prompts for a file location and name.

The template can be made read-only in the file system so it cannot be modified. To minimize the template file size, you may want to set the Screening filter to select few or no bridges. End-users will need to change the filter settings, then, to make the Screening list show the bridges for which they are responsible. They are automatically prompted to do this the first time they visit the Screening worksheet.

You can modify the Word document containing the Users Manual, and create a new Acrobat file from it. The Acrobat file must be named "Florida PLAT Users Manual.pdf". Use print driver settings that produce a bookmark pane and create hyperlinks. When you click the Users Manual button on the toolbar, the software searches first in the network templates path, then the local templates path, and finally in the directory containing the workbook (if it was previously saved), looking for this file. Your local templates path is the one that appears first when you save an Excel file as a template, or when you create a new Excel workbook from a template. You can change this path from File – Options in Excel.

A deployment checklist has been prepared to assist in designing an orderly deployment process. It is recommended that a regular process be undertaken to ensure data quality. See Data Management for information on the data used in the project level analysis tool.

The worksheets in the system are designed to be modified by advanced users. Such modifications can be gathered and deployed to all users in the subsequent release.

Deployment Checklist

The following steps should be completed each year to update the project level analysis tool and deploy it to all users in headquarters and district offices. To access the Excel worksheets containing administrative data and analytical inputs, you will need to click the Options button on the toolbar, then check the Advanced box and click OK. This turns off worksheet protection and exposes the worksheet tab bar, providing access to all the worksheets in the system.

- ❑ Update BrM analytical data
  - o Check definitions of elements and actions, updating if necessary.
  - o Adjust element preservation costs for inflation.
  - o Update deterioration models, if necessary, using the methodology in Sobanjo and Thompson 2010. Cost and deterioration models should receive a thorough update on 5-year intervals.
  - o Redevelop or update the life cycle cost model. This should at least be kept adjusted for inflation.
  - o Check the values of all other analysis parameters to ensure they are still up-to-date.
- ❑ Ensure bridge data quality control. All of the data items in the detailed list, especially the ones highlighted as being used in the analytical procedures, should be subject to a regular quality assurance program to detect and correct missing or suspicious data.
- ❑ Identify a clean copy of the latest Excel template and Users Manual, incorporating any software updates and refinements made in the past year.
- ❑ Check and update the information on the Configuration worksheet.
- ❑ Place the PLAT Results database in a location where it is accessible on the network, then set up an ODBC Profile for it on the computers that will output to it. Enter the appropriate database connect string on the Configuration worksheet.
- ❑ Finalize the Excel template for deployment.
  - o Ensure that the database connect string is correct for end-users.
  - o Clear the Advanced checkbox on the Options dialog.
  - o If file size is an issue, set the Screening filter to select few or no bridges.
  - o Save the file as an Excel template, along with the Users Manual, in the Office network templates directory.
  - o Set the file's read-only bit.
  - o Remove and archive the old template.
- ❑ Notify end-users of the new release. If necessary, send them a new shortcut file pointing to the new template.

Data Management

The database structure chart provides a detailed map of all the major data stores in the system that affect the project level analysis. This diagram is important if you ever plan to modify the worksheets or software, since it shows how all the major parts relate to each other. The three columns in the diagram indicate the three places where data are stored:

- BrM tables. The software reads data from the BrM tables in the left column, and does not write any data back to BrM.
- Data structures. Held in memory in VBA code, these hold the inputs, intermediate results, and outputs of the project-level analysis.
- Worksheets. Excel worksheets provide persistent storage for data that cannot be accessed efficiently, or at all, from the BrM database. They also present analytical results to the engineer.

All of the objects in the upper 3/4 of the chart are bridge-specific. Any time you change the selection of Bridge ID, the indicated BrM tables are accessed to load the necessary structure data. Any time any inputs to the project-level analysis may have changed, the data structures in the upper 3/4 of the center column are re-generated. The dark green Dashboard and Inventory worksheets at upper right are re-generated to show the new data and results.

If you create or modify custom candidates for a bridge, this information is stored in the light green Candidates and Scope Items worksheets. Data for only one bridge may be stored in a file: this bridge is identified on the toolbar. The Movable worksheet is used only for movable bridges and also stores data specific to one bridge.

If you click the Details button on the toolbar, the software prepares a detailed log of all the calculations in the project analysis on the dark blue Trace worksheet, and activates that worksheet. This action also has the effect of re-generating all the data structures in the upper 3/4 of the chart.

On the Screening worksheet, you can re-generate the list of bridges by clicking the Filter or Update buttons on the toolbar. This processes every bridge in the selected subset of the inventory. For each bridge, the system loads data from the BrM tables at upper left, rebuilds the upper data structures, and then updates the Screening worksheet. It does not change any of the other worksheets.

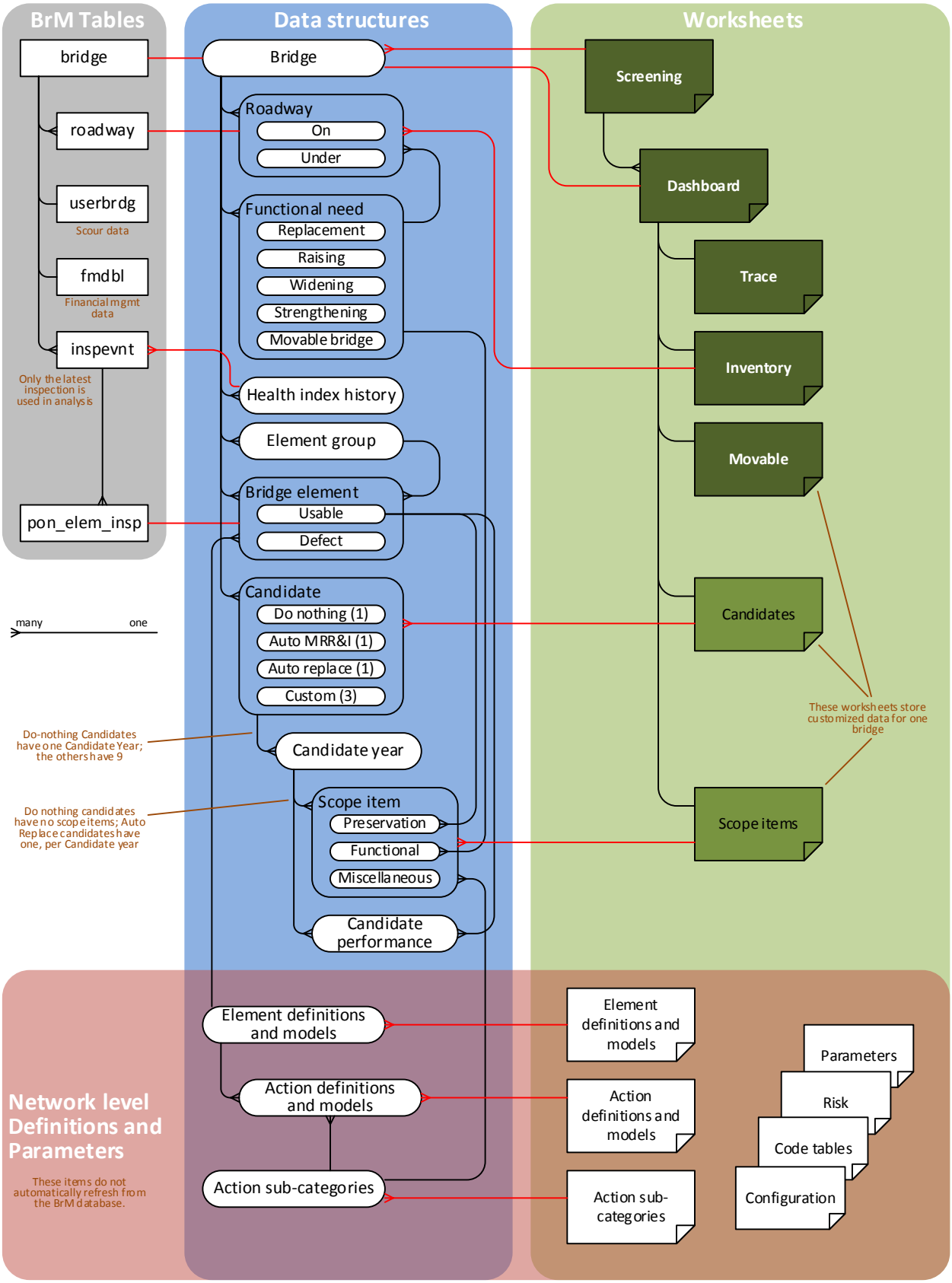
The lower 1/4 of the database structure chart shows the network level definitions and parameters used in the analysis. These are not read from the BrM database. Whenever the Excel file is opened, the indicated data structures are loaded into memory from the worksheets to speed the project level analysis computations. These data structures do not change when you move from one bridge to another in the same Excel workbook.

Since each workbook file has its own set of preservation model inputs, model parameters, and code tables, this information is not shared with other files. This information changes infrequently. It is recommended that you have an annual process to update all these inputs and create a new Excel template file, which should then be used in all subsequent gaming exercises. This would be done once in the head office, for use by all the districts. Re-using of custom candidate data from previous years is not recommended because of the likelihood that new inventory and inspection data will affect the decisions you make.

For more information about the use of BrM data, see Interaction with the BrM Database.

In addition to the data stores in the structure chart, there is a PLAT Results Database where you can optionally store analysis results if you plan to use the Network Analysis Tool (NAT). On the Dashboard toolbar, the Batch Process and Save buttons write outputs to this database.

Organization of Data



Interaction with the BrM Database

The project level analysis tool is designed to work with a direct connection to a BrM database. It will not operate unless a BrM 5.2.2 or higher database is available, an ODBC data source is correctly configured, and a correct connection string is provided on the Configuration worksheet.

The software reads data from the BrM tables in the left column of the database structure chart, and does not write any data back to BrM. This loading of data occurs when:

- You type a new Bridge ID in the upper left corner of the Dashboard, click one of the navigation arrow buttons next to the Bridge ID, select a bridge from the Screening worksheet, or click the Home button on the toolbar.
- The Excel workbook file is initially opened.
- The Dashboard worksheet is activated after visiting any other worksheet.

Access to the database to load a bridge is by means of an ADO 2.5 read-only forward-only shaped recordset with a client-side cursor. A connection to the database is opened, the recordset is populated, and then the connection is immediately released. All of this occurs before calculating the project level analysis or displaying the results.

Updating of the Screening worksheet works in a similar way. The client-side shaped recordset holds a smaller amount of data about each bridge, but holds all bridges selected by the filter all at once. A connection is opened, the recordset is populated in a single command that loads all the bridges, and then the connection is immediately released.

For a complete list of BrM data items, see Data Items Required from BrM.

Data Items Required from BrM

The table below lists all of the data items read from BrM. To gain maximum utility from the project level analysis tool, it is recommended that these items be monitored for missing or erroneous data on a regular basis. Items shaded in yellow are especially important for the analytical procedures. The other items are merely displayed on the Dashboard worksheet, and not used in any models.

bridge
bridge_gd
bridge_id
strucname
facility
featint
location
latitude
longitude
district
county
owner
custodian
paralstruc
yearbuilt
yearrecon
length
maxspan
mainspans
appspans
deckwidth
materialmain
designmain
materialappr
designappr
dkstructyp
dksurftype
dkmembtype
dkprotect
fc_detail
designload
orload
irload
ortype
irtype
posting
hclrult
hclrurt
vclrover
vclrunder
navcntrol
navvc
servtypon
servtypund

userbrdg
bridge_gd
pbrdgseq
scrratng
scrmode
higheval
evalrec1
evalrec2
evalrec3

fmdbl
brkey
lockstat
finproj
fsclccyr

roadway
bridge_gd
on_under
kind_hwy
levl_srvc
routenum
dirsuffix
kmpost
lrsinvrt
subrtnum
funcclass
trafficdir
lanes
roadwidth
aroadwidth
vclrinv
hclrinv
road_speed
det_speed
bypasslen
adttotal
adtyear
adtfuture
adtfutyear
truckpct

inspevnt
bridge_gd
inspkey
elinspdone
inspdate
inspname
railrating
transratin
arailratin
aendrating
oppostcl
underclr
wateradeq
pierprot
scourcrit
fcinspreq
appralign
dkrating
suprating
subrating
chanrating
culvrating
strrating
deckgeom
nbi_rating
suff_rate
suff_prefx
inspevnt_gd

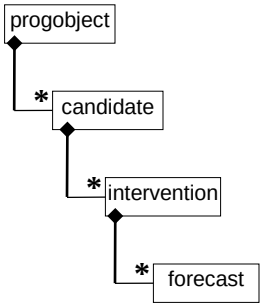
pon_elem_insp
bridge_gd
inspkey
elem_key
envkey
elem_qtystate1
elem_qtystate2
elem_qtystate3
elem_qtystate4
elem_notes
inspevnt_gd
pon_elem_insp_gd
parent_pon_elem_insp_gd

Yellow-shaded items are especially important for analysis

For more information about any of these data items, see the BrM help system. The userbrdg and fmdbl tables contain information specific to Florida.

PLAT Results Database

PLAT has the capability to output its analytical results to a Microsoft Access database, where they can be used for budgeting and programming by the Network Analysis Tool (NAT). This is something you would normally do once a year in a batch process that can run overnight, by clicking the Batch Process toolbar button on the Dashboard. You can also save one bridge at a time if you create custom candidates and want them reflected in the network level analysis. Keep in mind, however, that changes to individual bridges have minimal effect on network performance.



The entity-relationship diagram at left shows the four tables in the PLAT Results Database, and how they relate to each other. A program object (progobject) is currently the same thing as a bridge, but in the future it can be expanded to other types of transportation assets.

The candidate table contains the names of PLAT candidates, which are shown on the left side of the Candidate Pane on the Dashboard. An Intervention is one Candidate applied in one implementation year, represented by one cell in the Candidate Pane. A Forecast record contains the forecast performance that would occur in a given year as a result of a given Candidate.

In most cases, the PLAT Results database should be set up on a network server so it can be accessed from all PLAT workstations that will need to update the network level analysis.

Each PLAT workstation contributing to the network level analysis, needs to have an ODBC profile set up to point to the shared PLAT Results Database. The name of this ODBC profile must then be given on the Configuration worksheet. Leave this cell blank if the workstation will not have access to the PLAT Results Database.

Normally it is not necessary to set up password protection for this database, beyond the access control for its server, since it is not used by any other application and the data are easily re-generated by PLAT.

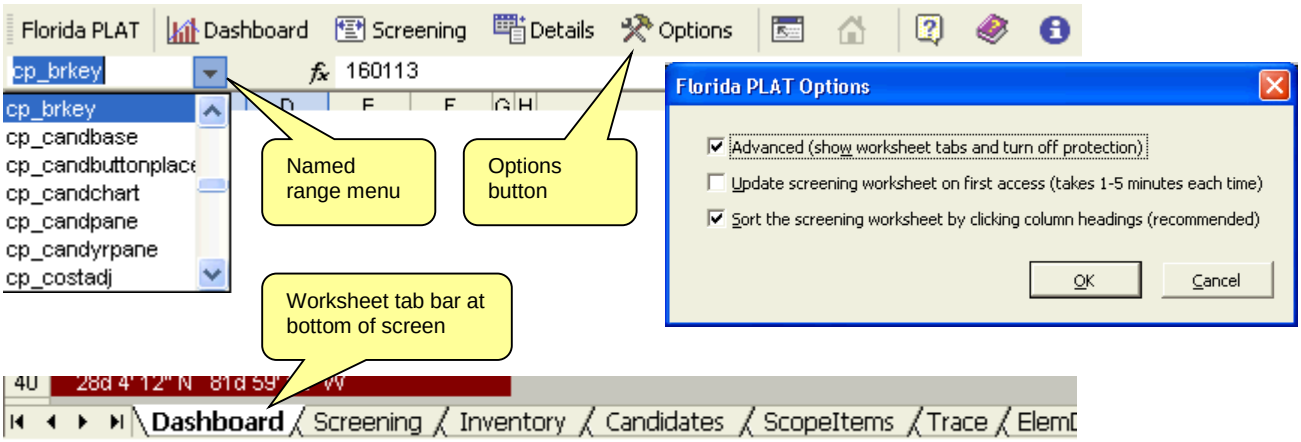
If desired, you can integrate the PLAT Results database with your BrM database. Use the provided Microsoft Access database as a model for table and column definitions. Be sure to set up a cascading delete referential integrity constraint as is done in the Access database. Then on the Configuration worksheet, the PLAT Results Database connect string would be the same as the BrM connect string. The two connections are never open at the same time.

Customizing Worksheets

One of the advantages of using Excel for the project level analysis tool is the ability to customize worksheets easily. You can add side calculations, display additional data from BrM, insert new tables and graphs, modify some of the system's computations, re-label data, or add your own help comments. You can even insert photos or other related documents.

When modifying the worksheets, keep in mind that the system does most of its work in Visual Basic code that reads and writes the worksheets. Many parts of the worksheets, especially Screening and Computation Details, are over-written by the software, so changes you make might also be over-written. It is also possible to make changes that interfere with the Visual Basic code, causing errors. So a careful and deliberate approach to customization is necessary.

Before customizing a worksheet, be sure to become familiar with the Excel named ranges defined for it. These are what the software uses to find information. To minimize the chances of introducing bugs, try to avoid modifying the named ranges. You can see the menu of named ranges to the left of the formula bar, just above the Excel worksheet column headings.



Regardless of what changes you plan to make, the following steps are generally necessary:

- Work with a fresh copy of the system, one that does not contain Custom Candidates that you want to save. You cannot modify the master template unless you are the administrator, so it is always possible to revert to the official version of the software. This rule does not apply if you are simply inserting comments, photos, or hyperlinks for a specific bridge.
- Click the Options button on the toolbar, and check the Advanced box (see above). This turns off worksheet protection and exposes the worksheet tab bar, allowing you to navigate to any worksheet in the system. You should clear this checkbox when you have finished making and testing all your changes.

Settings in the Options dialog are stored in the Excel file, so the "Advanced" setting will remain as you left it the last time you saved the file.

Although any of the system's worksheets can be modified, here are the changes believed most likely to be made:

> **Dashboard**. You may want to add or modify the information displayed on the Bridge Pane, or add more information in the unused space below the Bridge Pane or to the right. You may want to embed graphics and comments, or insert hyperlinks to related documents for a particular bridge.
>
> **Inventory**. You can arrange for additional BrM data items to be loaded into the file for any bridge you visit. You can then display the items, or results calculated from the items, on the Dashboard. The items you can add may come from the bridge table, the userbrdg table, the most recent inspection, or the roadway table.

Screening. You can add or subtract columns on the Screening worksheet, including additional BrM data items. These data items may come from the bridge table, the most recent inspection, or the roadway on the structure.

In addition, you can insert new worksheets and perform any calculations you like on them, using any features of Excel. For example, you can do a pivot table and/or graphic analysis of bridge data drawn from the Screening worksheet.

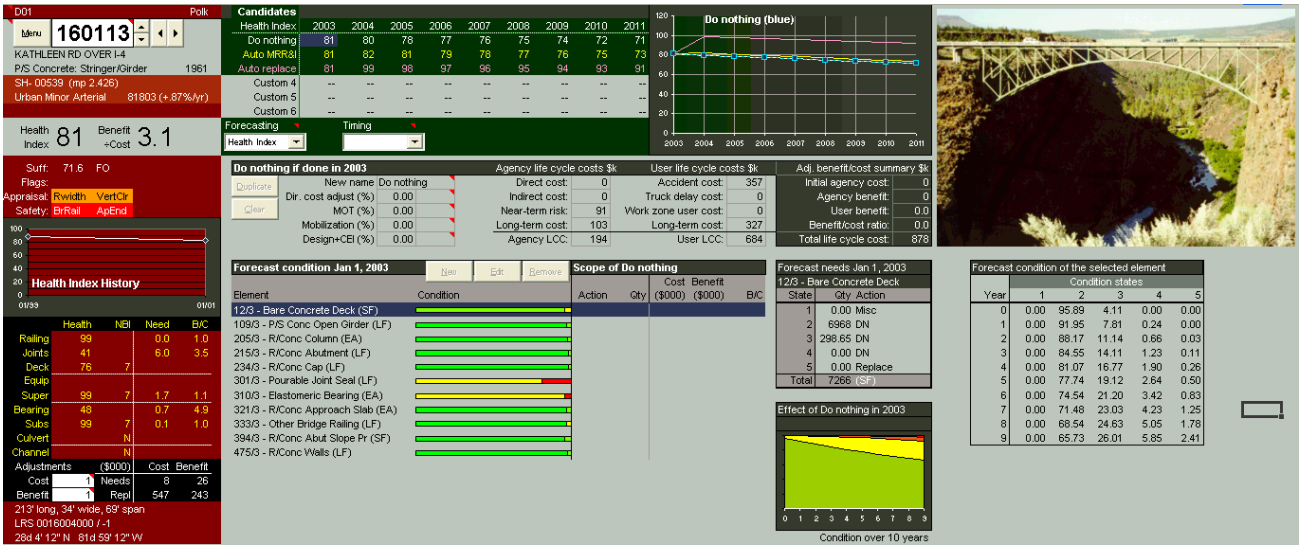
If you are modifying the main template for statewide deployment, see Administration for more guidance, including information about customizing the Users Manual.

Customizing the Dashboard

The Dashboard worksheet is a convenient place to attach bridge-specific comments, photos, and documents. All of the normal functionality of Excel is available for doing this. Aside from the general guidance on customizing worksheets, there are a few additional points to keep in mind when attaching things to the Dashboard:

- It is best to insert new content in unused cells, though you can insert a comment in any cell. In the Bridge Pane, you can determine whether a cell already is used by clicking it. If you see a name assigned in the range names box, or a formula or value in the formula bar, then the cell is already being used by the software.
- The Candidate Pane, Candidate Details, Scope Pane, and Element Forecast Pane are completely controlled by the software. If you type anything in these cells, they are likely to be erased by the software.
- The empty space below and to the right of the panes is free for your use. However, keep in mind that the height of the Scope Pane varies depending mainly on the number of element inspection records on the bridge. Certain bridges (especially moveable bridges) may extend far below the bottom of the Bridge Pane, and could obliterate anything you type in that space.

To insert a comment in any cell, right-click the cell and choose Insert Comment from the pop-up menu. A red triangle will appear in the upper right corner of the cell to indicate that a comment is there. To insert a photo, choose Insert – Picture – From File. You can position the photo anywhere on the worksheet (below). You can also insert hyperlinks to outside documents: right-click an empty cell and choose Hyperlink. Subsequently, all you have to do is click the cell to launch the document. You can even insert a picture and make it into a hyperlink.

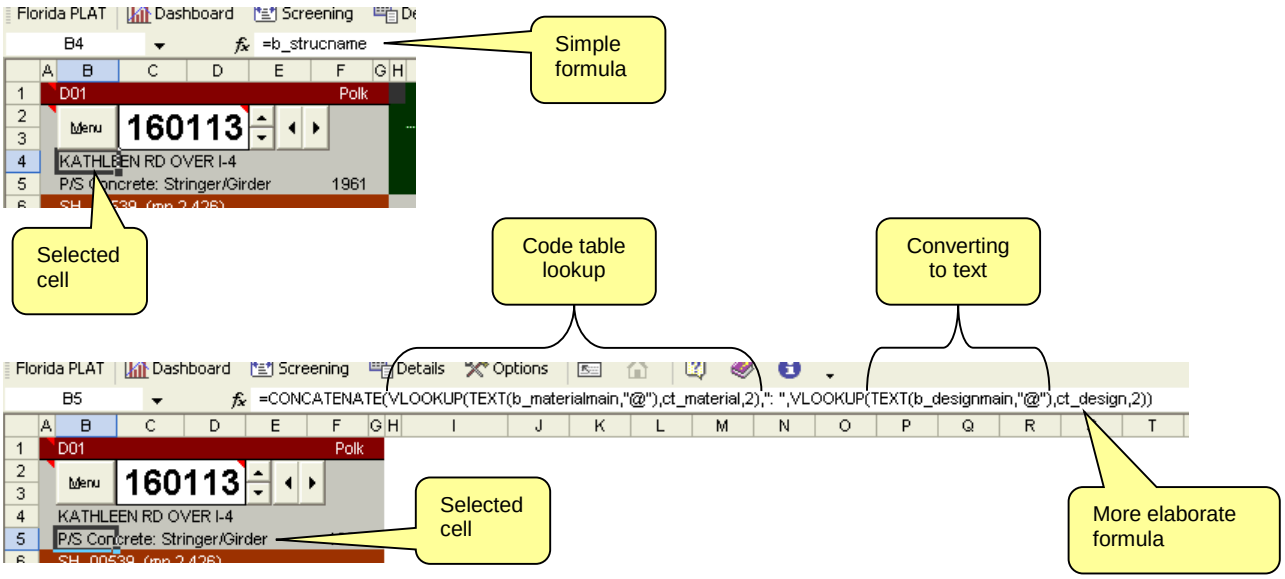


Any Dashboard cell that is not controlled by the project level analysis software can have a formula to present or compute information based on other cells, including cells from other worksheets. A common application used in the Bridge Pane is to compute cells using data from the Inventory worksheet.

The first example below is a very simple one, which presents the bridge structure name using the formula "=b_strucname". This refers to a named range on the Inventory worksheet, and simply copies what is found there. It takes advantage of the fact that the software automatically populates the Inventory worksheet every time the user moves from one bridge to another.

The second example demonstrates a more complex formula, that gets data from the Inventory worksheet (named ranges b_materialmain and b_designmain). These are coded NBI fields, so the formula gets more readable labels from code tables (named ranges ct_material and ct_design), and concatenates them together

with a colon separating them. As marked in the example, the formula uses the Excel VLOOKUP worksheet function to perform the lookup from the code table. All available code tables are found on the Code Tables worksheet. For uniformity, all NBI codes are stored as text data in the code tables, even though they often (but not always) appear numeric. VLOOKUP requires that the code tables be sorted in ascending order by the codes. The Excel TEXT worksheet function is used in the worksheet formulas to convert data to text so the table lookup will work properly.



If you plan to develop custom formulas for the Dashboard worksheet, you can find many examples already provided in the Bridge Pane.

Customizing the Inventory Worksheet

Every time you visit another bridge, either by typing its ID in the Dashboard, or clicking a navigation button, or selecting from the Screening worksheet, or by any other means, the software automatically populates the Inventory worksheet with all the data it will display and analyze. The information presented in the Bridge Pane of the Dashboard is calculated from this information, often by means of Excel formulas.

Only a subset of BrM data items are normally imported to the Inventory worksheet. If you would like the Dashboard to show an item not currently provided, you can add it. The Inventory worksheet (shown below) has two sections, bridge-level data on the left, and roadway data on the right. Bridge-level data include items from the bridge table, the userbrdg table, the roadway on the structure, the most recent inspevnt, and fmdbl. All roadway data are from the BrM roadway table. Since a bridge can have multiple roadways, they are shown in adjacent columns sorted by on_under (NBI 5A) in the order 1, 2, A, B, …, Z.

Inventory

Bridge Data						Roadway Data				
Name	Description	BrM table	BrM column	NBI	Value	Name	Description	BrM column	NBI	Value
b_bridge_gd	Unique bridge key	bridge	bridge_gd		8F980803BFC8409D83FC6BF5AF604201	r_bridge_gd	Unique bridge key	bridge_gd		8F980803BF
b_bridge_id	Agency bridge identifier	bridge	bridge_id		900020	r_on_under	Record type	on_under	5a	1
b_fmnumber	Financial mgmt number	FMDBL	FINPROJ		41372125201	r_kind_hwy	Route signing prefix	kind_hwy	5b	8
b_fscloeyr	Financial mgmt fiscal year	FMDBL	fscloeyr		20132014	r_levl_srvc	Designated level of service	levl_srvc	5c	8
b_strucname	Agency bridge name	bridge	strucname		OLD SEVEN MILE BRIDGE	r_routenum	Route number	routenum	5d	00000
b_facility	Facility carried by bridge	bridge	facility	7	PIGEON KEY ACCESS	r_dirsuffix	Directional suffix	dirsuffix	5e	0
b_featint	Feature intersected by bridge	bridge	featint	6a	KNIGHT CHANNEL	r_kmpost	Kilometerpoint	kmpost	11	0.000000
b_location	Location narrative	bridge	location	9	MARATHON KEY(MM 47)	r_lrsinvrt	LRS Inventory Route	lrsinvrt	13a	0090000024
b_latitude	Latitude	bridge	latitude	16	244221.04	r_subrtnum	LRS Subroute Number	subrtnum	13b	00
b_longitude	Longitude	bridge	longitude	17	810820.36	r_funcclass	Functional classification	funcclass	26	09
b_district	Agency district	bridge	district	2	06	r_trafficdir	Traffic direction	trafficdir	102	3
b_county	County location of bridge	bridge	county	3	087	r_lanes	Lanes on roadway	lanes	28	1
b_owner	Bridge owner type	bridge	owner	22	1	r_roadwidth	Bridge roadway width, curb to curb	roadwidth	51	19.830
b_custodian	Maintenance responsibility agency type	bridge	custodian	21	1	r_aroadwidth	Approach roadway width	aroadwidth	32	8.500
b_paralstruc	Parallel structure designation	bridge	paralstruc	101	N	r_vclrinv	Minimum vertical clearance	vclrinv	10	99.900
b_yearbuilt	Year built	bridge	yearbuilt	27	1912	r_hclrinv	Total horizontal clearance	hclrinv	47	19.830
b_yearrecon	Year reconstructed	bridge	yearrecon	106	1938	r_road_speed	Roadway speed	road_speed		15
b_length	Structure length	bridge	length	49	10480.000	r_det_speed	Detour speed	det_speed		0
b_maxspan	Maximum span length	bridge	maxspan	48	80.000	r_bypasslen	Bypass detour length	bypasslen	19	0.000000
b_mainspans	Number of spans of main unit	bridge	mainspans	45	135.000	r_adttotal	Average daily traffic	adttotal	29	0
b_appspans	Number of approach spans	bridge	appspans	46	0.000	r_adtyear	Year of average daily traffic	adtyear	30	2014
b_deckwidth	Deck width, out-out	bridge	deckwidth	52	23.830	r_adtfuture	Future average daily traffic	adtfuture	114	0
b_materialmain	Material/design of main unit	bridge	materialmain	43a	3	r_adtfutyear	Year of future average daily traffic	adtfutyear	115	2034
b_designmain	Design/construction of main unit	bridge	designmain	43b	3	r_truckpct	Average daily truck traffic (%)	truckpct	109	0
b_materialappr	Material/design of approaches	bridge	materialappr	44a	!	r_growth	Traffic growth rate			0.00
b_designappr	Design/construction of approaches	bridge	designappr	44b	-2	r_adt	Current estimated ADT			0
b_dkstructyp	Deck structure type	bridge	dkstructyp	107	2					
b_dksurftype	Deck wearing surface	bridge	dksurftype	108a	6					
b_dkmembtype	Deck membrane type	bridge	dkmembtype	108b	0					
b_dkprotect	Deck protection	bridge	dkprotect	108c	0					

See Customizing Worksheets for general guidance on modifying the Excel workbook. Here's how to add a BrM column to the list at the bridge level:

1. Select a row within the left section of the worksheet, right-click, and choose Insert. In the dialog that appears, choose Shift cells down. Alternatively, you can enter the new item in the first blank line at the bottom of the list. Do not leave blank lines within the list.
2. Fill in your new row, using the others as examples. The Name column must contain a unique range name beginning with "b_". BrM Table and BrM Column must be filled in correctly to locate the item in the BrM database.
3. Name the Value column cell by clicking the cell, then clicking the range name box, and then typing the name. This must agree with the Name column. Formulas on the Dashboard worksheet use the range name to find the data.

You can follow a similar process to add roadway items. Roadway range names begin with "r_" and are applied to the entire row. There is no BrM Table column since all items are understood to come from the BrM roadway table.

It is possible to calculate the values of the BrM Table and BrM Column cells using Excel formulas. Look at b_materialmain for an example, where the source location depends on the version of BrM.

It is also possible to create variables that are not imported from BrM, but are formulas further used by other formulas within the workbook. For example, the Value column of b_growth calculates an average growth rate from roadway data. BrM Table and BrM Column, are left blank since this item is not loaded from BrM.

Finally, you can edit or delete items from the Inventory worksheet as well. Do not delete any items used by the PLAT analysis. If you edit or delete an item used by formulas on the Dashboard or elsewhere, be sure you make corresponding changes where the item is used. To edit or delete a named range, use Formulas – Name Manager.

After making any of these changes to the Inventory worksheet, you must exit from the workbook (or from Excel), save the file as an Excel workbook or as a template, and then restart it. The software will present an error message if it is unable to load the items you named.

Customizing the Screening Worksheet

The Screening worksheet is a tool for quickly organizing and selecting bridges for the Dashboard, and it is also a useful analytical tool in its own right. You can use it as a convenient way to extract BrM data from the bridge table, the most recent inspection, and/or the roadway on the structure, for further analysis within Excel.

See Customizing Worksheets for general guidance on modifying the Excel workbook. To add, delete, or modify columns in the Screening worksheet, you need to make use of several rows that normally are hidden. Follow these steps:

1. Click Options on the toolbar. Check the "Advanced" checkbox and clear the "Sort the Screening worksheet" checkbox, then click OK. Doing this will enable you to select and edit the column headings.
2. Select rows 3 through 9 by click-dragging the row numbers at the far left.
3. Right-click the selection and choose Unhide. The worksheet will then appear as below.

	A	B	D	E	F	G	H	I	J	K	L
2		Screening									
3		Please click a Bridge ID to select it.									
6		bridge	bridge	calc	FMDBL	FMDBL	calc	calc	calc	calc	inspev
7		bridge_id	strucname	hicat	finproj	fsclccyr	totalcost	totalben	urgency	totbencost	suff_ra
8											
9		Bridge_ID	Structure Name	Action Cat	Financial Project Number	Fiscal Year	Total Cost ($000)	Total Benefit ($000)	Urgency	Total Benefit /Cost	Suf icien Rati
10		010001	US 41/CRESTWOOD WATERWAY	600-StRepl			0	256	0	0	76
11		010015	SR-31 OVER SHELL CREEK	600-StRepl			0	118359	0	0	87
12		010018	SR-31 OVER MYRTLE SLOUGH	600-StRepl			0	239	0	0	88
13		010026	US-41/ELKHAM WATERWAY	600-StRepl			0	25	0	0	84
14		010028	US-41/HARBOR SQ DRAINAGE	600-StRepl			0	1750	0	0	66
15		010031	SR 776 OVER SAM KNIGHT CREEK	600-StRepl			0	970	0	0	70
16		010032	US-41 NB OVER ALLIGATOR CREEK	100-ElRepl	43001115201	20122013	86	28	-0.04	0.33	98
17		010033	US 41 NB OVER OYSTER CREEK	0-DN	43001115201	20122013	0	0	0	0	98

Row 8 is always blank, to ensure that Excel recognizes row 9 as column headings. Rows 6 and 7 are table and column names for BrM.

To insert a column, right-click an Excel column heading (the letter at the very top), and choose Insert. Fill in the database table and column information in the new worksheet column, and be sure to provide a label in row 9 for the column heading. The remainder of the column can remain blank. Excel automatically formats the cells correctly, including underlining the column heading. You can add a left or right border to your column or make other format changes, if desired, using the Excel features on the Format menu.

You can also edit or delete columns. However, you may not change or delete columns A through C, which are used by the software to locate bridges. (Column C is hidden.)

The software also provides a number of calculated performance measures, identified with "calc" as the table name, that you can use as columns in the worksheet. Initially all of them are shown, but you can delete any of them if you don't want to see them. (Alternatively, you can hide or move their columns.) The performance measures are computed by performing the project-level analysis on all bridges in the list, and using the Candidate that provides the lowest life cycle cost in the first year of the program.

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