

Life-Cycle Cost Analysis Tool for Chem/Bio Protection of Buildings: Software Primer

Background

The National Institute of Standards and Technology (NIST) is a non-regulatory federal agency within the U.S. Commerce Department's Technology Administration. NIST develops and promotes measurement, standards, and technology to enhance productivity, facilitate trade, and improve quality of life. In the aftermath of the attacks of September 11, 2001, NIST has taken a key role in enhancing the nation's homeland security.

NIST's Building and Fire Research Laboratory (BFRL) has as its mission to meet the measurement and standards needs of the building and fire safety communities. A key element of that mission is BFRL's commitment to homeland security. Specifically, the goal of BFRL's homeland security effort is to develop and implement the standards, technology, and practices needed for cost-effective improvements to the safety and security of buildings and building occupants, including evacuation, emergency response procedures, and threat mitigation.

Due to concerns about potential airborne chemical and biological releases in or near buildings, building owners and managers and other decision makers are considering retrofitting their buildings to provide better protection against such events. A wide range of technologies and approaches are being proposed with varying levels of efficacy and cost, as well as with varying degrees of applicability to any particular building or ventilation system.

Through support from the EPA Safe Buildings Program, BFRL's Indoor Air Quality and Ventilation Group and the Office of Applied Economics (OAE) are developing guidance on building retrofit technologies and approaches to promote increased building protection from chemical and biological attack. This guidance will provide building owners, managers, engineers, and other decision makers with information about various retrofit strategies to improve the safety of their buildings against airborne hazards and with economic tools for use in selecting cost-effective approaches to mitigating those hazards.

The Life-Cycle Cost Analysis Tool (LCAT) for Chem/Bio protection of buildings incorporates and integrates research being conducted by OAE under the EPA Safe Buildings Program and under BFRL's homeland security effort. OAE's research focuses on developing economic tools to aid facility owners and managers in the selection of cost-effective strategies that respond to natural and man-made hazards. Economic tools include evaluation methods, standards that support and guide the application of those methods, and software for implementing the evaluation methods. OAE's research has produced a three-step protocol for developing a risk mitigation plan for cost-effective protection of constructed facilities. This protocol has three essential components: risk assessment, identification of potential mitigation strategies, and economic evaluation. *LCAT is designed to help implement the third step in the protocol, economic evaluation.*

A brief synopsis of the three-step protocol is provided here. Users interested in an in-depth description of the three-step protocol are referred to NISTIR 7073. Risk assessment is used to identify the risks confronting a facility and includes development of possible damage scenarios, probability assessments for these scenarios, and identification of the facility's vulnerabilities and critical areas. Identification of mitigation strategies provides performance and cost data for the possible combinations of risk mitigation strategies. Combinations of risk mitigation strategies are used to create a candidate set of alternatives for in-depth economic evaluation. The third

component, economic evaluation, enables building owners and managers to evaluate each alternative combination of risk mitigation strategies and the sequence of cash flows associated with their implementation. *The alternative combination that results in the lowest life-cycle cost is designated the cost-effective risk mitigation plan.*

Economic Evaluation Methods

Several methods of economic evaluation are available to measure the economic performance of a new technology, a building system, or like investment, over a specified time period. Two of these methods—life-cycle cost and present value of net savings—are especially well suited to the economic evaluation of Chem/Bio hazard mitigation retrofit strategies. OAE has extensive experience with both methods. OAE’s research on life-cycle cost analysis spans more than 30 years. Early work by OAE economists led to the development of an industry consensus standard, ASTM E 917, for the life-cycle cost method. OAE’s life-cycle cost research was extended to the economics of protection against natural disasters shortly thereafter. More recent work has focused on specifying cost-effective responses to terrorist risks. OAE’s research on present value of net savings paralleled its research on the life-cycle cost method and led to the development of an industry consensus standard, ASTM E 1074. OAE’s ongoing research links the standardized economic evaluation methods with a well-defined cost-accounting framework and software to make implementation straightforward. The algorithms “sit” behind the LCAT graphical user interface. OAE believes most users prefer it that way, so they can focus on only those data elements required to perform the life-cycle cost calculations. Users interested in mastering the calculation procedures/algorithms employed in LCAT are referred to NISTIR 7073.

Life-Cycle Cost Method

The life-cycle cost (LCC) method measures, in present-value or annual-value terms, the sum of all relevant costs associated with owning and operating a building over a specified period of time. The basic premise of the LCC method is that, to an investor or decision maker, all costs arising from that investment decision over time are potentially important to that decision. Applied to Chem/Bio hazard mitigation, the LCC method encompasses all relevant costs over a designated study period, including the costs of designing, retrofitting, constructing/installing, operating, maintaining, repairing, replacing, and disposing of a particular design or system. Pure benefits that result (e.g., increased rental income due to improvements) are also included in the calculation of LCC.

The LCC method is particularly suitable for determining whether the higher initial cost of a building or system specification is economically justified by lower future costs when compared to an alternative with a lower initial cost but higher future costs. If a design or system specification has both a lower initial cost and lower future costs relative to an alternative, an LCC analysis is not needed to show that the former is economically preferable.

The alternative with the lowest initial investment cost (i.e., first cost) is typically referred to as the base case. The LCC method compares alternative, mutually exclusive, Chem/Bio retrofit strategies that satisfy a minimum level of functionality to determine which is the least-cost means (i.e., minimizes life-cycle cost) of satisfying that level over a specified study period.

Present Value of Net Savings Method

Information used to compute LCC can also be used to calculate the present value of net savings (PVNS). PVNS measures the net savings from investing in a given alternative instead of investing in the foregone opportunity (e.g., the base case). PVNS equals the difference between the LCC of the base case and the LCC of the mutually exclusive alternative under consideration. Any pure benefits that result (e.g., increased rental income due to improvements) are included in the calculation of PVNS, since they are included in the LCC calculation. With respect to the base case, if PVNS is positive, the alternative is economic; if it is zero, the alternative is as good as the base case; if it is negative, the alternative is uneconomical.

Getting Started

The software includes four case study applications. The four case study applications are: (1) a high-rise office building; (2) an office building lobby; (3) an office building mail room; and (4) a single-story office building. Associated with each case study application are two case study files. One file is a high-level summary of the proposed retrofit alternatives. The second file contains a detailed listing of cost items associated with each of the proposed retrofit alternatives. The case study files provide a convenient frame of reference through which you can learn about the capabilities of the software and experiment with the various means for editing, creating, and deleting data elements. The case study files are designed to illustrate a wide variety of software features through a set of simplified, yet fairly realistic building-related examples.

Tips on Analysis Strategy

Developing a cost-effective risk mitigation plan is a complicated process, entailing two distinct levels of analysis. This “analysis strategy” systematically adds increased detail to the decision problem. The first level is referred to as the baseline analysis. Here we are working with our best “guess” estimates. The baseline analysis provides a frame of reference for the sensitivity analysis, which systematically varies, selected sets of data elements to measure their economic impacts on project outcomes, such as the life-cycle costs of competing alternatives.

The starting point for conducting an economic evaluation is to do a baseline analysis. In the baseline analysis, all data elements entering into the calculations are fixed. For some data, the input values are considered to be known with certainty. Other data are considered uncertain and their values are based on some measure of central tendency, such as the mean or the median, or input from subject matter experts. Baseline data represent a fixed state of analysis. For this reason, the analysis results are referred to as the baseline analysis. The term baseline analysis is used to denote a complete analysis in all respects but one; it does not address the effects of uncertainty. When you open any of the case study files, the data elements displayed on the various software screens are the baseline values.

Sensitivity analysis measures the impact on project outcomes of changing the values of one or more key data elements about which there is uncertainty. Sensitivity analysis can be performed for any measure of economic performance (e.g., life-cycle cost or present value of net savings). Therefore, a sensitivity analysis complements the baseline analysis by evaluating the changes in output measures when selected data inputs are allowed to vary about their baseline values.

Overview of the Case Study Applications

The case study applications describe a variety of Chem/Bio retrofit strategies for four prototypical building renovation projects. Note that the cost estimates are for purposes of illustration only—actual renovations of different building types will face different costs and different risk profiles. The cost data associated with the four prototypical building renovation projects are presented at two levels of detail. A “summary” format highlights the key cost items. The summary listing records the type of cost information that would be suitable for presentation to senior management or other decision makers. The summary formats provide the basis for the four sets of Summary case study files—one for each prototypical building renovation project. A “detailed” format covers the type of cost information that would be provided as part of a building condition assessment. The detailed listing of cost items “rolls up” into the cost items listed in the summary format. The detailed formats provide the basis for the four sets of Detailed case study files.

Assumptions and Cost Data

Each of the four case study applications covers a 20 year period beginning in 2005. Life-cycle costs are calculated using a 7 % real discount rate for the baseline analysis. Information on cost items is needed in order to calculate life-cycle costs. Cost items are classified under two broad headings: (1) protection costs and (2) event-related losses.

Protection costs represent all costs tied to the building or facility under analysis that are not associated with an event. Protection costs include the initial capital investment outlays for facilities and site work, future costs for filter replacements and electricity for fan motors, future costs for space heating and cooling, future renovations, and any salvage value for plant and equipment remaining at the end of the study period. Protection costs are classified as either investment costs or non-investment costs.

Event-related losses are based on annual outcomes, each of which has a specified probability of occurrence. Each outcome has a non-negative number of cost items associated with it (i.e., an outcome may have no cost items associated with it if it results in zero losses). *Note that although logic is included within the software tool to handle event-related losses, no estimates of these losses are included in the case study applications.*

High-Rise Office Building

The objective is to protect an 11 story high-rise office building from external discharge of contaminants from a single source near the outside air intakes and from a larger cloud approaching the building. The floor area of the 11 story high-rise office building is 11 148 m² (120 000 ft²). The building was erected in the mid-1960s and has a rectangular configuration. The building has been well maintained and does not show significant signs of aging. The outside air intake louvers are approximately 6.1 m (20 ft) above the ground. A variety of materials compose the exterior envelope, including granite, marble, face brick, glass, and extruded aluminum. The facades on the short axis of the building are faced with grey face brick. The facades on the long axis of the building are insulated porcelain spandrel panels and fixed aluminum frame windows.

The high-rise office building includes a lobby and a mail room. Retrofit strategies to protect the lobby from a discharge of contaminants carried by an individual and to protect the mail room from introduction of contaminants in mail packages are handled in separate analyses.

To protect the building from an external release of contaminants, it is desirable to seal the building envelope and retrofit filters in the air-handling units. The proposed improvements are presented as three options. Each option has a different filtration level.

Retrofit Alternatives for Protecting the High-Rise Office Building

Option 1 (Filtration Level 1) provides a low level of particle filtration capability and no gaseous capability. Option 1 involves the following set of improvements. Sealing the exterior windows to make the building more airtight. Relocating the outside air intake to the roof. Replacing existing Minimum Efficiency Reporting Value (MERV) 6 filters with MERV 11 high capacity filters. Modifying the electrical feeders to accommodate higher motor horsepower. Providing an electrical quick shut off mechanism to stop the air handlers and return exhaust fans as needed during an emergency. Sealing and isolating six conference rooms to serve as shelters-in-place during an emergency.

Option 2 (Filtration Level 2) provides a high level of protection against particles but no gaseous protection. Option 2 involves the following set of improvements. Sealing the exterior windows to make the building more airtight. Relocating the outside air intake to the roof. Replacing existing MERV 6 filters with a three-stage filter consisting of: MERV 8 pre-filter, 85 % efficient MERV 13 intermediate filter, and a 99.97 % High Efficiency Particulate Air (HEPA) filter. Modifying the electrical feeders to accommodate higher motor horsepower. Providing an electrical quick shut off mechanism to stop the air handlers and return exhaust fans as needed during an emergency. Sealing and isolating six conference rooms to serve as shelters-in-place during an emergency.

Option 3 (Filtration Level 3) provides a high level of protection against particle and gaseous agents. Option 3 involves the following set of improvements. Sealing the exterior windows to make the building more airtight. Relocating the outside air intake to the roof. Replacing existing MERV 6 filters with a five-stage filter consisting of: MERV 8 pre-filter, 85 % efficient MERV 13 intermediate filter, 99.97 % HEPA filter, 99.9 % gas phase filter, and MERV 11 post filter. Modifying the electrical feeders to accommodate higher motor horsepower. Providing an electrical quick shut off mechanism to stop the air handlers and return exhaust fans as needed during an emergency. Sealing and isolating six conference rooms to serve as shelters-in-place during an emergency.

Office Building Main Lobby

The objective is to protect the main lobby from a discharge of contaminants carried by an individual. The main lobby is a 4.3 m (14 ft) high space that is approximately 325 m² (3 500 ft²) in size. The lobby is defined by exterior glass curtain walls on two sides and marble finished walls on the other two sides. It is accessed from the exterior through a 14 m² (150 ft²) glass enclosed vestibule with a series of two rows of four balanced glass doors. The lobby is open to an elevator bank.

To protect the main lobby from a discharge of contaminants carried by an individual, it is desirable to isolate the lobby with airtight walls and doors and to provide an air conditioning system dedicated to the lobby capable of maintaining the entire lobby under negative pressure. The system must also be capable of purging the lobby—one hundred percent outside air and exhaust—and filtering the supply and exhaust air. The proposed improvements are presented as two options. Each option has a different filtration level. The two options link to Filtration Levels 2 and 3 for the high-rise office building. Filtration Level 1 was not considered because it would not provide the level of protection desired for the main lobby.

Retrofit Alternatives for Protecting the Main Lobby

Option 1 (Filtration Level 2) provides a high level of protection against particles but no gaseous protection. Option 1 involves the following set of improvements. Isolate the open side of the lobby from the rest of the building by installing tempered glass partitions with self-closing doors that allow building occupants continued access to the lobby. Install a new air handling unit to serve the main lobby only. Relocate the outside air intake to the roof. Equip the air handling unit with a three-stage filter consisting of: MERV 8 pre-filter, 85 % efficient MERV 13 intermediate filter, and a 99.97 % HEPA filter. Modify electrical feeders to accommodate higher motor horsepower. Remove the existing exhaust fan and install two new exhaust fans: one to serve as return/exhaust fan to the existing air handling unit the second to return/exhaust the air to the new air handling unit and run an exhaust duct from the return duct to an existing louver near the fan and install filters at the discharge side of the new exhaust fan. Install a quick shut off mechanism to stop the fans. Maintain the main lobby under negative pressure with respect to the surrounding areas and the outdoors during normal operations and during an emergency.

Option 2 (Filtration Level 3) provides a high level of protection against particle and gaseous agents. Option 2 involves the following set of improvements. Isolate the open side of the lobby from the rest of the building by installing tempered glass partitions with self-closing doors that allow building occupants continued access to the lobby. Install a new air handling unit to serve the main lobby only. Relocating the outside air intake to the roof. Equip the air handling unit with a five-stage filter consisting of: MERV 8 pre-filter, 85 % efficient MERV 13 intermediate filter, 99.97 % HEPA filter, 99.9 % gas phase filter, and MERV 11 post filter. Modify electrical feeders to accommodate higher motor horsepower. Remove the existing exhaust fan and install two new exhaust fans: one to serve as return/exhaust fan to the existing air handling unit the second to return/exhaust the air to the new air handling unit and run an exhaust duct from the return duct to an existing louver near the fan and install filters at the discharge side of the new exhaust fan. Install a quick shut off mechanism to stop the fans. Maintain the main lobby under negative pressure with respect to the surrounding areas and the outdoors during normal operations and during an emergency.

Office Building Mail Room

The objective is to protect the mail room from contaminants coming in via mailed packages. The mail room is approximately 334 m² (3 600 ft²) in size. It has a 2.3 m (7 ft 8 in) high suspended acoustical ceiling and is enclosed with CMU walls and modular steel partitions. The mail room has three interior walls and one exterior wall. One wall and all interior partitions extend to the height of the ceiling. On two walls, a total of three single and double doors lead directly into interior corridors. There is a roll-up door on the exterior wall, which serves as a receiving area for the mail room.

To protect the mail room from contaminants coming in via mailed packages, it is desirable to isolate the mail room with airtight walls and doors and to provide a separate dedicated air conditioning system capable of maintaining the mail room under negative pressure. The system must also be capable of purging the mail room—one hundred percent outside air and exhaust—and filtering the supply and exhaust air. The proposed improvements are presented as two options. Each option has a different filtration level. The two options link to Filtration Levels 2 and 3 for the high-rise office building. Filtration Level 1 was not considered because it would not provide the level of protection desired for the mail room.

Retrofit Alternatives for Protecting the Mail Room

Option 1 (Filtration Level 2) provides a high level of protection against particles but no gaseous protection. Option 1 involves the following set of improvements. Seal mail room envelope; walls, ceiling, doors, and slabs. Provide upgraded filtration to the existing air conditioning system and provide a new dedicated return/exhaust fan. Equip the existing air handling unit with a three-stage filter consisting of: MERV 8 pre-filter, 85 % efficient MERV 13 intermediate filter, and a 99.97 % HEPA filter. Modify electrical feeders to accommodate higher motor horsepower. Equip the existing exhaust fan with a MERV 8 pre-filter, an 85 % efficient MERV 13 intermediate filter, and a 99.97 % HEPA filter. Install a quick shut off mechanism to stop the fans. Maintain the mail room negative with respect to the surrounding areas and the outdoors during normal operations and during an emergency.

Option 2 (Filtration Level 3) provides a high level of protection against particle and gaseous agents. Option 2 involves the following set of improvements. Seal mail room envelope; walls, ceiling, doors, and slabs. Provide upgraded filtration to the existing air conditioning system and provide a new dedicated return/exhaust fan. Equip the existing air handling unit with a five-stage filter consisting of: MERV 8 pre-filter, 85 % efficient MERV 13 intermediate filter, 99.97 % HEPA filter, 99.9 % gas phase filter, and MERV 11 post filter. Modify electrical feeders to accommodate higher motor horsepower. Equip the existing exhaust fan with a MERV 8 pre-filter, an 85 % efficient MERV 13 intermediate filter, a 99.97 % HEPA filter, a 99.9 % gas phase filter, and a MERV 11 post filter. Install a quick shut-off mechanism to stop the fans. Maintain the mail room negative with respect to the surrounding areas and the outdoors during normal operations and during an emergency.

Single-Story Office Building

The objective is to protect a single-story office building from external discharge of contaminants from a single source near the outside air intakes and from a larger cloud approaching the building. The gross floor area of the office building is 1 612 m² (17 350 ft²). The air conditioning system consists of 28 rooftop heat pumps. Each heat pump controls its own outdoor intake making it necessary to protect 28 air intake locations. The system does not have exhaust fans. The excess air is relieved through barometric dampers. Therefore, controlled purging is not possible. In addition, the rooftop units cannot be retrofitted with the necessary filters due to the low static pressure of the fans and lack of space to install the filters.

The physical arrangement of this building makes it difficult to retrofit the filters. The proposed improvements are presented as three options. Each option has a different filtration level. The three options link to Filtration Levels 1, 2, and 3 for the high-rise office building.

Retrofit Alternatives for Protecting the Single-Story Office Building

Option 1 (Filtration Level 1) provides a low level of particle filtration capability and no gaseous capability. Option 1 involves the following set of improvements. Seal the exterior envelope to make the building more airtight. Replace existing MERV 4 filters with MERV 11 filters. Install quick shut-off mechanism to stop the rooftop heat pumps.

Option 2 (Filtration Level 2) provides a high level of protection against particles but no gaseous protection. Option 2 involves the following set of improvements. Seal the exterior envelope to make the building more airtight. Provide an outside fan with a three-stage filter consisting of: MERV 8 pre-filter, 85 % efficient MERV 13 intermediate filter, and a 99.97 % HEPA filter. Duct the filtered air to the intake of each rooftop unit. Install the fan and filter on a new platform at roof level with the ductwork on the roof. Install quick shut-off mechanism to stop the rooftop heat pumps and outdoor air fans.

Option 3 (Filtration Level 3) provides a high level of protection against particle and gaseous agents. Option 3 involves the following set of improvements. Seal the exterior envelope to make the building more airtight. Provide an outside fan with a five-stage filter consisting of: MERV 8 pre-filter, 85 % efficient MERV 13 intermediate filter, 99.97 % HEPA filter, 99.9 % gas phase filter, and MERV 11 post filter. Duct the filtered air to the intake of each rooftop unit. Install the fan and filter on a new platform at roof level with the ductwork on the roof. Install quick shut-off mechanism to stop the rooftop heat pumps and outdoor air fans.

The Cost-Accounting Framework

The flexibility of the life-cycle cost method enables us to classify and analyze costs in a variety of ways. The result is a more focused representation of costs, referred to as the cost-accounting framework. The cost-accounting framework provides a convenient means for summarizing all costs entering into the life-cycle cost calculations. The framework is organized around a Budget Category classification. The Budget Category classification uses cost types and cost items. The cost types are used as placeholders for summarizing and reporting aggregated cost information. Each cost type is a collection of cost items. Each cost item has a unique set of identifiers that places it within the cost-accounting framework.

The Budget Category classification has three cost types based on which category of the budget the funds come from. These cost types are: (1) Capital Investment; (2) O&M (Operations and

Maintenance); and (3) Other. These cost types correspond to widely used budget categories for private and public sector cost accounting. *It is important to note that the dollar amounts accruing to all three cost types are inclusive of any expected event-related losses.* In the context of the previous section, Capital Investment costs accrue to the investment cost category and O&M and Other costs accrue to the non-investment cost category. All acquisition costs, including costs related to planning, design, purchase, and construction, are investment-related costs and fall under the Capital Investment cost type. *Residual values (resale, salvage, or disposal costs) and capital replacement costs are also investment-related costs.* Capital replacement costs are usually incurred when replacing major systems or components (e.g., replacing an exhaust fan) and are paid from capital funds. Cost items falling under the O&M cost type include energy and water costs, maintenance and repair costs, and minor replacements (e.g., replacing belts and seals) related to maintenance and repair. O&M costs are usually paid from an annual operating budget, not from capital funds. Other costs are non-capital costs that cannot be attributed to the O&M cost type.

Navigating Within the Software

This section gives you a guided tour of Version 1.0 of the Life-Cycle Cost Analysis Tool (LCAT 1.0). The goal of the guided tour is for you to work systematically through the hierarchy of screens used to input, analyze, and display project-related data.

Opening/Creating a Project File

Launch the software by clicking on LCAT 1.0 icon found on your desktop or by clicking LCAT 1.0 in the Start menu in Programs/Life-Cycle Cost Analysis Tool. The first screen to appear prompts you to open an existing project file, create a new project file, or open an example project. Figure A1 is a reproduction of the Prompt window. Recall that the software comes with a set of case study files. Thus, even when you launch the software for the first time, there are already several example project files, any of which you may choose to open. If you select *Open an Existing Project* or *Open an Example Project* and click the *Start* button, then you will be taken to the Open Project window. The Prompt window also includes a *View Tips* check box. If you select *View Tips* and click the *Start* button, you will be taken to the Software Tips window. (Throughout this section, software features (e.g., buttons) are highlighted through the use of *italics* font.)

Figure A2 displays the Software Tips window. The Software Tips window is designed as a handy reference for first-time users. It highlights material contained in this Primer as well as several basic concepts for navigating within the software and for saving results.

As a first step, open one of the case study files and use the *File Save As* feature to make additional copies with *lcc* extensions. Suggested file names are *test01.lcc* and *test02.lcc*. Use the test files to gain familiarity with the software. This way, if you inadvertently change or delete a data element, or create a new data element, you can go back to the case study file for the reference solution. When you use the *File Save As* feature with one of the case study files, the new file (e.g., *test01.lcc*) will be saved in the “existing projects” directory. If you exit the software and later wish to open a user-created “test” file, you will need to select *Open an Existing Project* from the Prompt window.

Figure A3 is a sample Open Project window. Figure A3 lists the various case study files provided with the software. The Open Project window shown in Figure A3 was opened by

selecting the *Open an Example Project* option in the Prompt window and clicking the *Start* button. Note that the high-rise office building has two case study files—*High-Rise Office (Summary).lcc* and *High-Rise Office (Detailed).lcc*. The “summary” file is an abbreviated version of the high-rise office building case study. It provides a convenient means for highlighting key features of the software. It is used within the Primer to illustrate these software features. The “detailed” file demonstrates how to handle a fairly complicated retrofit project. It focuses on breaking out the various cost items presented in the summary file into their constituent parts.

Highlighting the desired file and clicking the *Open* button opens that file. Double clicking on the highlighted file opens the file as well. The Open Project window includes a *Cancel* button. If you click on the *Cancel* button, you will return to the Prompt window.



Figure A1 Life-Cycle Cost Analysis Tool Prompt Window

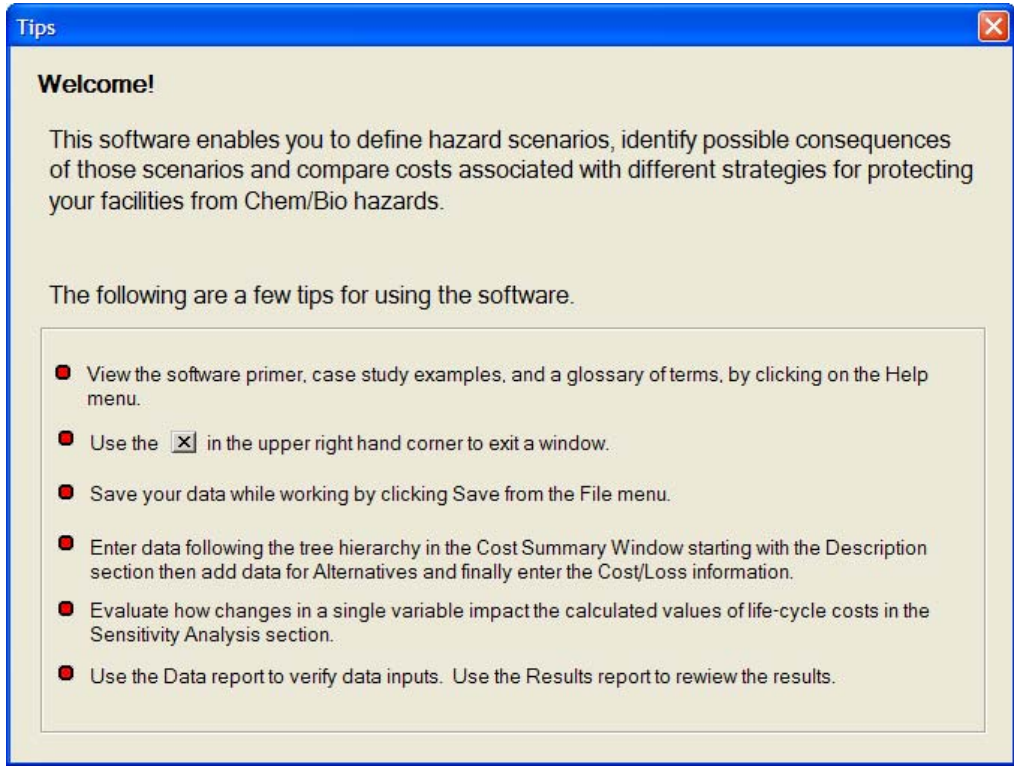


Figure A2 Software Tips Window

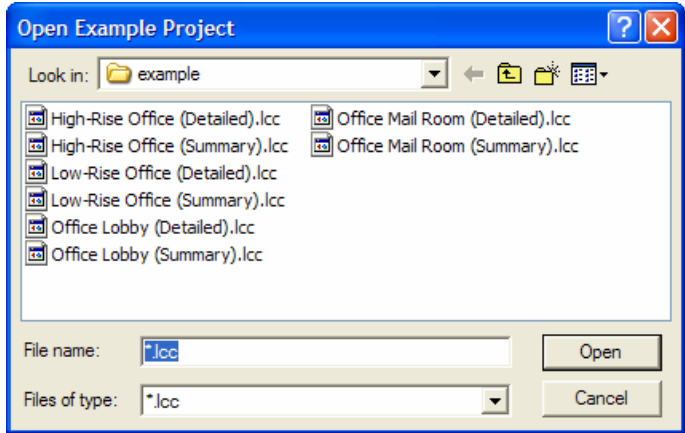


Figure A3 Open Project Window

Cost Summary Window and Main Menu

The Cost Summary window is displayed whenever a new project is started, an existing project file is opened, or a case study file is opened. When a project is created, the Cost Summary window is blank. Figure A4 is an example of the Cost Summary window display when starting a new project. As you enter data into the software, the Cost Summary window displays the current value of life-cycle costs for each cost type and alternative being analyzed. It is recommended that

you keep the Cost Summary window open while working in the software. If you wish to close the window, it can be reopened at any time by selecting *Project* from the tool bar and then selecting *Cost Summary*.

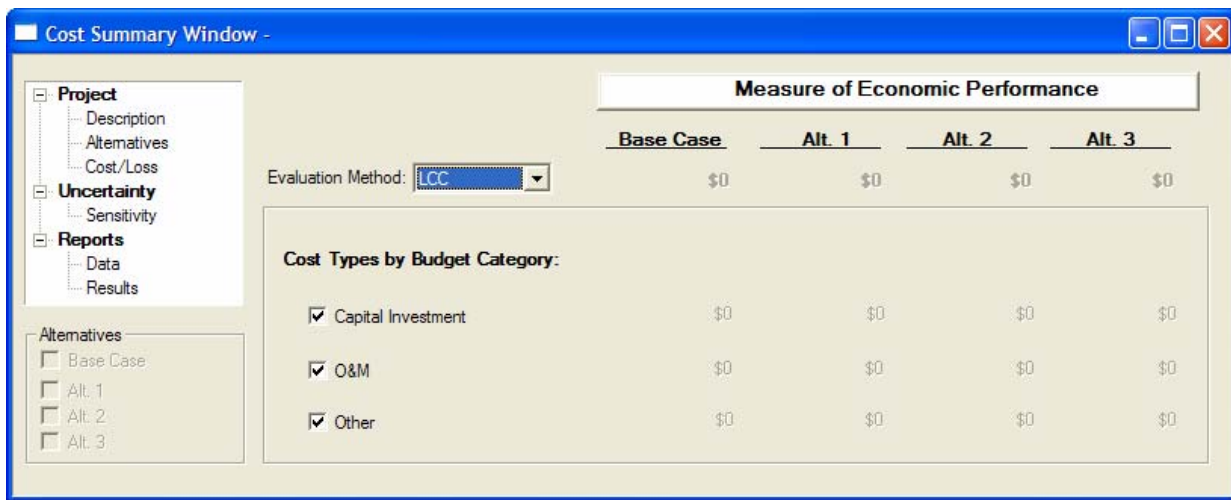


Figure A4 Cost Summary Window When Starting a New Project

The software is designed to analyze up to four alternatives (see Figure A4). The Cost Summary window allows you to select both the cost types and the alternatives to be included in the economic evaluation. These “choices” are represented in Figure A4 by the “cost type” check boxes and the “alternative” check boxes within the Alternatives group box in the lower left-hand corner.

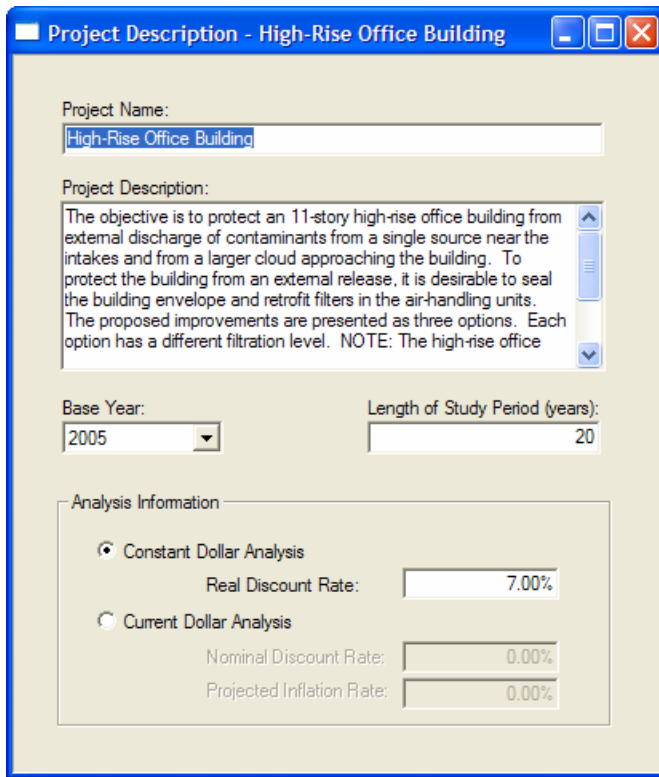
A tree on the left-hand side of the Cost Summary window serves as the Main Menu to the software. The tree contains three top-level nodes: *Project*, *Uncertainty*, and *Reports*. Recall that software features are highlighted through the use of *italics* font. The tool bar at the top of the Cost Summary window provides another means for accessing the three top-level nodes. The tool bar also includes *File* and *Help* options. *File* options include *Save*, *Save As*, *Close Project*, and *Exit*. *Help* options include *Tips*, which opens the Software Tips window, and *Help*, which opens an on-line version of the Primer and a Glossary of Terms. If you wish to print the on-line Primer from the *Help* menu, click *Print the selected topic* option from the Print Topics pop-up window and then select which printer from the pop-up Print window.

Project Information

The options listed under the *Project* node allow you to enter project information, define alternatives, and manage cost-related information.

Clicking the *Description* option on the Main Menu opens the Project Description window. Here you can enter project information such as the project’s name, a brief description of the project, the base year selected for all present value calculations, the length of the study period, whether a constant dollar or current dollar analysis is to be performed, and the discount rate. Note that when a constant dollar analysis is selected, you must use a real discount rate. When a current dollar analysis is selected, you must use a nominal discount rate. Within LCAT 1.0, the nominal discount rate and the real discount rate are linked via a formula that includes a term for general

inflation. Figure A5 displays the Project Description window for the high-rise office building case study. The descriptive material is designed to help decision makers differentiate among multiple projects competing for limited investment funds.



Project Name: High-Rise Office Building

Project Description:
The objective is to protect an 11-story high-rise office building from external discharge of contaminants from a single source near the intakes and from a larger cloud approaching the building. To protect the building from an external release, it is desirable to seal the building envelope and retrofit filters in the air-handling units. The proposed improvements are presented as three options. Each option has a different filtration level. NOTE: The high-rise office

Base Year: 2005 Length of Study Period (years): 20

Analysis Information

Constant Dollar Analysis
Real Discount Rate: 7.00%

Current Dollar Analysis
Nominal Discount Rate: 0.00%
Projected Inflation Rate: 0.00%

Figure A5 Project Description Window for the High-Rise Office Building Case Study

Clicking the *Alternatives* option opens the Project Alternatives window, which allows you to add and delete project alternatives as well as enter information about the alternatives. Figure A6 displays the Project Alternatives window for the high-rise office building case study. The Base Case tab is selected. The window is constructed so you can switch from one alternative to another. The text box in the middle of the window allows you to enter a brief description of the alternative, which serves to differentiate one alternative from another.

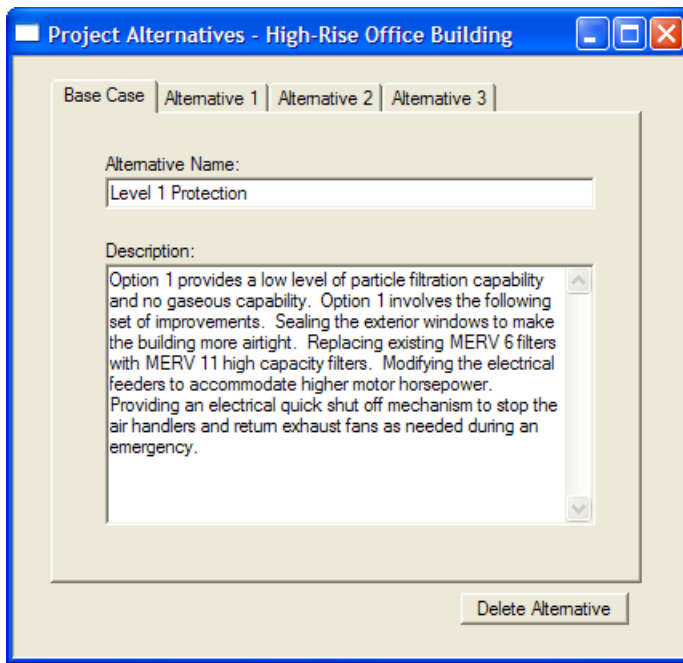


Figure A6 Project Alternatives Window for the High-Rise Office Building Case Study

Cost-related input screens for the software product are of two basic types: (1) protection costs and (2) event-related losses. You access these screens by selecting the *Cost/Loss* option on the Main Menu.

Protection Costs

Clicking the *Cost/Loss* option opens the Protection Costs/Event-Related Losses window. This screen manages the creation, deletion, and editing of protection costs and event-related losses. Upon entering the Protection Costs/Event-Related Losses window, you must select the alternative for which information is to be reviewed or input. Both the costs and events portions of the window are active for the selected alternative. Since our focus is on protection costs, however, we will address only the cost portion of the window here. The following subsection deals with event-related losses. Once the alternative is selected, the Protection Costs/Event-Related Losses window displays all cost items associated with that alternative. Figure A7 is an example of the Protection Costs/Event-Related Losses window for the Base Case. Notice that the protection costs are listed in alphabetical order according to their Budget Category—Investment, O&M, and Other. If a large number of cost items have been entered, some costs will be hidden, but can be viewed by scrolling down the list. In this case, no costs are hidden.

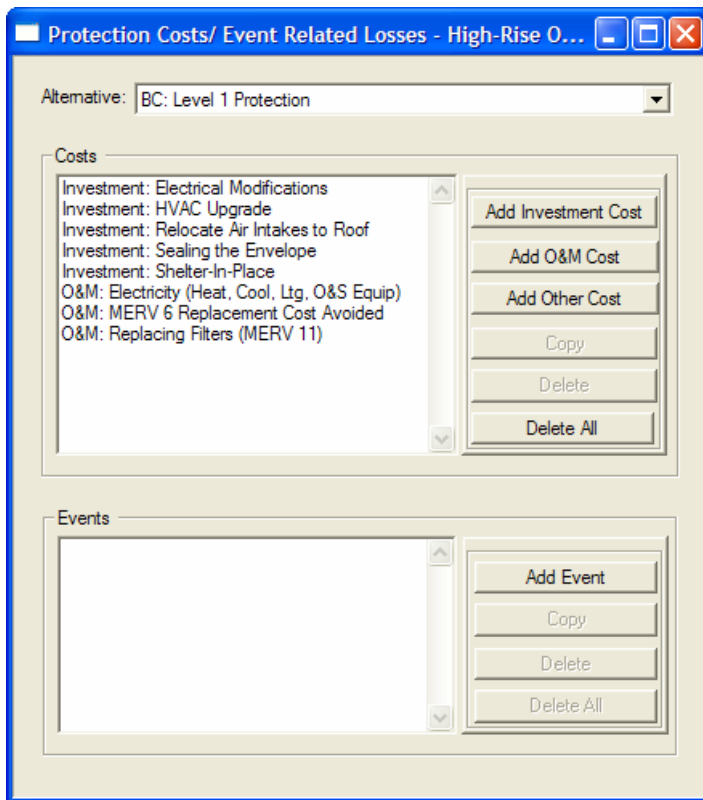
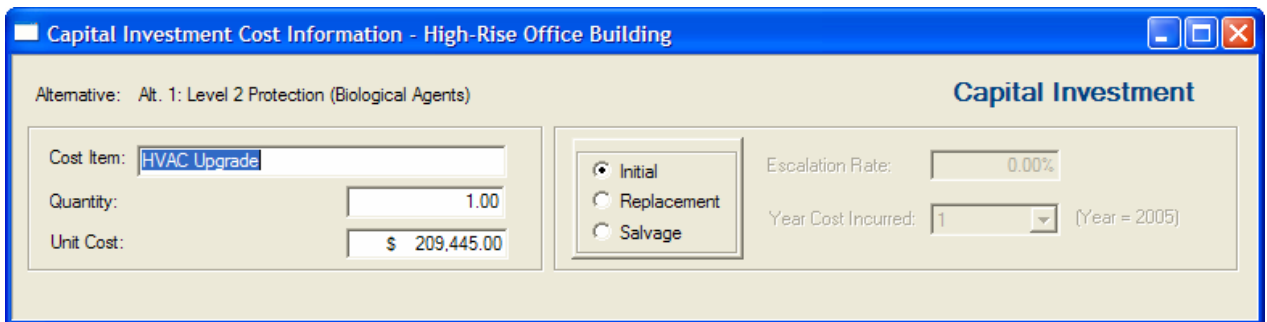


Figure A7 Protection Costs/Event-Related Losses Window for the High-Rise Office Building Case Study: Protection Costs for the Base Case

Highlighting and clicking the selected cost item opens the appropriate Cost Information window. This “edit” feature allows you to review and, if desired, modify any previously recorded information for the cost item of interest. Figure A8 is an example of the Capital Investment Cost Information window for the high-rise office building case study. Figure A8 displays information on the HVAC Upgrade cost item for Alternative 1 (Option 2, enhanced protection from biological agents). Figure A9 is an example of the O&M Cost Information window for the Replacing HEPA Filters cost item for Alternative 1. Figure A10 is an example of the Other Cost Information window for the Change in Traffic Pattern cost item for Alternative 2 (Option 3, enhanced protection from chemical and biological agents).

The Protection Costs/Event-Related Losses window is the means through which new cost items are created. The creation of a new cost item is accomplished by selecting the appropriate Budget Category cost type button—*Add Investment Cost*, *Add O&M Cost*, or *Add Other Cost*—from the list on the right. The software then opens the Cost Information window associated with the selected cost type. The Cost Information windows allow you to name the cost item, generate a cost estimate via separate entries for quantity and unit cost, and specify the timing of cash flows and any escalation rates that need to be applied (see Figures A8, A9, and A10).



Alternative: Alt. 1: Level 2 Protection (Biological Agents)

Capital Investment

Cost Item: HVAC Upgrade

Quantity: 1.00

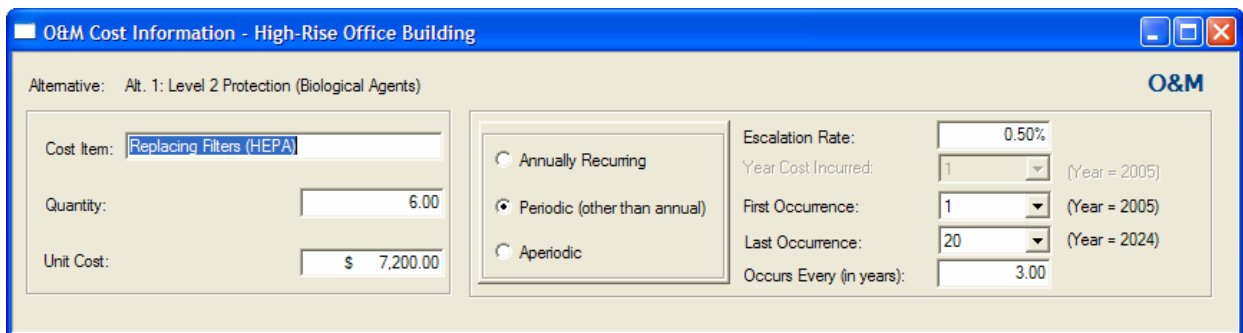
Unit Cost: \$ 209,445.00

Initial
 Replacement
 Salvage

Escalation Rate: 0.00%

Year Cost Incurred: 1 (Year = 2005)

Figure A8 Capital Investment Cost Information Window for the High-Rise Office Building Case Study: HVAC Upgrade for Alternative 1



Alternative: Alt. 1: Level 2 Protection (Biological Agents)

O&M

Cost Item: Replacing Filters (HEPA)

Quantity: 6.00

Unit Cost: \$ 7,200.00

Annually Recurring
 Periodic (other than annual)
 Aperiodic

Escalation Rate: 0.50%

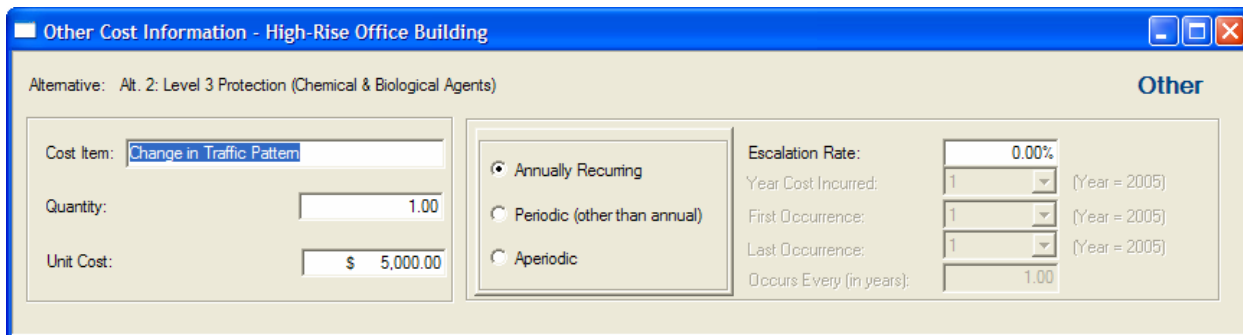
Year Cost Incurred: 1 (Year = 2005)

First Occurrence: 1 (Year = 2005)

Last Occurrence: 20 (Year = 2024)

Occurs Every (in years): 3.00

Figure A9 O&M Cost Information Window for the High-Rise Office Building Case Study: Replacing HEPA Filters for Alternative 1



Alternative: Alt. 2: Level 3 Protection (Chemical & Biological Agents)

Other

Cost Item: Change in Traffic Pattern

Quantity: 1.00

Unit Cost: \$ 5,000.00

Annually Recurring
 Periodic (other than annual)
 Aperiodic

Escalation Rate: 0.00%

Year Cost Incurred: 1 (Year = 2005)

First Occurrence: 1 (Year = 2005)

Last Occurrence: 1 (Year = 2005)

Occurs Every (in years): 1.00

Figure A10 Other Cost Information Window for the High-Rise Office Building Case Study: Change in Traffic Pattern for Alternative 2

Reference to Figures A8, A9, and A10 record the cost choices that map individual cost items into the cost types reported in the Cost Summary window. The Capital Investment Cost Information window offers three choices for classifying a cost item: (1) Initial; (2) Replacement; and (3) Salvage. An initial investment cost, as its name implies, occurs at the beginning of the Base Year (i.e., Year 1 or, in this case, 2005). A capital replacement cost occurs in some future year. Use the drop down menu to specify the year in which the capital replacement is to take place, recalling that Year 1 is the Base Year. A salvage value is a negative capital cost (i.e., a receipt) occurring at the end of the study period. The salvage value is the value of the asset, assigned for

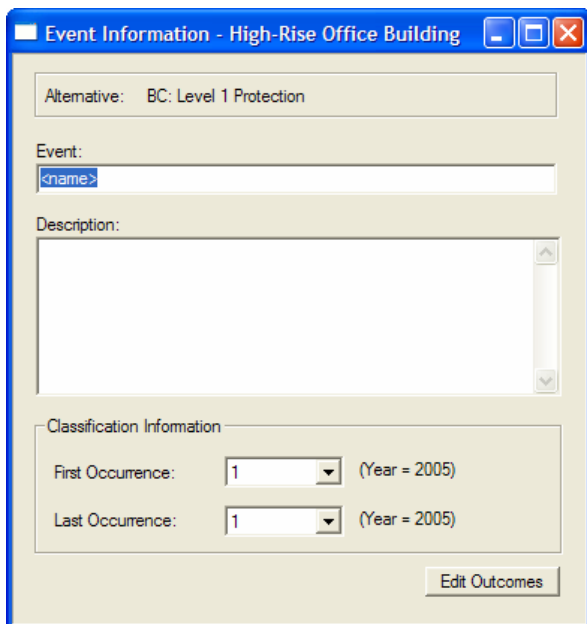
tax computation purposes, that is expected to remain at the end of the depreciation period. The choices for classifying a cost item for O&M and Other costs (see Figures A9 and A10) are the same: (1) Annually Recurring; (2) Periodic (other than annual); and (3) Aperiodic. Periodic costs, such as HEPA filter replacements, occur less frequently than annually—say every three years. Aperiodic costs are one-time costs that occur at some point in the future. If feasible, when preparing estimates for a cost item, include allowances for design/engineering services, taxes, overhead, and other indirects.

Event-Related Losses

Treatment of event-related losses is an important part of a “balanced” life-cycle cost analysis whenever chem/bio or other man-made or natural hazards are involved. LCAT 1.0 treats events as a hierarchy. Associated with an event are outcomes and outcome probabilities. Associated with outcomes are outcome costs. The combination of outcome probabilities and outcome costs are the “losses” associated with a given event.

As noted earlier, clicking the *Cost/Loss* option opens the Protection Costs/Event-Related Losses window. This screen manages the creation, deletion, and editing of protection costs and event-related costs. Upon entering the Protection Costs/Event-Related Losses window, you must select the alternative for which information is to be reviewed or input. Both the costs and events portions of the window are active for the selected alternative. However, we will address only the event-related costs portion of the window here. Once the alternative is selected, the screen displays all events associated with that alternative.

Highlighting and clicking the selected event opens the Event Information window. This feature allows you to review and, if desired, modify any previously recorded information for the event of interest. The Protection Costs/Event-Related Losses window is the means through which new events are created. The creation of a new event is accomplished by selecting *Add Event* from the list on the right. The software then opens the Event Information window. The Event Information window allows you to name the event, provide a brief description of the event, enter the dates of first and last occurrence, and edit event-related outcomes. First occurrence and last occurrence specify the period of time over which a specific set of event-related losses occur. The rationale behind “breaking” events up into segments over the study period is that some mitigation measures may affect outcome probabilities. Such mitigation measures, if implemented in the future, might significantly reduce outcome probabilities and hence event-related losses. Figure A11 is an example of the Event Information window.



The screenshot shows a software window titled "Event Information - High-Rise Office Building". The window has a standard Windows-style title bar with minimize, maximize, and close buttons. The main content area is divided into several sections:

- Alternative:** A text box containing "BC: Level 1 Protection".
- Event:** A text box containing the placeholder text "<name>".
- Description:** A large, empty text area with a vertical scrollbar on the right side.
- Classification Information:** A section containing two rows of data:
 - First Occurrence:** A dropdown menu showing "1" followed by the text "(Year = 2005)".
 - Last Occurrence:** A dropdown menu showing "1" followed by the text "(Year = 2005)".
- Edit Outcomes:** A button located at the bottom right of the window.

Figure A11 Event Information Window

Associated with each event is a set of outcomes. Information on event-related outcomes is accessed via the Outcomes/Outcome Costs window. This screen is reached by clicking the *Edit Outcomes* option in the Event Information window (see Figure A11). Clicking the *Edit Outcomes* option opens the outcomes portion of the Outcomes/Outcome Costs window. Figure A12 is an example of the Outcomes/Outcome Costs window. This screen manages the creation, deletion, and editing of outcomes. The Outcomes/Outcome Costs window displays all outcomes associated with the event of interest. The event/outcome costs portion of the Outcomes/Outcome Costs window is initially grayed out, indicating that it is inactive. However, once an outcome is selected, the costs associated with that outcome become active.

Highlighting and clicking the selected outcome opens the appropriate Outcome Information window. This feature allows you to review and, if desired, modify any previously recorded information for the outcome of interest. The Outcomes/Outcome Costs window is the means through which new outcomes are created. The creation of a new outcome is accomplished by selecting *Add Outcome* from the list on the right. The software then opens the Outcome Information window. The Outcome Information window allows you to name the outcome, provide a brief description of the outcome, assign a probability of occurrence for the outcome (outcome probabilities are a byproduct of the risk assessment), update the sum of all outcome probabilities for the event of interest, and edit outcome-related cost items. Figure A13 is an example of the Outcome Information window.

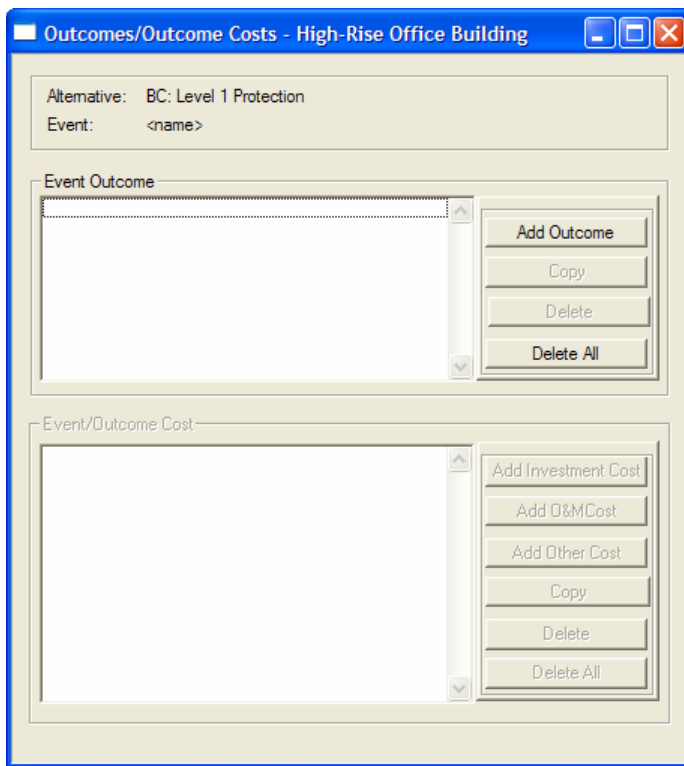


Figure A12 Outcomes/Outcome Costs Window

Outcomes are characterized by their severity and their occurrence probabilities. An event includes the full range of outcomes from no damage to extreme damage. For a given event, the sum of all outcome probabilities equals 1.0. Thus the no damage outcome would usually have a very high probability, corresponding to maintenance of the *status quo*, whereas an extreme damage outcome would have a very low probability. *Outcome probabilities are the “key” driver of event-related losses, since these losses are “expected” values.* Outcome probabilities are expressed as annual values. Thus, the “chance” an event-outcome combination occurs in a given year equals its outcome probability.

Because event-related losses are expected to have a major influence on which alternative is the most cost effective, the sum of all outcome probabilities is required to equal 1.0 in order for either the Data Report or the Results Report to be output. OAE’s objective was to avoid situations where losses were either ignored (i.e., a sum less than 1.0) or double counted (i.e., a sum greater than 1.0). *Once an event has been created and one or more outcomes assigned to it, it is possible to edit the outcome probabilities.* Once the sum of all outcome probabilities equals 1.0 (100 % in the Probability Information group box), it is possible to generate both the Data Report and the Results Report. The Data Report is designed as a check on user-supplied inputs, so it includes the outcome probabilities.

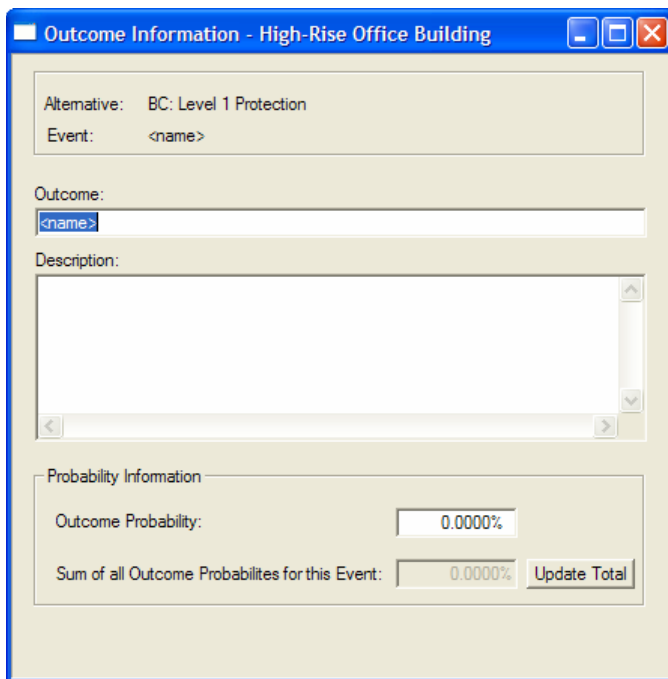


Figure A13 Outcome Information Window

Associated with each outcome is a set of event-related cost items. Typical event-related cost items are damage to the facility, loss of use of the facility (e.g., function and contents), and medical expenses. For example, if an event-outcome combination produced damage to the facility, equipment replacements might result. Information on event-related cost items is accessed by closing the Outcome Information window (see Figure A13), which reveals the event/outcome cost portion of the Outcomes/Outcome Costs window. This screen manages the

creation, deletion, and editing of event-related cost items. The Outcomes/Outcome Costs window displays all event-related cost items associated with the outcome of interest.

Highlighting and clicking the selected event-related cost item opens the appropriate Event/Outcome Cost Information window. This feature allows you to review and, if desired, modify any previously recorded information for the event-related cost item of interest. The Outcomes/Outcome Costs window is the means through which new event-related cost items are created. The creation of a new event-related cost item is accomplished by selecting the appropriate Budget Category cost type button—*Add Investment Cost*, *Add O&M Cost*, or *Add Other Cost*—from the list on the right. The software then opens the Event/Outcome Cost Information window. The Event/Outcome Cost Information window allows you to name the event-related cost item, generate a cost estimate via separate entries for quantity and unit cost, and specify any escalation rates that need to be applied. Figure A14 is an example of the Event/Outcome Cost Information window.

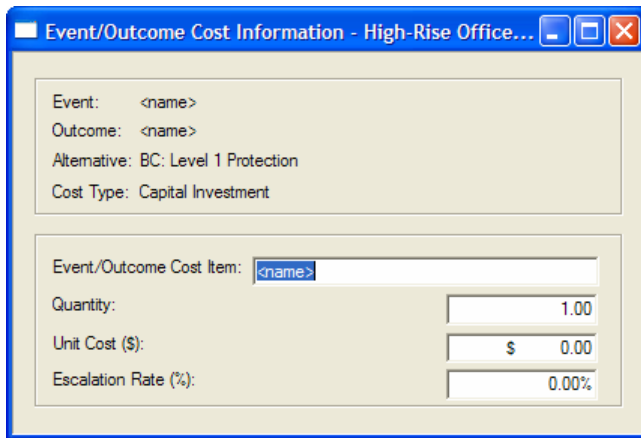


Figure A14 Event/Outcome Cost Information Window

Cost Summary Window

Once all data have been input, the Cost Summary window displays the life-cycle costs for each alternative. Costs are reported for each cost type and in total. Figure A15 reproduces the Cost Summary window for the completed baseline analysis for the high-rise office building case study.

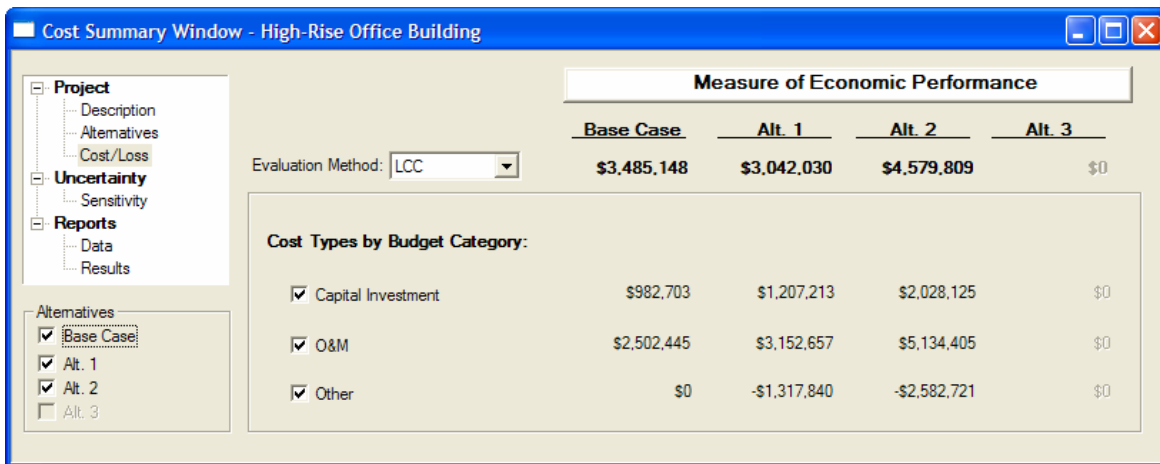


Figure A15 Cost Summary Window for the High-Rise Office Building Case Study: Baseline Analysis

The Cost Summary window provides the option for you to view calculated values for a measure of economic performance other than life-cycle costs. The drop down menu in the Evaluation Method box lets you select the PVNS (present value net savings) as an alternative measure of economic performance. The PVNS values reported on the Cost Summary window are calculated vis-à-vis the Base Case. PVNS measures net savings of investing in the given alternative instead of investing in the Base Case. Thus when the PVNS method is selected, the only meaningful values are the ones listed under the column headings Alt. 1, Alt. 2, and Alt. 3.

Sensitivity Analysis

Recall that in the baseline analysis all data elements entering into the calculations are fixed. Thus, the baseline analysis is a complete analysis in all respects but one: it does not address the effects of uncertainty. Note that the baseline analysis for the four case study applications includes only protection costs.

Sensitivity analysis, as implemented in LCAT 1.0, lets you evaluate how changes in a single variable impact the calculated values of life-cycle costs. The sensitivity analysis feature in LCAT 1.0 is based on techniques presented in ASTM Standard Guide E 1369. Depending on the variable selected, it may impact a single alternative or it may impact all alternatives.

The Sensitivity Analysis window is entered by clicking the *Sensitivity* option under the *Uncertainty* node. The window, as configured in Version 1.0, has a single tab, Change in a Single Factor.

The left-hand side of the Change in a Single Factor tab lists the hierarchy of factors that can be evaluated. Each factor is associated with a node in the hierarchy. Upon entering the tab, the Project and Alternatives nodes appear at the left. All alternatives evaluated in the baseline analysis are listed immediately below the Alternatives node. The squares immediately to the left of each node in the hierarchy are marked with a + (plus sign) or a - (minus sign). A plus sign means that additional nodes and/or factors reside beneath that node. A minus sign means that a node has been opened. Since each project has alternatives associated with it, upon entering the

Change in a Single Factor tab, you will note that the Alternatives node has a minus sign in its square on the left.

Nodes can be opened or closed. For example, clicking the square by the Project node opens the node and the single factor Discount Rate (7.00 %) appears beneath it. Note that there is no square to the left of Discount Rate. This means that Discount Rate is a factor that can be selected for evaluation. Note that the factor line in the hierarchy includes both the factor name (Discount Rate) and its value (7.00 %). Highlighting the factor Discount Rate (7.00 %) selects that factor. The right-hand side of the screen includes the Results group box, a drop down menu for percent changes about the baseline value of the selected factor, and a *Compute* button. Clicking on the *Compute* button causes three sets of values to be computed. Figure A16 shows the results of a 10 % deviation about the baseline value of the discount rate. Note that the name of the factor appears at the upper left-hand corner of the Results group box. Since the Discount Rate is the same for each alternative, results for the Base Case, Alternative 1, and Alternative 2 are reported. Note that the Minimum, Baseline, and Maximum values for the factor, Discount Rate, are displayed. Reference to Figure A16 shows that the discount rate has a fairly strong impact on the computed value of life-cycle costs for the Base Case, Alternative 1, and Alternative 2.

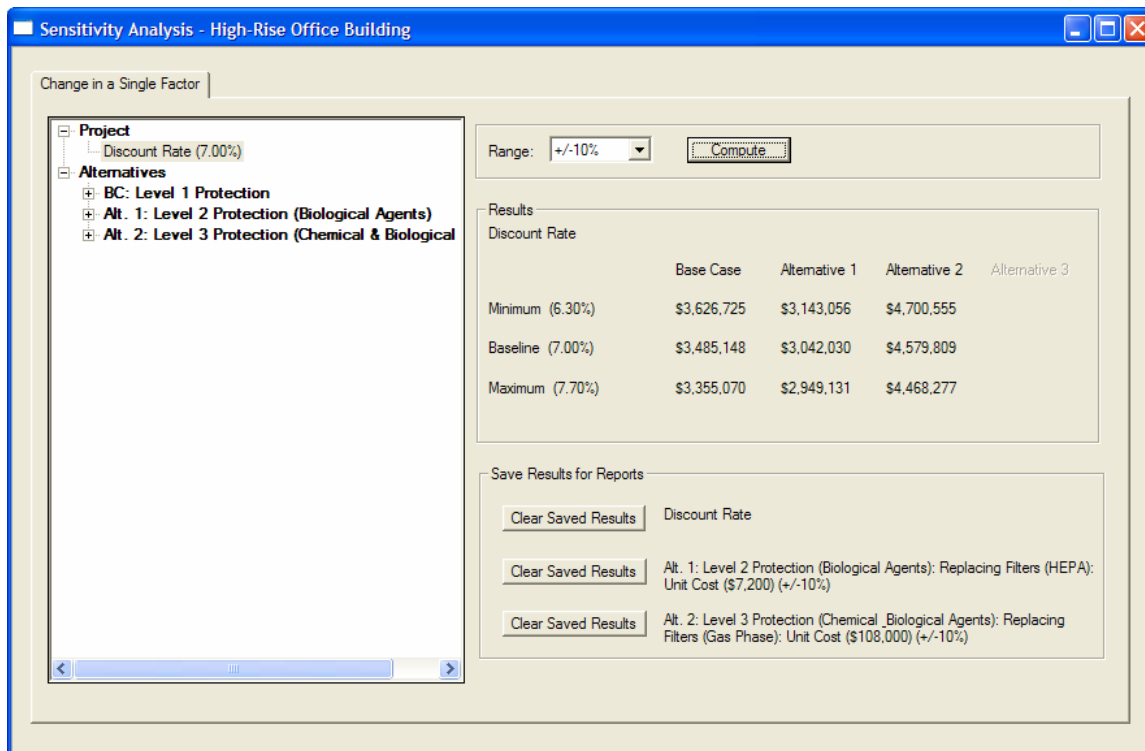


Figure A16 Sensitivity Analysis Window: Using the Change in a Single Factor Tab to Evaluate the Impact of the Discount Rate on Life-Cycle Costs

Figure A17 uses Alternative 2 to illustrate how to open up the hierarchy within a given alternative. The nodes immediately beneath the Alt. 2: Level 3 Protection (Chemical & Biological Agents) node are labeled Costs and Events. Additional nodes are listed beneath the Costs node. Opening the Costs node, we see that 11 nodes are listed beneath it. These nodes correspond to the cost items entered via the Capital Investment, O&M, and Other Cost

Information windows. Note that each of the 11 nodes indicates the budget category it falls under. One of the 11 nodes has been opened—O&M: Replacing Gas Phase Filters—to reveal factors. The factor selected for analysis is the Unit Cost of Replacing Gas Phase Filters. Under the Range drop down menu, we have selected a 10 % deviation about the baseline value of the annually recurring Unit Cost of \$108 000 (i.e., \$648 000 for all six units). Clicking the *Compute* button causes three sets of values to be computed. Because this factor only affects Alternative 2, only values for Alternative 2 are displayed. Reference to the Results group box reveals that this factor has a strong impact on life-cycle costs.

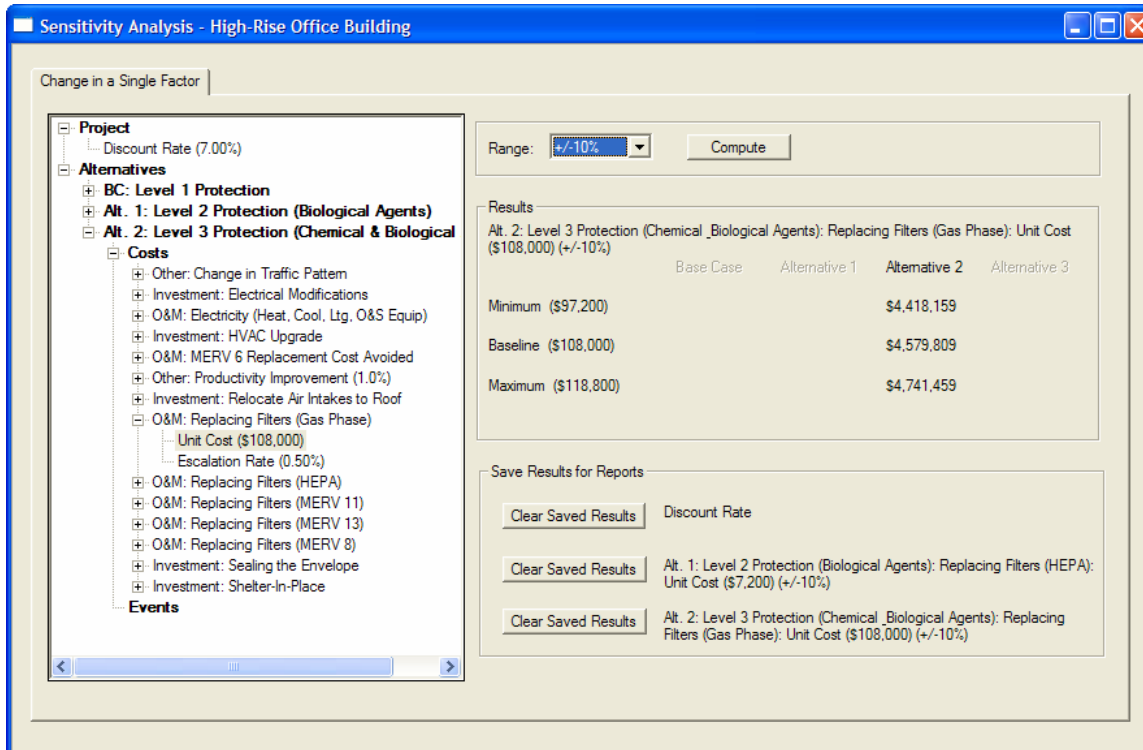


Figure A17 Sensitivity Analysis Window: Using the Change in a Single Factor Tab to Evaluate the Impact of the Unit Cost of Replacing Gas Phase Filters on Life-Cycle Costs for Alternative 2

Event-related costs are evaluated by opening the Events node for the alternative of interest. If events have been entered, the nodes listed beneath the Events node are the individual events defined by the user. Beneath each individual event node are the outcomes. If an outcome had costs associated with it, then the event/outcome cost items are listed as nodes beneath it. The factors—unit cost and escalation rate—appear beneath each event/outcome cost item.

The bottom right-hand portion of the window contains the Save Results for Reports group box. As its name suggests, the *Save Results* buttons may be used to save up to three sets of computed results. For example, the discount rate had a strong impact on life-cycle costs for the Base Case, Alternative 1, and Alternative 2. Thus, saving these results might prove useful in supporting a recommendation for one alternative over another. Any results that you choose to save will appear in the Results Report. Note that more than one range can be used and saved for a single factor.

Reports

The Life-Cycle Cost Analysis Tool produces two types of reports. Although the reports share a number of similarities in terms of their content, their functions are very different. Each report is accessed via the *Reports* node on the main menu. Clicking the *Data* or *Results* option under the *Reports* node takes you to the selected report type.

The Data Report is intended as a means for checking the accuracy of the information that you entered into the Life-Cycle Cost Analysis Tool. The Results Report is designed to help you “drill down” on how individual cost items are distributed across Budget Category cost types. This approach gives you a snapshot of all of the costs entering the analysis, expressed in present value terms, which “roll up” into the life-cycle costs recorded in the Cost Summary window. The Results Report also includes any sensitivity analyses you decide to save. The Results Report is intended for submission to senior management as part of the documentation supporting the specific project being considered for funding. The Results Report is sufficiently detailed to provide a concise snapshot of the underlying data, including the candidate set of alternatives evaluated, the types of analyses performed, and the results of those analyses.

Clicking on the *Data* option under the *Reports* node opens the Data Report. The Data Report consists of: (1) a Cover Sheet; (2) Background Information on the project (e.g., Project Name, Project Description, Study Period, and Analysis Information); (3) Alternative Information – Descriptive Summary (e.g., Alternative Name, Alternative Description, Event Name, Event Description, Outcome Name, Outcome Description, and Key Parameters); (4) Alternative Information – Protection Cost Data Summary (e.g., Cost Item and Dollar Amount); and (5) Alternative Information – Event/Outcome Cost Data Summary (e.g., Event, Outcome, Event/Outcome Cost Item, and Dollar Amount). Figure A18 reproduces the Cover Page of the Data Report for the high-rise office building case study.

Verifying the accuracy of input data is essential to ensure that the results of the economic evaluation are consistent with the underlying data. The Data Report is specifically designed to verify the accuracy of the input data. Figure A19 provides information on the protection costs for Alternative 1.

High-Rise Office Building

Data Report

12/01/2006

Life-Cycle Cost Analysis Tool for
Chem/Bio Protection of Buildings



Figure A18 Cover Page of the Data Report for the High-Rise Office Building Case Study

Alternative Information - Protection Costs Data Summary

Protection Costs Summary: Level 2 Protection (Biological Agents)

Cost Item	First Year	Last Year	Occurs Every	Category	Escalation Rate	Amount (\$)
Electrical Modifications	2005	2005	1.00	Capital Investment	0.00%	107,365.00
Electricity (Heat, Cool, Ltg, O&S Equip)	2005	2024	1.00	O&M	-0.10%	278,981.00
HVAC Upgrade	2005	2005	1.00	Capital Investment	0.00%	209,445.00
MERV 6 Replacement Cost Avoided	2005	2024	1.00	O&M	0.50%	-2,880.00
Productivity Improvement (0.5%)	2005	2024	1.00	Other	0.60%	-118,293.00
Relocate Air Intakes to Roof	2005	2005	1.00	Capital Investment	0.00%	225,261.00
Replacing Filters (HEPA)	2005	2024	3.00	O&M	0.50%	43,200.00
Replacing Filters (MERV 13)	2005	2024	3.00	O&M	0.50%	18,000.00
Replacing Filters (MERV 8)	2005	2024	1.00	O&M	0.50%	720.00
Sealing the Envelope	2005	2005	1.00	Capital Investment	0.00%	625,326.00
Sheriter-In-Place	2005	2005	1.00	Capital Investment	0.00%	39,816.00

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Figure A19 Protection Costs Data Summary Page of the Data Report for Alternative 1

Clicking on the *Results* option under the *Reports* node opens the Results Report. The Results Report consists of: (1) a Cover Sheet; (2) Background Information on the project (e.g., Project Name, Project Description, Study Period, and Analysis Information); (3) Alternative Information – Descriptive Summary (e.g., Alternative Name, Alternative Description, Event Name, Event Description, Outcome Name, Outcome Description, and Key Parameters); (4) Summary of Life-Cycle Costs; (5) Summary of Costs by Alternative sorted by Budget Category (e.g., Cost Item and Present Value Dollar Amount); (6) Summary of Annual Costs by Alternative and Budget Category (e.g., Present Value Dollar Amounts for each Year for Capital Investment, O&M, Other, and in Total); (7) Summary of Annual Costs by Alternative (e.g., Present Value Dollar Amounts for each Year for each Alternative); and (8) any saved sensitivity analyses.

Figure A20 reproduces the Summary of Life-Cycle Costs Page of the Results Report for the high-rise office building case study. When you examine Figure A20, you will note that it is a reproduction of the Cost Summary window for the baseline analysis. Figure A20 includes the check boxes to indicate clearly whether any data elements have been excluded from the life-cycle cost totals. Figure A20 is the starting point for the “drill down” analysis of the computed values for life-cycle costs.

Summary of Life-Cycle Costs				
		Base Case (\$)	Alternative 1 (\$)	Alternative 2 (\$)
	Total Life-Cycle	3,485,148	3,042,030	4,579,809
Category:	x Capital Investment	982,703	1,207,213	2,028,125
	x O&M	2,502,445	3,152,657	5,134,405
	x Other	0	-1,317,840	-2,582,721

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Figure A20 Summary of Life-Cycle Costs Page of the Results Report for the High-Rise Office Building Case Study

Figure A21 is the second page of the three-page Summary of Costs by Alternative portion of the Results Report. Figure A21 covers Alternative 1. All costs are expressed in present value dollar amounts and include designations for the cost types, which map them into the cost-accounting framework. If you wish to examine how a particular cost item contributes to the amounts shown on the Summary of Life-Cycle Costs page, choose the cost item, see where it fits in the cost-accounting framework, and then trace it back to Summary of Life-Cycle Costs page.

Because event-related cost items are very similar across alternatives (e.g., damage to the facility and loss of use of the facility) but differ in their magnitude, it is sometimes desirable to use the Summary of Costs by Alternative to calculate a “loss differential” between the Base Case and one of more of the alternatives. This can be done for either a single event-related cost item, a combination of event-related cost items, or all event-related losses. For example, if damage to the facility were the event-related cost item of interest, subtract its value for the alternative of interest from its value for the Base Case. To do this, you will need to pull values from at least two Summary of Costs by Alternative sections of the Results Report—one for the Base Case and one for each alternative of interest.

Summary of Costs by Alternative

Alternative 1: Level 2 Protection (Biological Agents)		
Budget Category	Cost Item	Present Value (\$)
Capital Investment	Electrical Modifications	107,365
	HVAC Upgrade	209,445
	Relocate Air Intakes to Roof	225,261
	Sealing the Envelope	625,326
	Shelter-In-Place	39,816
O&M	Electricity (Heat, Cool, Ltg, O&S Equip)	2,931,084
	MERV 6 Replacement Cost Avoided	-31,815
	Replacing Filters (HEPA)	173,248
	Replacing Filters (MERV 13)	72,187
	Replacing Filters (MERV 8)	7,954
Other	Productivity Improvement (0.5%)	-1,317,840
	Total	3,042,030

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Figure A21 Summary of Costs by Alternative Page of the Results Report for Alternative 1

In developing a cost-effective risk mitigation plan, it is useful to see how costs are distributed over time. The Results Report provides two separate means for examining and assessing annual costs. The Summary of Annual Costs by Alternative and Budget Category provides a detailed disaggregated synopsis of annual costs. Thus, if you want to examine how major equipment

replacements affect annual costs, examine the entries under the Capital Investment heading and look for years in which significant increases in costs occur. The Summary of Annual Costs by Alternative provides aggregated side-by-side comparisons of the alternatives being evaluated. Figure A22 reproduces the Summary of Annual Costs by Alternative page for the high-rise office building case study. These side-by-side comparisons are useful in determining when a particular alternative has a “bulge” in costs—say at the beginning of the study period or associated with a major replacement—or when one alternative’s annual costs begin to escalate at a significantly higher rate. Both pieces of information are useful in understanding the pros and cons of each alternative being evaluated. It is important to recognize that the goal of the analysis is to gain insights into the decision problem.

Summary of Annual Costs by Alternative

Year	Present Value (\$)		
	Base Case	Alternative 1	Alternative 2
2005	1,205,155	1,411,918	2,767,280
2006	207,682	136,715	66,741
2007	193,893	126,948	60,949
2008	181,019	165,502	103,253
2009	169,000	109,436	50,727
2010	157,779	101,597	491,134
2011	147,303	133,779	81,561
2012	137,522	87,544	38,300
2013	128,391	81,255	34,817
2014	119,866	108,115	64,323
2015	111,907	69,984	353,913
2016	104,477	64,942	26,004
2017	97,539	87,355	50,639
2018	91,063	55,907	21,288
2019	85,016	51,866	19,225
2020	79,371	70,565	277,525
2021	74,101	44,627	15,612
2022	69,181	41,391	14,036
2023	64,587	56,990	31,200
2024	60,298	35,595	11,282

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Figure A22 Summary of Annual Costs by Alternative Page of the Results Report for the High-Rise Office Building Case Study

Next Steps

Now that you have completed the guided tour, use the test files to gain familiarity with the software. Experiment with the various means for editing, creating, and deleting data elements. Create simple applications using your own data to master the full capabilities of the Life-Cycle Cost Analysis Tool. Build more complex applications and use the sensitivity analysis feature to evaluate how changing the values of key inputs affect economic performance. Use the Results Report to learn how to drill down on key cost drivers and use that information to help guide you in conducting and saving additional sensitivity analyses. Have as a goal to use the software as a decision support tool; it is largely self documenting, it lays out the information going into the analysis, and provides guidance in choosing a cost-effective risk mitigation plan.

Visit the OAE website (<http://www.bfrl.nist.gov/oae/oae.html>) to learn about future updates and pending software releases.