Critical Infrastructure Protection Decision Support System Decision Model: Overview and Quick-Start User's Guide

Decision and Information Sciences Division

Critical Infrastructure Protection Decision Support System Decision Model: Overview and Quick-Start User's Guide

by
M.E. Samsa, J.C. VanKuiken, and M.J. Jusko
Decision and Information Sciences Division, Argonne National Laboratory

CONTENTS

FIGURES

FIGURES (Cont.)

TABLE

CRITICAL INFRASTRUCTURE PROTECTION DECISION SUPPORT SYSTEM DECISION MODEL: OVERVIEW AND QUICK-START USER'S GUIDE

by

M.E. Samsa, J.C. VanKuiken, and M.J. Jusko

EXECUTIVE SUMMARY

The Critical Infrastructure Protection Decision Support System Decision Model (CIPDSS-DM) is a useful tool for comparing the effectiveness of alternative risk-mitigation strategies on the basis of CIPDSS consequence scenarios. The model is designed to assist analysts and policy makers in evaluating and selecting the most effective risk-mitigation strategies, as affected by the importance assigned to various impact measures and the likelihood of an incident. A typical CIPDSS-DM decision map plots the relative preference of alternative risk-mitigation options versus the annual probability of an undesired incident occurring once during the protective life of the investment, assumed to be 20 years. The model also enables other types of comparisons, including a decision map that isolates a selected impact variable and displays the relative preference for the options of interest — parameterized on the basis of the contribution of the isolated variable to total impact, as well as the likelihood of the incident. Satisfaction/regret analysis further assists the analyst or policy maker in evaluating the confidence with which one option can be selected over another.

1 INTRODUCTION

CIPDSS-DM is a software tool that assists in analyzing complex tradeoffs represented by the results of simulation scenarios generated in case studies by the CIPDSS consequence models. The CIPDSS case study scenario results include multidimensional consequences (impacts) that derive from different types of responses to an hypothesized event. Impacts might be measured in terms of fatalities, nonfatal injuries, nonfatal illnesses, economic losses, impacts on public confidence, and the costs of implementing various mitigation strategies. Case study event scenarios might include, for example, a specified unmitigated chemical release incident together with any number of similar event scenarios, each including the benefit of some mitigation measure of interest. Each CIPDSS scenario is typically run up to several hundred times with varying input assumptions to characterize the uncertainty in the analysis.

Making comparisons between alternative mitigation actions is very difficult under the following circumstances: (1) when a large number of options is under consideration; (2) when the scenarios are evaluated on the basis of multiple, and sometimes conflicting, measures of effectiveness; and (3) when there are many scenario runs to characterize uncertainty. CIPDSS-DM was designed to facilitate exactly these types of complex comparisons. It provides a visualization framework that combines multiple measures of cost and impacts into a single measure of merit, which is a relative preference metric based on the decision maker's value structure. It then constructs graphs that reveal which of the alternative mitigation strategies produces the most favorable outcomes under different threat conditions. The analysis is based on the relative value the decision maker assigns to multiple measures that reflect such important objectives as sustaining human health and safety, the economy, and public confidence. In a single decision map, the user is shown which of the possible actions lead to the most favorable expected outcomes as a function of the likelihood that the incident will occur. CIPDSS-DM also constructs satisfaction/regret curves that reveal the likelihood that a decision maker would be satisfied with a particular choice of mitigation strategy should the incident occur.

Provisions are included for characterizing alternate decision makers who have different value structures and risk tolerances. For example, separate profiles can be constructed for decision makers who place the highest value on reducing fatalities and who are averse to risks; for others who might be most sensitive to costs and who are tolerant of risk; and for yet others who seek to balance costs with human health impacts or national economic impacts and who may be indifferent, or neutral, to risk.

Although CIPDSS-DM was designed to focus specifically on CIPDSS scenario comparisons, it can be used to analyze and display virtually any set of alternatives that lends itself to multidimensional comparisons. The primary requirement for applying this decision support modeling tool to examine alternative problems is to observe the appropriate data structure used to define inputs.

This report serves as a quick-start user's guide and describes the basic features of CIPDSS-DM. It describes (1) data requirements, (2) examples of comparisons that can be performed, and (3) interpretation of the information and charts produced by the model.

2 MODEL SETUP AND ANALYSIS OPTIONS

2.1 BASIC CONCEPTS

CIPDSS-DM operates on multiple measures, typically referred to as decision metrics, that are calculated by the CIPDSS consequence model uncertainty runs. These decision metrics are quantifications of high-level objectives deemed by the President and adopted by the U.S. Department of Homeland Security to be the most important factors to consider when making infrastructure protection decisions. They include impacts on human health and safety, the U.S. economy, public confidence, and the cost of the mitigation measures. Many other metrics are available from the CIPDSS consequence models, such as the amount of energy not delivered, demand for hospital beds, and the number of emergency service calls. While these metrics provide decision makers and analysts with insights about the scenarios, their true importance — from a decision standpoint — to the ultimate choice of a mitigation measure is reflected in their contribution to one or more of the fundamental objectives included in CIPDSS-DM.

CIPDSS uses the case study framework illustrated in Figure 2-1 to calculate the decision metrics associated with the set of alternative mitigation options of interest in a particular decision problem. A case study comprises at least two scenario pairs, a base scenario pair and one or more alternative scenario pairs. Each scenario pair includes a readiness scenario and an incident scenario.
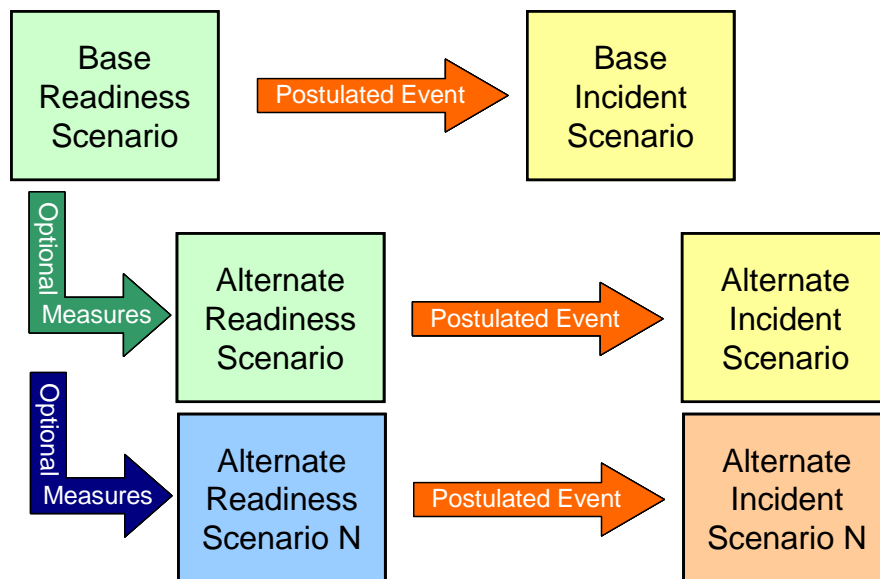

FIGURE 2-1 CIPDSS Case Study Framework

The Base Readiness Scenario depicts the state of the world just before and during the period of the postulated event. Existing measures are in place and no event is postulated; it is the

status quo. Then, an event, such as a terrorist attack, is assumed to be perpetrated on the Base Readiness state, resulting in the Base Incident Scenario. The Base Incident Scenario measures the consequences of the postulated event in the absence of any of the alternatives to be considered in the decision problem.

Next, one of the alternative measures (or decision options) under consideration is described and characterized within the Base Readiness state, resulting in an Alternate Readiness Scenario. Typically, the only difference between the Base Readiness Scenario and an Alternate Readiness Scenario is the cost and operational impacts associated with the mitigation option.

Finally, the postulated event is again perpetrated on the Alternate Readiness state, resulting in an Alternate Incident Scenario with consequences that would be mitigated or otherwise affected by the mitigation option relative to the Base Incident Scenario. In like manner, a pair of Alternate Scenarios is constructed for each alternative mitigation option under consideration.

2.2 OVERVIEW OF CASE STUDY DATA MANAGEMENT

CIPDSS-DM uses the hierarchical folder structure under the CIPDSS-DM/data/ThreatAreas folder to define the threat area categories and case study titles. CIPDSS-DM reads this folder structure at start-up and uses the structure to define the threat areas and case study hierarchy displayed on its opening screen. Figure 2-2 is an example of such a hierarchical folder structure showing (1) a Biological Exposure to Humans Threat Area folder [Bio-Human], which contains a single Smallpox Attack Case Study folder [Smallpox], and (2) a Chemical Exposure Threat Area folder [Chemical], which contains a single Chlorine Release Case Study folder [Chlorine]. While any number of case studies can be contained in a threat area folder, the data files for each case study must be contained in separate case study folders. Note that the user can rename or entirely redefine the threat areas and case study titles simply by editing this folder structure.
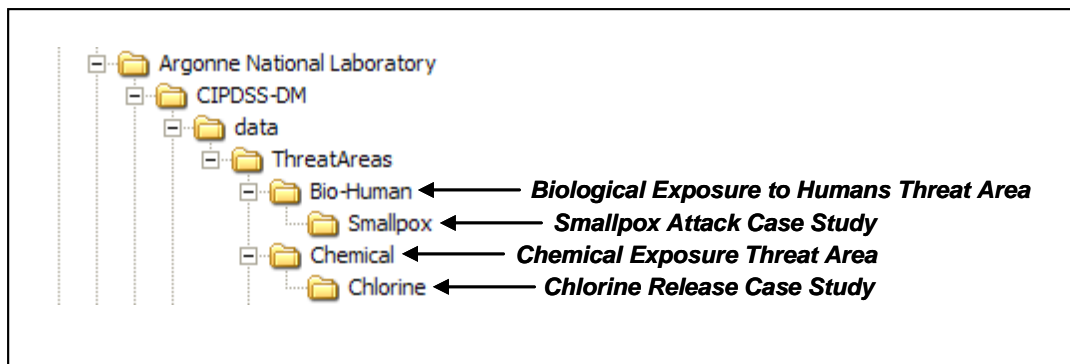

FIGURE 2-2 Example of Hierarchical Folder Structure Showing Threat Areas and Case Studies

Each case study folder contains a single Microsoft Access® database file with all the required case study data, including scenario names, decision metric names, scenario run numbers, decision metric values for each run, and the path and file name for a text or Microsoft Word®

file containing any desired case study documentation. Case study documentation is optional and need not be included if the user chooses to omit it. Regardless of the name given to the Access database, it is associated with the case study name assigned to the folder in which it is placed. However, the user should name the Access database file the same as the case study folder to avoid possible confusion when editing the folder structure or moving case study data files at a later date.

Decision metric data for CIPDSS case studies are as follows:

- Cost of mitigation measures ($M),
- Fatalities (persons),
- Nonfatal injuries (persons),
- Nonfatal illnesses (persons),
- Economic losses[1] ($M), and
- Public confidence[2] (PC point).

Note that units for mitigation measure costs and economic losses are millions of dollars, whereas the CIPDSS consequence models generally report these metrics in dollars. Thus, some conversion of units is necessary when the CIPDSS consequence model data are transferred to the CIPDSS-DM case study databases. Also, some of the CIPDSS consequence models report total illnesses and injuries, which include those that ultimately result in fatalities, while other CIPDSS models report nonfatal injuries and illnesses. These inconsistencies need to be resolved in the process of transferring CIPDSS consequence data to CIPDSS-DM. To avoid double-counting of impacts, CIPDSS-DM appropriately uses fatalities, *nonfatal* illnesses, and *nonfatal* injuries as measures of human health and safety impacts.

Also, the *cumulative* level of costs, economic losses, fatalities, and other impacts over the duration of the CIPDSS scenarios is what determines the relative preference of the mitigation options. Thus, only the cumulative values of the decision metric data, generally taken from the last time period of each scenario run, are required by CIPDSS-DM. Another time period could be chosen by the analyst if there is an interest in exploring the relative preference ratings on the basis of other time slices through the scenarios.

Details of the database schema for the Microsoft Access case study data files are presented in Appendix A.

---

[1] As the CIPDSS consequence models developed, this decision metric evolved to be defined as the aggregate sum of all economic consequence measures, including lost gross domestic product (GDP), emergency response costs, value of lost assets, and others, depending on how those losses were defined and characterized in the consequence models.

[2] See "The Effect of Terrorism on Public Confidence: An Exploratory Study," ANL/DIS-08/6, for a full description of the public confidence metric.

2.3 DECISION-MAKER CHARACTERIZATIONS

CIPDSS-DM enables different types of decisions makers to be characterized, each with different relative values for the decision metrics and each with a different attitude toward risk. This feature provides great flexibility in assessing the sensitivity of preferred options to the relative importance of factors such as cost, health and safety, or economic impacts among and between different decision makers. When more than one decision maker is involved in the selection of a preferred option, CIPDSS-DM can be used to highlight differences among decision makers and help focus their discussions on those areas in which their different value structures would actually result in different choices.

2.3.1 Decision-Maker Value Structure

Decision-maker value profiles are typically constructed through a structured elicitation process designed to quantify the importance that the subject decision maker assigns to a unit change in one decision metric relative to a unit change in another decision metric. The process continues until value relationships are established for all the decision metrics that satisfy the decision maker.

In lieu of eliciting a value structure for a specific decision maker, as would normally be done if CIPDSS were applied to a specific decision problem for a specific decision maker, an analyst can use CIPDSS-DM to explore the sensitivity of the preference measure relative to a range of self-constructed value structures. To do this, the user simply needs to define any number of decision-maker value structures covering some range of interest. In doing so, however, the user must understand the meaning of the numerical values that make up the decision-maker value structures.

To properly interpret the decision-maker value structures, it is important to pay attention to both the units in which the decision metrics are specified and the numerical quantities that define the decision maker's value structure. Both are important.

In the example shown in Table 2-1, Decision Maker 1 places a single unit value on economic losses of $1 million and on costs for protective mitigation measures of $1 million. This decision maker also places a value of 50 on public confidence dropping by 1 point (on a 9-point constructed scale). That is, for Decision Maker 1, a 1-point decline in public confidence is exactly equivalent to $50 million in economic losses or $50 million spent on protective measures.

Like Decision Maker 1, Decision Maker 2 also displays a relative value of 1 for economic losses of $1 million and for $1 million spent on protective measures. He places a value of 0 on public confidence, meaning that no matter what happens to public confidence, it will have no influence on his overall preference for one option over another. He does, however, place a value of 50 on 1 fatality, thus valuing each fatality as equivalent to $50 million in economic losses or $50 million spent on protective measures. The value of 2 assigned to each injury or illness means that, according to this decision maker's value structure, each illness or injury is equivalent to 2/50 fatalities, or $2 million in either protective measures cost or economic losses.

TABLE 2-1 Examples of Alternative Decision-Maker Value Structures

	Decision-Maker Value Structures		
Impact Variable	**1**	**2**	**3**
Cost of mitigation measures ($M)	1	1	40
Public confidence (PC point)	50	0	10
Human health and safety			
Fatalities (persons)	20	50	60
Nonfatal injuries (persons)	0.2	2	20
Nonfatal illnesses (persons)	0.2	2	10
Economic losses ($M)	1	1	60

Decision Maker 3 is interesting because he values the $1 million spent on protective measures less than he values $1 million in economic losses that result from some type of event. By placing a value of 40 on $1 million in protective measures costs and a value of 60 on $1 million in economic losses, the decision maker demonstrates that he or she values expenditures for protection at two-thirds the value of an equivalent amount of economic loss. Furthermore, this decision maker places a low value on human fatalities (relative to the other decision makers), equating each fatality (60/60) to $1 million in economic losses and $1.5 million (60/40) in protective measures costs. Other equivalences can be determined in a similar manner.

Note that the numerical values used to specify the decision makers' value structures account for the units in which the decision metrics are specified, and on that basis, they are relative to each other only within a single decision maker's structure. CIPDSS-DM calculates the relative value of each metric for each decision maker on the basis of the numerical quantities specified by the user regardless of the numerical range used. However, for clarity, the user should follow one of two conventions when specifying decision-maker value structures: (1) select a single decision metric to represent a unit value of importance, and then assign values relative to that metric to unit changes in the other metrics, either more or less important, keeping in mind the units in which each metric is specified; or (2) assign a value of 100 to the metric for which a unit change is most important,[3] and then assign the same (if equally important) or an appropriate lesser value to unit changes in the other metrics.

2.3.2 Attitude Toward Risk

The specification of one additional parameter for each decision maker completes the decision-maker profiles. The decision maker's attitude toward risk, defined by a Risk Parameter, specifies the degree to which the decision maker is averse to or tolerant of risk. A decision maker who is averse to risk seeks to avoid possible outcomes that result in undesirable consequences greater than the mean, or expected value, of all possible outcomes represented by the CIPDSS consequence model uncertainty runs. The risk characteristic of this type of decision maker is that, as undesirable consequences get *incrementally larger*, this decision maker's preference for

---

[3] To identify the most important metric, the following steps can be helpful: (1) think of all the metrics to be set at some highly undesirable value; (2) write these values on a piece of paper; (3) ask the question, "If I could improve just one metric by one unit of measure, which one would I improve first?;" and (4) answer the question and assign 100 to that metric.

them *drops at an increasing rate*. Conversely, as undesirable consequences get *increasingly smaller*, this decision maker's preference for them *increases at a declining rate*. The risk-averse function in Figure 2-3 represents a Risk Parameter equal to +1.0. Specification of larger positive values results in greater curvature in this function or greater deviation in the center region of the scale from the linear, or risk-neutral, function.
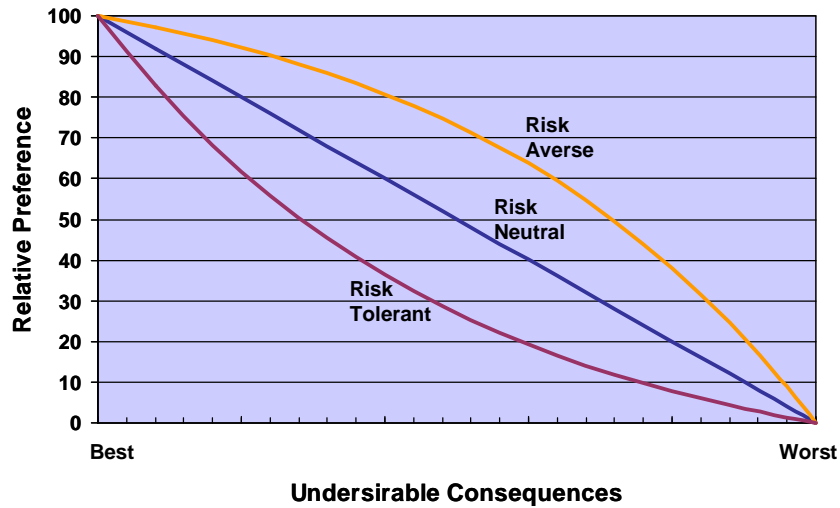
FIGURE 2-3 Decision Makers' Attitudes to Risk

On the other hand, a decision maker who is risk tolerant is willing to accept the possibility of large undesirable outcomes in hopes of achieving an outcome that has less impact than the mean, or expected value, of all possible outcomes represented by the CIPDSS consequence model uncertainty runs. The risk characteristic of this type of decision maker is that, as undesirable consequences get *incrementally smaller*, this decision maker's preference for them *grows at an increasing rate*. Conversely, as undesirable consequences get increasingly larger, this decision maker's preference for them *declines at a declining rate*. The risk-tolerant function in Figure 2-3 represents a Risk Parameter equal to −1.0. Specification of larger negative values results in greater curvature in this function or greater deviation in the center region of the scale from the linear, or risk-neutral, function.

A third type of decision maker is said to be risk neutral because this type of decision maker is not differentially affected by the possibility of larger or smaller consequences than the mean, or expected value, of all possible outcomes represented by the CIPDSS consequence model uncertainty runs. This decision maker's preference for outcomes over the best-to-worst possible range is exactly linear. The risk-neutral function in Figure 2-3 represents a Risk Parameter equal to 0.

In general, the specification of a risk-tolerant decision maker (negative risk parameter) results in relative preference curves in the Standard Decision Map that decline faster with the increasing likelihood of an incident than with the specification of a risk-neutral decision maker (risk parameter = 0). The converse results from the specification of risk-averse decision maker

(positive risk parameter). The Standard Decision Map and other analytical features of CIPDSS-DM are described in Section 3.3.

The attitude-to-risk functions represented in Figure 2-3 are used by CIPDSS-DM to convert the consequences calculated by the CIPDSS consequence models to a relative measure scale on the basis of each decision maker's risk preference profile. Because the attitude-to-risk functions represent only the shape of the decision maker's attitude toward risk, scaled within a range of 0 to 1, and not an absolute attitudinal value for each decision maker, the quantitative values of relative preference between one decision maker and another, with different risk parameters, are not directly comparable. However, the incident-likelihood values at which one decision maker would select one mitigation option over another mitigation option are comparable across decision makers with different attitude-to-risk functions.

2.3.3 Editing the config.xml File

To add or delete a decision-maker profile or to modify either the name assigned to a decision maker, the value-structure quantities, or the decision maker's risk parameter, the user needs to edit only the config.xml file, located in the CIPDSS-DM/data folder, with a text editor. A copy of a typical config.xml file is shown in Appendix B. Should the user desire to do so, he or she can create multiple configuration files with different sets of decision-maker profiles, providing an easy way to change the file by deleting the unwanted confg.xml file from the CIPDSS-DM/data folder and copying the replacement file to the same folder.

3 OPERATING OPTIONS AND RESULTS

3.1 OPENING SCREEN

The image in Figure 3-1 shows the opening screen and basic options for CIPDSS-DM. There are three tabs: Case Selection, Graphics, and Help.

Note that the left panel on the opening screen reflects the threat area and case study folder structure discussed in Section 2.2. Any case study folder that does not contain an Access case study database appears in gray rather than black type.

3.2 CASE SELECTION TAB

The model opens within the Case Selection tab, and the user begins by highlighting an entry under the left column labeled Threat Areas and Their Cases. After a case is highlighted, the right side of the screen displays all the scenarios and decision metrics that have been modeled for that case. After locating and highlighting the case of interest, the user proceeds by clicking on the Accept Selected Case button at the bottom of the screen. The selected case name appears at the top of the screen, confirming that the selection has been successfully completed.
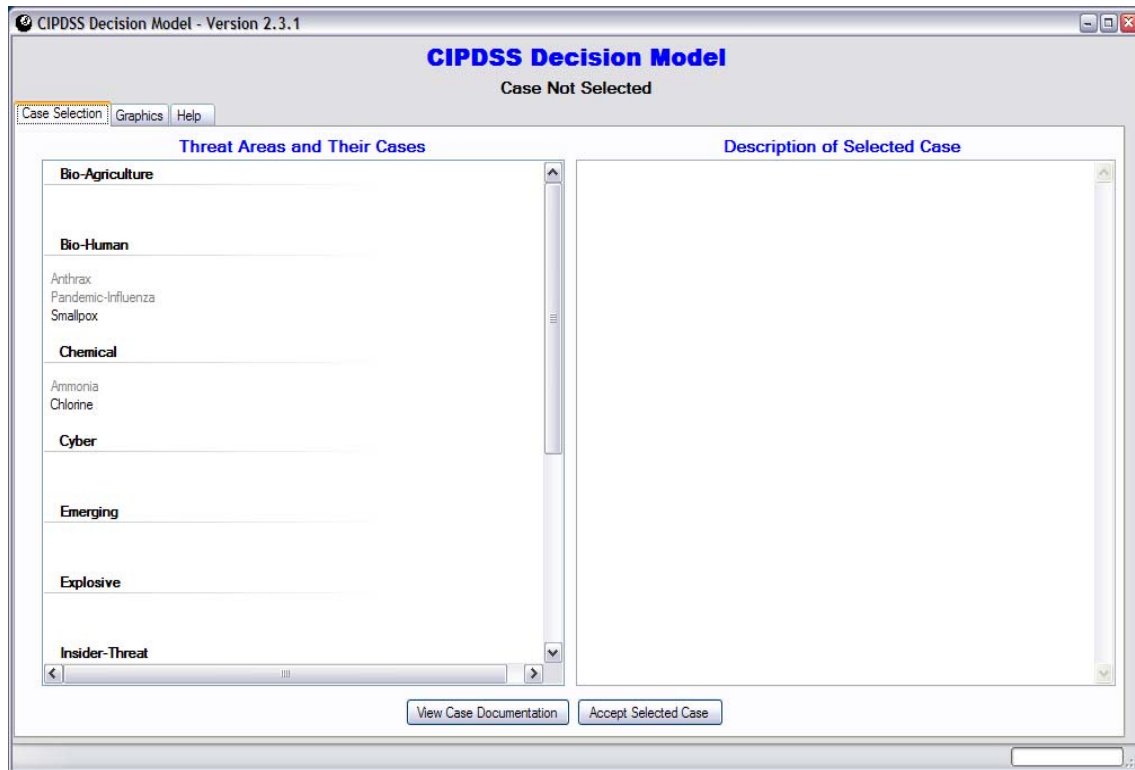

FIGURE 3-1 Opening Screen for CIPDSS-DM

If a case documentation file has been included and appropriately referenced in the case study database, the user can view that document from the opening screen by clicking on the View Case Documentation button.

3.3 GRAPHICS TAB

After a case is selected, the Graphics tab near the top left of the CIPDSS-DM screen is used to initiate the comparison of results. Figure 3-2 is an example of the screen image that appears when the Graphics tab is selected. From this screen the user can:

1. Select either of two types of decision maps or the satisfaction/regret chart to view.
2. Select a decision-maker profile to use in calculating the relative preferences displayed in the decision maps.
3. Select the decision metric that is to be used as the parameterization metric in the Parameterized Decision Map and that will be the equivalent metric measure for the Satisfaction/Regret analysis, both of which appear as the X-axis in the corresponding charts.[4]
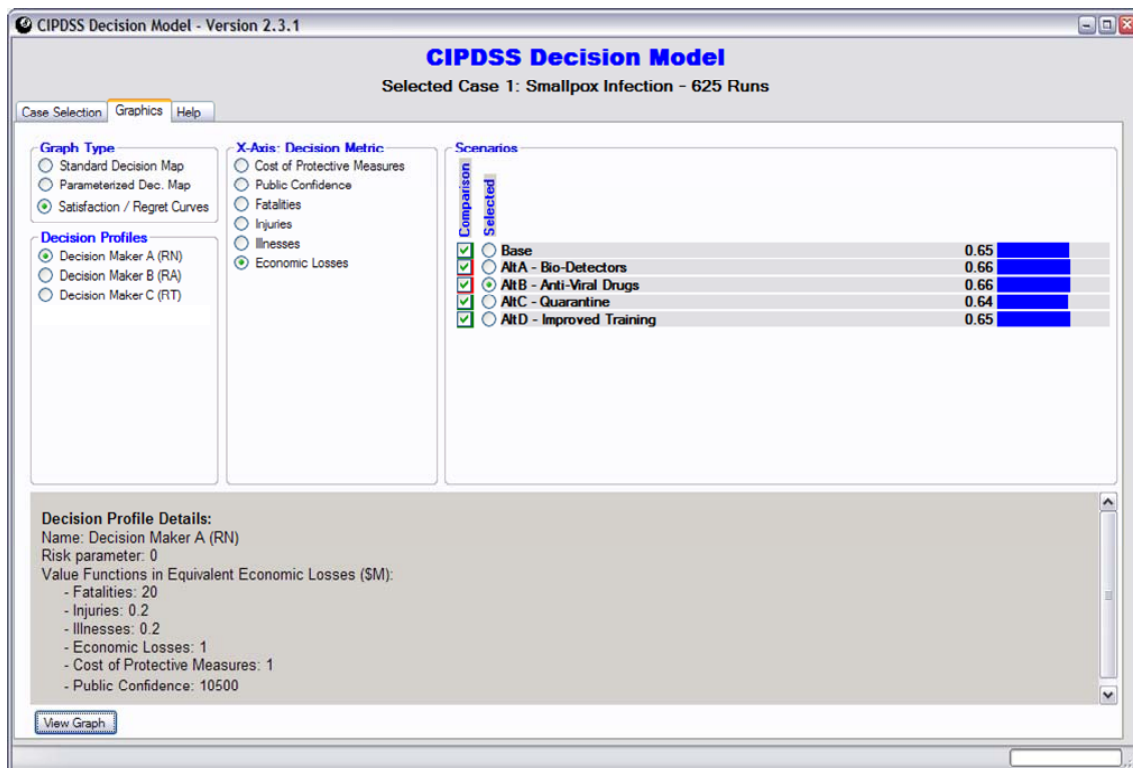4. Select the scenarios to be compared in all three charts.

FIGURE 3-2 Graphics Options Window

---

[4] This parameter is not used for the Standard Decision Map.

When a decision-maker profile is selected, information describing the selected decision maker's value structure is displayed in the gray text box at the bottom of the window. For clarity and simplicity, the decision maker's value structure is expressed in terms of an "equivalent" decision metric. As a default, the decision metric used for this equivalency calculation is $1 million in economic losses. Thus, the decision-maker value structure shown in Figure 3-2 is expressed in units of "equivalent million dollars of economic losses." For this decision maker, a single fatality has the same influence on his multi-attribute preference as $20 million in economic losses.

Although the economic losses metric is used as a default equivalent measure, the user can change this basis by editing the appropriate entries in the config.xml file located in the CIPDSS-DM/ data folder. A copy of the original config.xml file installed with CIPDSS-DM is reproduced in Appendix B.

In the Scenarios area in the top right portion of the window (Figure 3-2), the user can select which scenarios from the case are to be compared and included in the graphic displays. Here there are two columns; one column is a series of check boxes for the user to choose which scenarios to include as comparisons, and another column is a series of radio buttons for the user to check one scenario that is to be treated as the reference scenario, against which others will be compared in the Satisfaction/Regret Chart.[5]

Also shown near the farthest right side of the Scenarios area is a bar chart of the relative preference for each of the scenarios, assuming that the modeled incident occurs. These values reflect the value structure of the decision maker that was selected on the left side of the window. As the user toggles between different decision makers, the relative rankings of the scenarios change in relation to the different decision makers' value structures. This provides a quick and easy way to compare the preference values for the selected decision maker *under the assumption that the incident scenario does occur*. Remember, because the attitude-to-risk functions represent only the shape of the decision maker's attitude toward risk, scaled within a range of 0 to 1, and not absolute attitudinal values for each decision maker, the quantitative values of relative preference between one decision maker and another are not directly comparable because each has different risk parameters. Comparisons between decision makers with equivalent risk parameters, however, are meaningful.

The Graph Type options are:
- Standard Decision Map,
- Parameterized Decision Map, and
- Satisfaction/Regret Curves.

3.3.1 Standard Decision Map

Figure 3-3 is an example of the Standard Decision Map. This chart shows the relative preference of the various risk reduction scenarios as a function of the range of annual incident likelihood values. The range of annual incident likelihood in Figure 3-3 is plotted from 0 to 1%, but can be displayed over any range of likelihood from 0 to 5%.

---

[5] This selection applies only to the Satisfaction/Regret chart and not to either of the decision maps.

Note that, because many mitigation measures involve capital investments that would provide protective value over many years, it was the convention in CIPDSS analyses to estimate the cost of all mitigation measures over a "protective life" of 20 years. The Standard Decision Map is displayed on an annualized likelihood or probability basis derived from the probability of an incident occurring once (and only once) in that 20-year period.[6]
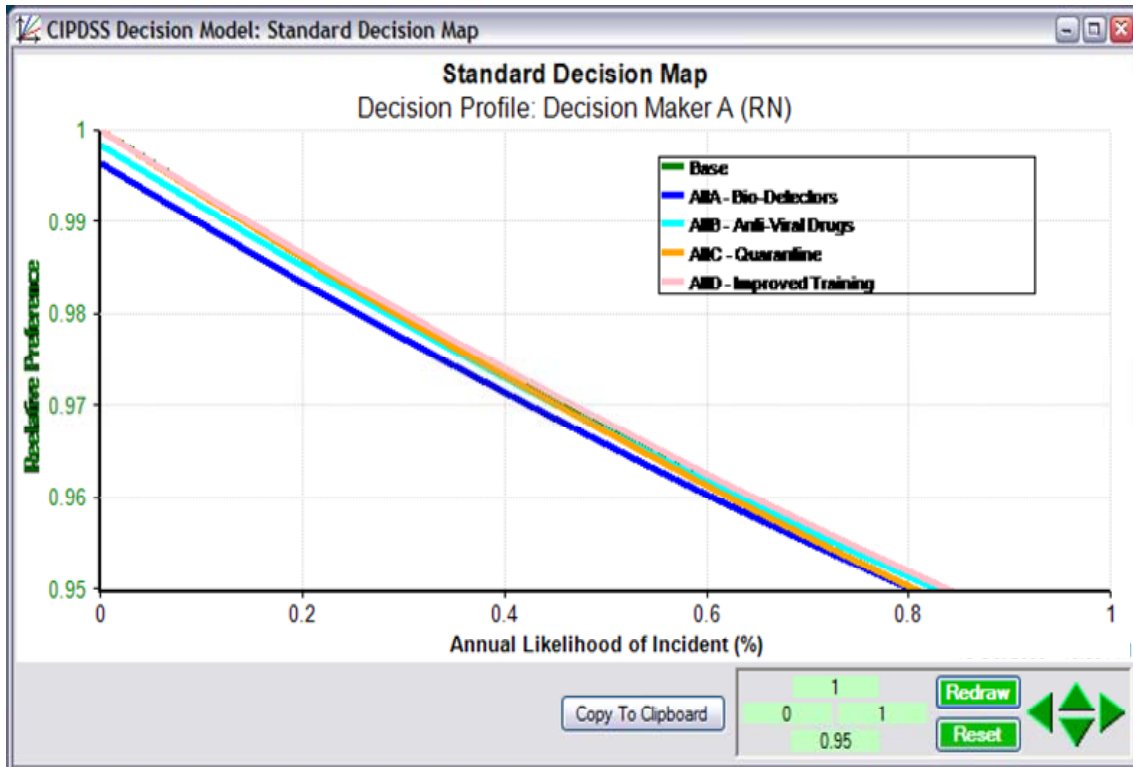

FIGURE 3-3 Example of Standard Decision Map

The area at the bottom of this window provides a feature that enables the user to zoom in or out on the graph, rescale either axis, navigate around the chart, or reset the chart to its default display scale, 0 to 5% likelihood. Also available is a Copy to Clipboard button, which copies the displayed window to the clipboard for pasting into other applications.

When the graph is originally drawn, the legend is placed in the upper left portion of the plot area. The legend can be repositioned by moving the pointer to the upper left corner of the legend box, clicking and holding the left mouse button, and moving the pointer to a new position. The legend redisplays at the new position when the left mouse button is released; it does not move on the screen while the pointer is being moved to the new location.

---

[6]   The relationship between the probability of x occurrences in n years, P, and the annual probability, P_a, of occurrence, assuming the possibility of only one occurrence in a year, is $P = \{n!/[(-x)! \, x!]\} * P_a * (1 - P_a)^{n-x}$. So, for $n = 20$ and $x = 1$, this reduces to $P = (20*P_a)*(1 - P_a)^{19}$.

3.3.2 Parameterized Decision Map

For Parameterized Decision Maps such as illustrated in Figure 3-4, the Y-axis charts a range of probability of the threat incident occurring one time in the 20-year protective life of the mitigation measure, and the X-axis displays the percentage of the parameterization metric that is included in the overall relative preference calculations for each alternative. The parameterization metric is the decision metric selected in the X-Axis: Decision Metric area in Figure 3-2, and in this example, it is Economic Losses. At the 0 end of the X-axis, the parameterization metric is totally *excluded* from the relative preference calculations, and at the 100 end of the X-axis, the parameterization metric is fully included in the calculations. The chart enables a user to examine the sensitivity of relative preference to any of the individual component metrics and to view a full range of conditions under which the various threat reduction scenarios are preferred.

Note that the Probability of Incident scale used in the Parameterized Decision Map is not the same as the Incident Likelihood scale used in the Standard Decision Map; however, they are related. The probability of incident used in the Parameterized Decision Map is the probability of an incident occurring once in 20 years. It is related to the annual likelihood of the incident occurring in 1 year out of 20 by the equation in footnote 6.

This preference map format was originally developed in response to a CIPDSS case study in which one of the decision metrics that played a dominant role in the calculation of the overall relative preference values was itself dominated by a human behavioral response in the consequence models that was profoundly uncertain. This format was used to isolate the contribution of that metric and show its influence on the relative preference of the alternatives by parameterizing that metric over the range of its contribution to relative preference.
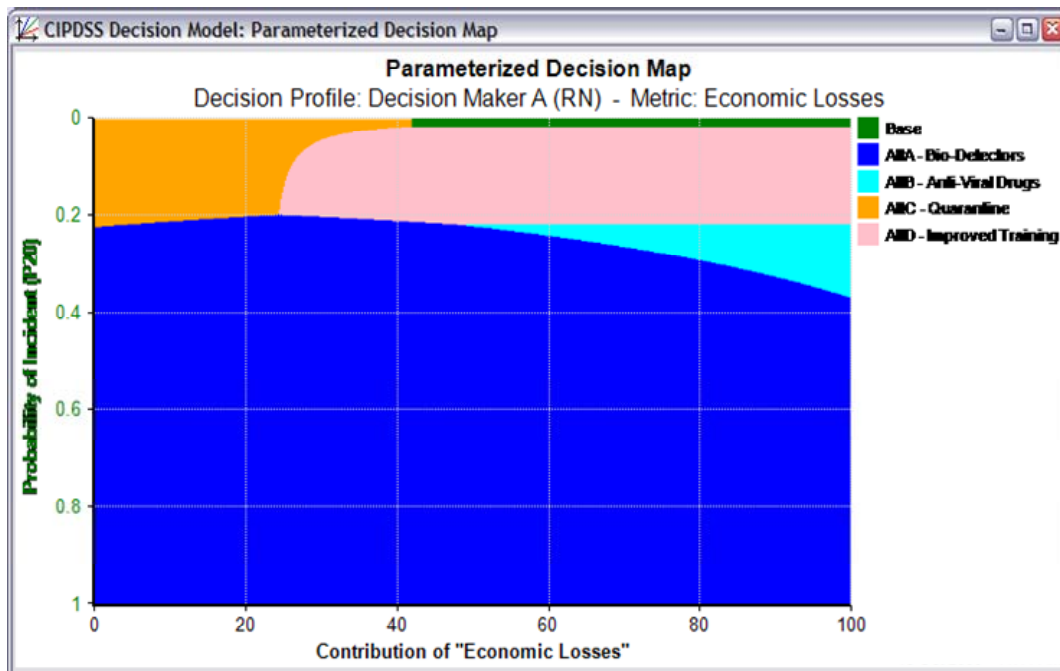

FIGURE 3-4 Example of Parameterized Decision Map

3.3.3 Satisfaction/Regret Chart

Knowledge and insights derived from the CIPDSS consequence simulation models combined with the relative preference maps from CIPDSS-DM are key tools in the goal to better understand and structure difficult critical infrastructure protection decisions. However, because of uncertainty, any choice of protection or mitigation measure, even the optimally preferred choice based on the decision maker's elicited preferences, can have some chance of resulting in greater losses than a less-preferred alternative if an incident does occur.

CIPDSS-DM calculates the confidence level with which one alternative can be selected over another on the basis of the results of the full set of CIPDSS consequence model uncertainty runs. CIPDSS-DM also calculates several statistical risk parameters related to satisfaction and regret.

Satisfaction is defined as the occurrence of a *less undesirable* consequence than what otherwise would have occurred in the same incident because of the choice of one option over another. Conversely, *regret* is defined as the occurrence of a *more undesirable* consequence than what otherwise would have occurred in the same incident because of the choice of one option over another.

Figures 3-5 and 3-6 show the results from specifying economic losses as the parameterization metric and choosing Satisfaction/Regret Curves from the menu in Figure 3-2. They exemplify a satisfaction/regret analysis based on the choice of selecting Alternative B, Anti-Viral Drugs, over any of the other alternatives. Note in Figure 3-2 that the radio button in the Selected Scenario column next to the Alternative B Anti-Viral Drugs option is activated, designating this scenario as the one to which all the others that are selected in the Comparison Scenarios column are to be compared in the Satisfaction/Regret analysis. In this example, the Satisfaction/Regret analysis enables the analyst or the decision maker to examine the following risk questions based on the CIPDSS consequence model simulations:

1. If the Anti-Viral Drug option is selected over the other options, what level of confidence is there that the Anti-Viral Drug option will outperform the other options if an event occurs?

2. If the Anti-Viral Drug option does outperform the other options in an event, how much better off will society be than if any of the other options were selected? What are the maximum, conditional average, and expected levels of satisfaction?

3. If the Anti-Viral Drug option does not outperform other options in an event, how much worse off will society be than if another option were selected? What are the maximum, conditional average, and expected levels of regret?

The information in Figure 3-5, the Satisfaction/Regret Curves, and Figure 3-6, the Satisfaction/ Regret Curve Statistics, answers these questions.
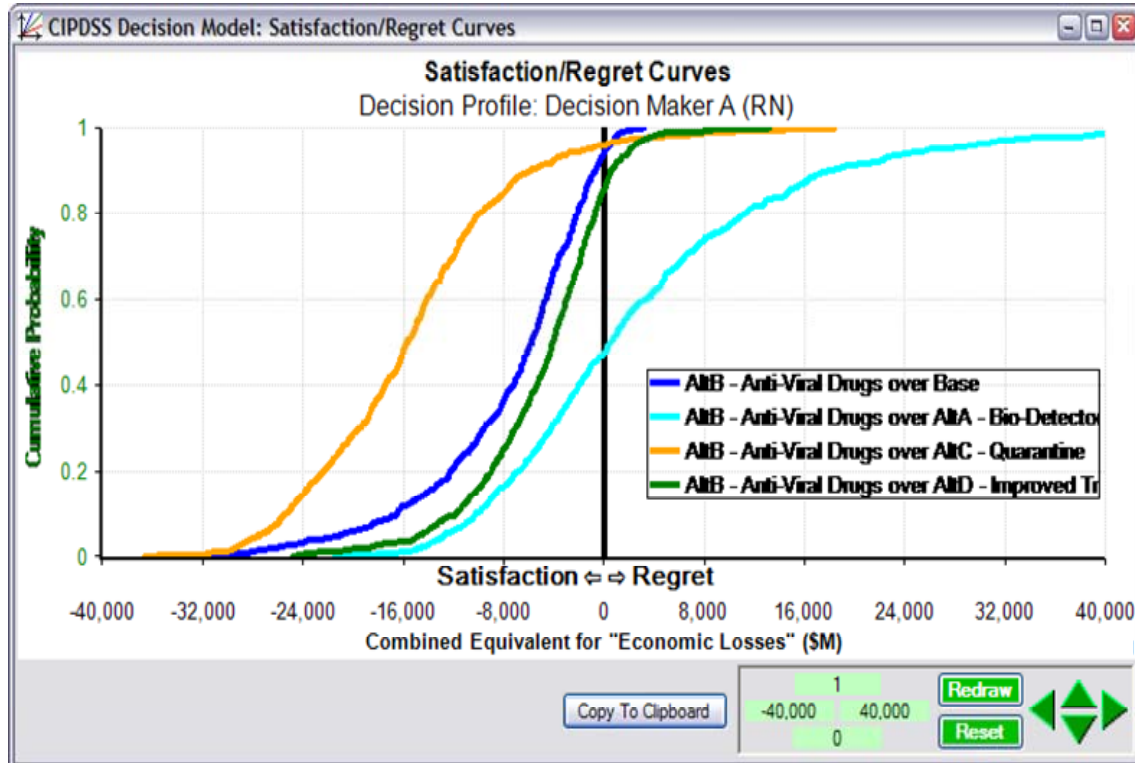
FIGURE 3-5 Satisfaction/Regret Curves

In this example, the Satisfaction/Regret chart plots the cumulative probability of the difference in consequence, on the basis of the incident scenarios (i.e., assuming an incident occurs), between the Anti-Viral Drug option and the other options. Consequence is plotted on the X-axis and, in this example, is expressed in terms of an Equivalent for Economic Losses ($M), because this metric was selected in Figure 3-2 under the X-Axis: Decision Metric option.

The standard CIPDSS convention is to describe undesirable consequences (costs, losses, and so on) as positive values. Thus, the regret region in Figure 3-5, where, in this example, the *consequences of the Anti-Viral Drug option are greater than the consequences of the other options to which it is compared,* is to the right of 0, and the satisfaction region is to the left of 0 on the X-axis; that is, negative costs are benefits or gains relative to the Anti-Viral Drug option.

The cumulative probability at which each of the curves crosses $0 equivalent cost is the likelihood of achieving some level of satisfaction with the selected alternative if an event occurs. In other words, it is also the level of confidence with which the chosen option, in this case the Anti-Viral Drug option, can be selected over the other option to which it is being compared with an expectation of being better off by doing so. For example, in the case illustrated here, there is a 94% chance that consequences will be lower if an event occurs and if the Anti-Viral Drug option is selected over the base option of not taking any additional mitigation action. That is, the decision maker can be 94% confident that selecting the Anti-Viral Drug option will produce more desirable results if an event occurs than if the decision maker were to choose to not invest in any additional mitigation measures.

FIGURE 3-6 Satisfaction/Regret Statistical Risk Parameters

The decision maker can be slightly more confident, 96%, of being better off by choosing the Anti-Viral Drug option over the Quarantine option if an incident occurs. However, he can be only 47% confident that implementing the Anti-Viral Drug option instead of the Bio-Detectors option will result in lower consequences if an event occurs, and only 85% confident of a better outcome if the Anti-Viral Drug option is selected over Improved Training of emergency and health care responders.

The table in Figure 3-6 summarizes a number of important statistical risk parameters corresponding to the satisfaction/regret curves. The table is organized into three horizontal sections: a satisfaction section (green background), a regret section (white background), and an overall payoff line (last line, green background). Four risk parameters are detailed in the satisfaction section:

1. Likelihood of Satisfaction, expressed as a decimal fraction, is where the particular satisfaction/regret curve crosses the 0 value on the X-axis. As described above, this is also the level of confidence with which the decision maker can select the modeled option over the designated alternative with the expectation of lower overall consequences if an event occurs.

2. Maximum Possible Satisfaction is the most extreme value in the satisfaction region. It represents the best possible outcome of choosing the selected option over the designated alternative on the basis of the CIPDSS consequence model runs.

3. Average Conditional Satisfaction is the mean level of satisfaction based on all values falling in the satisfaction region, that is, conditioned on satisfaction being achieved.

4. Expected Satisfaction is the Average Conditional Satisfaction times the Likelihood of Satisfaction.

Four complementary risk parameters are calculated in the regret section:

1. Likelihood of Regret, expressed as a decimal fraction, is simply 1 minus Likelihood of Satisfaction.

2. Maximum Possible Regret is the most extreme value in the regret region. It represents the worst possible outcome of choosing the selected option over the designated alternative on the basis of the CIPDSS consequence model runs.

3. Average Conditional Regret is the mean level of regret based on all values falling in the regret region, that is, conditioned on regret being achieved.

4. Expected Regret is the Average Conditional Regret times the Likelihood of Regret.

The last risk parameter, Expected Overall Payoff, is the expected value when accounting for all possible satisfaction outcomes and all possible regret outcomes. It is the X-axis value of each curve at 50% (0.50) cumulative probability.

APPENDIX A   CIPDSS-DM Case Study Database Schema

Table Name	Description
Header	Case and study information, including date/time and comments.
Scenarios	List of scenarios contained in this case/study.
Variables	List of names of variables and constants in this case/study.
Data	"Last" time-slice's variable and constant values for each scenario.

Header Table

Field	Type	Length	Description
caseId	long	10	Case ID, such as "1002120."
caseName	string	50	Name of case, such as "Smallpox."
comments	memo		Description and comments relevant to these data.
runDate	date		Date/time these data were created.
studyId	long	10	Study ID, such as "1000201."
studyName	string	50	Name of study, such as "Initial" or "Revised Infection Rate."

Scenarios Table

Field	Type	Length	Description
isBase	bool		Flag indicating whether this is a "base" scenario.
isReadiness	bool		Flag indicating whether this is a "readiness," rather than an incident scenario.
scenarioId	long	10	Scenario ID, such as "1008995," unique within a study.
scenarioName	string	50	Name of scenario, such as "Alt A" or "Base Incident."

Variables Table

Field	Type	Length	Description
description	memo		Text description summarizing the variable, with references to metrics contributing to this total.
isConstant	bool		Flag indicating whether this variable is a constant or an output (usually aggregate) variable.
units	string	50	Units used for this variable, such as "person" or "$M."
variableId	long	10	Variable ID, such as "2002506."
variableName	string	50	Name of variable, such as "N.Mt._Illness."

Data Table

Field	Type	Length	Description
isMetro	bool		Flag indicating whether this variable represents data from a "Metro" model, as opposed to a "National" model.
runId	long	10	Monte Carlo run number.
scenarioId	long	10	Scenario ID, such as "1008995," referenced in Scenarios table.
variableId	long	10	Variable ID, such as "2002506," referenced in Variables table.
variableValue	double	15	Value of this variable for this scenario/run, at a given (usually the last) time period. May be duplicate if this is a constant variable.

APPENDIX B Config.xml File

An XML text file named **config.xml** establishes consistent metric definitions and decision-maker profiles for all scenarios. The default configuration file is shown below and can be carefully changed with a text editor. The config.xml file is contained in the CIPDSS-DM/data installation folder.

```xml
<?xml version="1.0" encoding="utf-8"?>
<Config xmlns="http://www.dis.anl.gov">
 <Decision_Metrics>
```

```xml
        <Metric id="1" name="Cost of Protective Measures" units="$M" withReadiness="true" />
        <Metric id="2" name="Public Confidence" units="PC Points" withReadiness="false" />
        <Metric id="3" name="Fatalities" units="persons" withReadiness="false" />
        <Metric id="4" name="Injuries" units="persons" withReadiness="false" />
        <Metric id="5" name="Illnesses" units="persons" withReadiness="false" />
        <Metric id="6" name="Economic Losses" units="$M" withReadiness="false" />
```

```xml
</Decision_Metrics>
 <Decision_Profiles>
```

```xml
        <Profile name="Decision Maker A">
         <riskParameter>0</riskParameter>
         <equivalentMetric name="Economic Losses" units="$M" />
         <Metric_Weights>
          <Metric_Weight Name="Fatalities" Weight="20" />
          <Metric_Weight Name="Injuries" Weight="0.2" />
          <Metric_Weight Name="Illnesses" Weight="0.2" />
          <Metric_Weight Name="Economic Losses" Weight="1" />
          <Metric_Weight Name="Cost of Protective Measures" Weight="1" />
          <Metric_Weight Name="Public Confidence" Weight="50" />
         </Metric_Weights>
        </Profile>
```

```xml
        <Profile name="Decision Maker B">
         <riskParameter>0</riskParameter>
         <equivalentMetric name="Economic Losses" units="$M" />
         <Metric_Weights>
          <Metric_Weight Name="Fatalities" Weight="20" />
          <Metric_Weight Name="Injuries" Weight=".2" />
          <Metric_Weight Name="Illnesses" Weight="0.2" />
          <Metric_Weight Name="Economic Losses" Weight="1" />
          <Metric_Weight Name="Cost of Protective Measures" Weight="1" />
          <Metric_Weight Name="Public Confidence" Weight="10.5" />
         </Metric_Weights>
        </Profile>
```

FIGURE B-1 Default Configuration File

FIGURE B-1 (cont.)

```
<Profile name="Decision Maker C">
 <riskParameter>0</riskParameter>
 <equivalentMetric name="Economic Losses" units="$M" />
 <Metric_Weights>
  <Metric_Weight Name="Fatalities" Weight="5" />
  <Metric_Weight Name="Injuries" Weight=".1" />
  <Metric_Weight Name="Illnesses" Weight="0.1" />
  <Metric_Weight Name="Economic Losses" Weight="1" />
  <Metric_Weight Name="Cost of Protective Measures" Weight="1" />
  <Metric_Weight Name="Public Confidence" Weight="50" />
 </Metric_Weights>
</Profile>
```

```
</Decision_Profiles>
</Config>
```

There are two major sections in the configuration file: one that defines all decision metrics and one that defines all decision-maker profiles.

Data associated with the *<Decision_Metrics>* tag define variables for all cases. The names of the decision metrics must match those in the "variables" field of each case's database (MDB) file. The names of each variable's units in this configuration file override those in the database file.

Data associated with the *<Decision_Profiles>* tag contain parameters that define each decision maker in this configuration file.

- The *<riskParameter>* tag contains the intrinsic risk parameter for the decision maker. Typically, these values are between −1 and +1.
  - A value of 0 represents a risk-neutral decision profile,
  - A value > 0 represents a risk-averse decision profile, and
  - A value < 0 represents a risk-prone decision profile.

- The *<equivalentMetric>* tag establishes a metric that serves as a point of comparison for all other metrics. Its name is ignored, but its units are used in graphics and reports. As shown above, all three decision makers use the "economic losses" equivalent metric, measured in $M, as a basis of comparison.

- The *<Metric_Weight>* tag of each variable defines the equivalent value of that variable expressed in terms of the "equivalent metric." For example, an "illnesses" weight of 0.2 means that each illness is valued by the decision maker at $0.2 million worth of "economic losses."