Risk-Based Performance Assessment of Large Projects – 10441

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ABSTRACT

Government and commercial nuclear projects have been criticized for the lack of a formal risk-based decision support tool for use in properly prioritizing large projects with significant uncertainties. Predicus LLC collaborated with the GoldSim Technology Group LLC to develop this state-of-the-art process to address this need for both government and commercial clients. Predicus LLC was supported by Neptune and Company to develop the specific example shown in this paper.

INTRODUCTION

The Predicus Process (the Process) utilizes a sophisticated risk assessment process that structures and provides defensible inputs into a dynamic probabilistic project performance assessment software tool—a decision support simulation model. The model can be applied to the analysis of uncertainties and sensitivities inherent in complex projects. The process and its associated decision support model allow identification and evaluation of alternative approaches to reduce risk, optimize costs and schedules, and achieve compliance with multiple metrics.

This type of simulation model is a logical and effective evolution of GoldSim™, a modern Monte Carlo simulation software technology, currently in use by a number of government and commercial clients, both nationally and internationally. For example, the U.S. Department of Energy (DOE) has used GoldSim to assess the performance and risk for the Yucca Mountain Project (YMP) and many other radioactive waste disposal sites within the weapons complex [1, 2, 3, 4]. The DOE has also commissioned the development of GoldSim models [5, 6, 7] in order to address decision-making with respect to nuclear projects, in addition to traditional performance assessment. These have ranged from construction and maintenance of nuclear facilities to the disposition of unique waste forms. The Process is designed to achieve the following benefits:

- Promote understanding of all project risks, technical and non-technical.

- Allow comprehensive, integrated risk evaluation over the entire life cycle of major projects.
- Provide flexible and rapid evaluation of changes in funding profiles (short and long term) on a portfolio of projects.
- Allow efficient discrimination and optimization of options and priorities.
- Provide effective visual communication and rapid adaptation during interactions with stakeholders.
- Allow rapid assessment of alternative management approaches.

An example is provided that demonstrates the utility of the process to support more effective inputs to decision-making for large projects or portfolios of projects.

PROCESS ACTIVITES

The three main activities associated with the Process are carried out in phases over a 4- to 6-month period: 1) develop a Success Precedence Diagram (SPD), 2) establish uncertainties and probability distributions, and 3) conduct probabilistic simulations using a GoldSim model created from the SPD. Due to space limitations, this paper will focus on the SPD activity and provide an example of a subsequent simulation.

The first phase requires mapping out the existing baseline project plan. This ensures that the plan incorporates all the necessary components and adequately addresses all of the requirements for success. Once this clear definition of a successful outcome is established, the client, with support from risk assessment process experts, must determine all the possible steps and interactions that lead up to or away from the successful outcome. This logical structure of sequences and precedence requirements leading to success is rendered graphically into an SPD. After the SPD is developed, the next activity is to characterize the uncertainty in each component in the baseline plan, especially in terms of its contribution to success or failure, cost, and time required. Other key uncertainties may include things like availability of resources, costs of financial borrowing, legal events, etc. Contingency plans to address these deviations from the baseline plan are mapped out. For example, “If a required permit is refused or delayed, what action could be taken?” Finally, key go/no-go milestones are established for the project and the bases for the go/no-go decisions are established. The final product of the process is the probabilistic simulation of the SPD. Following generation of the model’s results, the client typically will reconfigure the baseline project plan in order to address problems revealed by the analysis of the results. If the project baseline plan is not finalized at the time of the first Process activities, then the analysis of the model could result in consideration of several alternatives for key project components.

The GoldSim simulation software is used for this risk assessment process because it is a sophisticated state-of-the-art tool with all of the elements necessary for strategic management and financial decisions. GoldSim is accepted and validated by the NRC and has been adopted as the tool of choice for performance assessments of both public and private radioactive waste repositories. Use of GoldSim is a crucial factor in the Process because it provides a tool to manage the inevitable requests for more information from regulators and permitting authorities. A GoldSim simulation model produces probability distributions of the ultimate goal of success. It also assesses subsidiary goals such as receiving necessary permits, and total project cost and schedule. These actions will improve the quality of executive decisions regarding the cost-effectiveness of various steps modeled in the process. It provides a master project plan, which has proven useful for assessing project performance through time. It also allows comparisons between alternative approaches to the project.

The process described above is for a single cycle of the Process. Our experience has shown that while a single cycle has significant value there is additional value in repeating the process at appropriate intervals for projects that remain in the client's portfolio. These intervals are best determined when significant events occur or project progress resolves or reduces uncertainties. In these cases the SPD will likely be expanded and refined, especially as the uncertainties will have changed. The resultant simulations will reveal whether the probability of success in meeting the overall goals is improving and what activities or events contributed to the change. Further, if the probability of success is decreasing, then there will be clear incentive for continued analysis in order to understand the activities or events, and uncertainties contributing to the change in order to guide executive decisions about whether to allocate resources for improvement, or to terminate the project.

Development Process Plan

Application of the Process seeks to portray system performance in response to multiple activities in a probabilistic framework, and it is conceived as a comprehensive, fully integrated, and transparent strategic planning tool that will ultimately encompass all significant project activities. It is designed to capture relationships not only between specific tasks and project- or portfolio-wide perspectives but also the consequences of changes in policies, priorities, funding levels, or other events. An important design goal is the enhancement of the ability to manage programmatic and project-level risks by identifying a broad spectrum of risks. These include not only environmental, safety, technical, and funding risks but also those arising from linkages with other program elements and socioeconomic, legal, political, and other non-technical “soft” risks that can significantly impact projects. The Process is designed to model and evaluate this broadly defined set of risks in a transparent and defensible manner.

As noted in Fig. 1, “Model Development Process Plan Contents/Boundaries”, the *SPD Development Plan* (*Plan*) is one of three interlinked management plans that collectively define the development process. Development of one or more SPDs plays a key role in support of the modeling that will result in a specific application. SPDs are graphical tools that describe the basic logic structure reflected in the components and sequences of a modeled project or activity. An SPD is normally developed in a workshop setting that engages client subject matter experts and the members of the modeling team. In order to be meaningful to the modeling effort, the SPD must be developed holistically, beginning with an examination of the desired outcome, then identifying the various precedents (or pathways of precedence requirements) that lead to the desired outcome. Events that impact the desired outcome may be *endogenous* (originating or occurring within the organizational boundaries of the project or activity being modeled), or *exogenous* (originating or occurring outside the project or activity being modeled). Once a holistic structure is established, it can be mapped to the client’s Work Breakdown Structure (WBS), or any other planning structure, and additional precedence requirements are then added to the logical sequence as appropriate or necessary. The SPD can then be used to guide the next phases of the Process and the development of the GoldSim model.

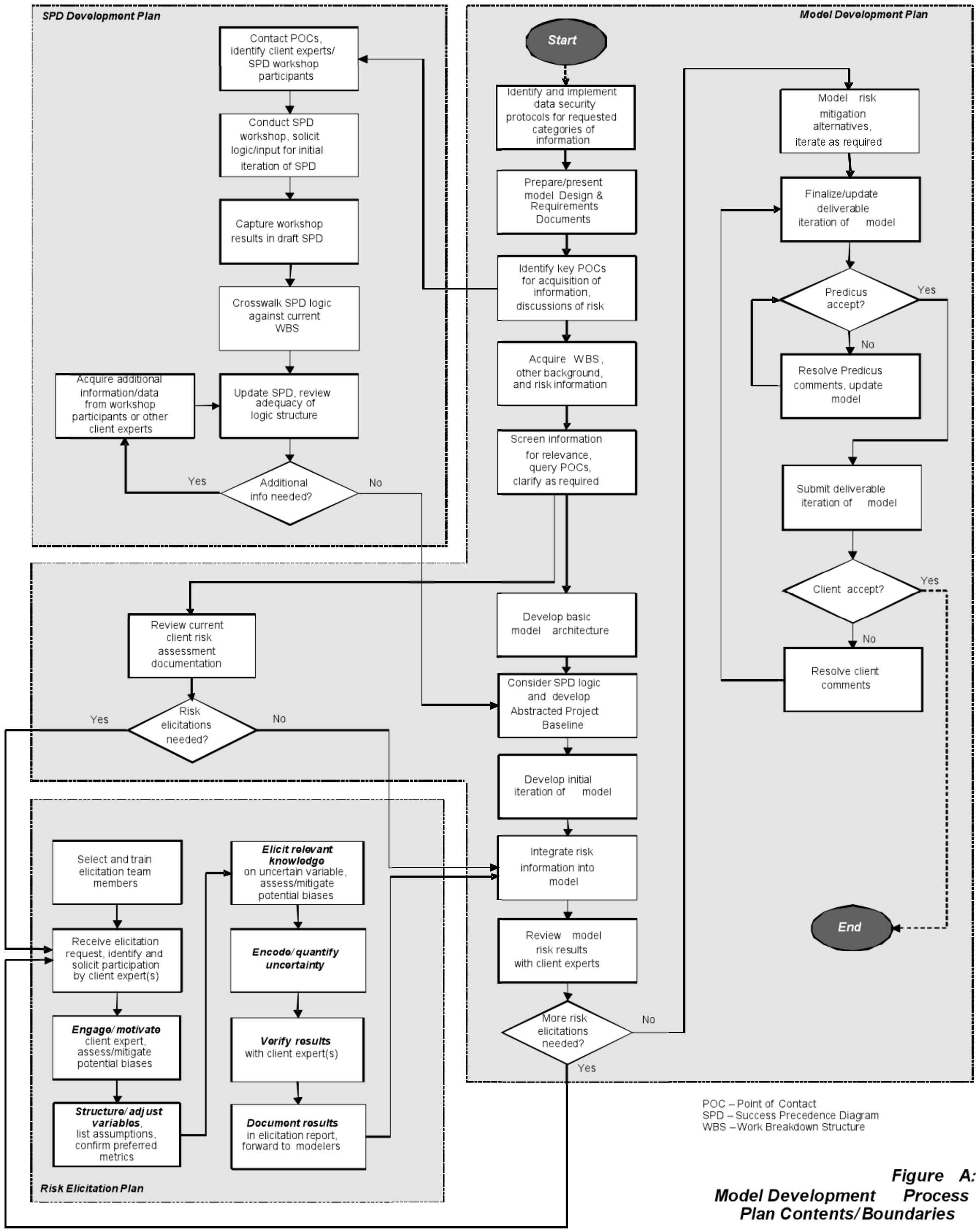

Fig. 1. Model development process plan contents and boundaries

Although some potential risks may be identified in the workshop leading to the development of the SPD, identification of risks is primarily a model development consideration, to be addressed under the *Model Development Plan.* If deemed necessary as part of the modeling effort, uncertainties associated with specific risks may be further evaluated in accordance with the *Risk Elicitation Plan*.

Roles and Responsibilities

The primary responsibilities of the key participants in the SPD development process are listed as follows:

- **Client Participants/Experts –** Selected client participants and experts are engaged to contribute detailed project and process understanding to support development of the SPD and the underlying logic that will be reflected in the development of the project. These participants will also provide support for the mapping of existing WBS or other planning structures to the logic depicted in the draft SPD. The client's participants should have substantial practical experience with the project, task, or WBS elements being modeled, including experience with external stakeholder issues and operational, organizational, and planning activities.

- **Lead Modeler –** Leads the SPD workshop, and evaluates the adequacy of the draft SPD in relation to the initial development goals. The Lead Modeler is assisted by the Senior Modeling Advisor or other individuals who have specific expertise in areas to be examined as part of the development of SPD logic.

- **Senior Modeling Advisor –** Provides technical advice to Lead Modeler on the overall structural considerations for SPD logic, the associated capabilities of the GoldSim modeling platform, and the overall modeling approach that the SPD is developed to support.

- **Information Specialist –** At the Lead Modeler's direction, develops and updates the graphical representation of the SPD based on the notes and diagrams generated by the SPD workshop. The Information Specialist will also prepare a set of general minutes from the meeting.

SPD Workshop

Based on the process flow represented in the SPD section of Fig. 1, the general sequence of activities required for conducting a successful SPD workshop includes the following:

1) **Team Selection:** The Project Manager will confer with the Lead Modeler and/or Senior Modeling Advisor and select the modeling and other subject matter experts to participate in the SPD workshop, based on their experience and/or specific area of expertise and relevance to the project, task, or activities being modeled.

2) **Client Participants and Experts:** The Lead Modeler will confer with the Project Manager and identify the client participants/experts selected for the SPD workshop.

3) **Definition of Model Boundaries and Identification of Endogenous Events:** SPD development will typically begin at the Project Baseline Summary (PBS) level, and it will involve the identification of the critical success-precedence relationships that will be required for the successful completion of a PBS-level project. Lower-level SPDs may be developed as needed, based on the complexity of the PBS project and the number of individual lower-tier projects included in the PBS.

   Participants will be encouraged to think holistically, outside of the organizational constraints or existing planning structures that may have been established to support the desired outcome. As an example, participants will be encouraged to consider the entire life-cycle of the project being evaluated, which may have a decades-long duration. The Lead Modeler will then guide participants in discussions that identify of all the various preceding endogenous events (or endogenous event pathways) that lead to the outcome.

4) **Identification of Linkages to Exogenous Precedents:** Exogenous precedents that have a reasonable potential for occurrence and that could have a potentially significant impact on or relationship to the desired outcome should also be identified. Such requirements may be non-technical and may vary significantly in the extent to which they may be connected to other areas of SPD logic. Examples of such precedents could include those with human or organizational characteristics (e.g., management of contractual relationships to preclude labor problems, management of legal obligations and community relations in a manner that minimizes the likelihood of lawsuits or protests). Precedents may also occur within the boundaries of other organizations.

5) **"Crosswalk" with Existing Planning Structures:** Once the interim SPD sequences involving endogenous and exogenous events are

identified, they will be compared to the existing WBS or other planning structure that currently contains or supports the desired outcome. Certain WBS items may be inserted in the project plan if logical gaps are identified. Some potential exists for other WBS items nominally associated with the desired outcome to not fit well into the logical sequence of the SPD being developed as part of this exercise. Any such "orphan" WBS items should be noted and discussed with project stakeholders later in the presentation of model output.

It should be noted that an SPD that has been properly "cross walked" to current WBS or project planning structures will normally be adequate for guiding model development. However, as part of the SPD workshop, participants may identify known or potential *disruptors* (events that could significantly affect the technical, budgetary, or schedule aspects of the desired outcome), potential *terminators* (events that could prevent the desired outcome from occurring as planned), or associated mitigation measures. This information should be captured by the Lead Modeler.

6) **Participant Review and Consensus and Preparation of Draft Graphical Output:** At the conclusion of the workshop, the overall output of the workshop should be reviewed with the client participants and clarifications and adjustments made as appropriate. A general consensus should be sought with respect to the overall realism of the logic structure represented in the draft SPD.

Review and Approval of SPD

The Lead Modeler and Senior Modeling Advisor shall review the draft graphical representation of the SPD as well as the meeting minutes, and identify any gaps requiring acquisition of additional information from client participants and experts. All of this information will inform the SPD to the extent that it can be used as a structural reference in the development of an Abstracted Project Baseline (APB) that will become the basis for the development of the actual model. The SPD will be updated as necessary to resolve the results of this review, and it will be approved by the Lead Modeler and Senior Modeling Advisor prior to being released for development as described in the *Model Development Plan.* Copies of the approved SPD are retained as project records, along with a list of workshop attendees and workshop meeting minutes and all approved versions of this *Plan.*

An Example Decision Support Simulation Model

A demonstration decision-support model is developed in order to illustrate the process. In this example, a decision is to be made regarding the disposition of a problematic radioactive waste. After constructing a flow chart identifying the interrelationships between decisions, events, and outcomes (see Fig. 2), the various options for final waste disposition are encoded into the model. Stochastic distributions are derived in order to reflect the uncertainty inherent in input parameters. In this example some of the decision options may be controlled by the model user, as shown in Fig. 3.

In this hypothetical problem, some radioactive waste of uncertain condition has been stored temporarily at a DOE facility, and it needs to find a final resting place. One possibility would be to dispose of it at the local DOE site after exhumation and processing, though this would require, at a minimum, waste characterization sufficient to perform (or update) a site-specific Environmental Impact Statement (EIS) and to develop a radiological Performance Assessment (PA) or two, depending on the nature of the waste. There is no guarantee that the results of the EIS and the PA will permit local disposal, and if they do not, the waste will have to be packaged, transported, treated, and disposed an off-site facility.

Another possibility at the heart of one of the principal decisions to be made is that of pursuing off-site disposal from the outset, precluding the potentially fruitless costs of developing the EIS and PAs. The off-site disposal option includes waste exhumation, treatment at some specialized facility, and final packaging and disposal at an off-site facility that already has a PA and existing waste acceptance criteria. It is assumed that the waste can be processed to meet these disposal criteria, and the costs of doing so are estimated. While choosing to dispose off-site saves the cost of the local EIS and PA work, the transportation costs will be expensive, as suitable transport casks will have to be commandeered. To complicate matters further, the waste treatment could take place at one of two facilities – one at an on-site location (Facility A) and one at a third off-site location (Facility B). Depending on the current (and incompletely known) configuration

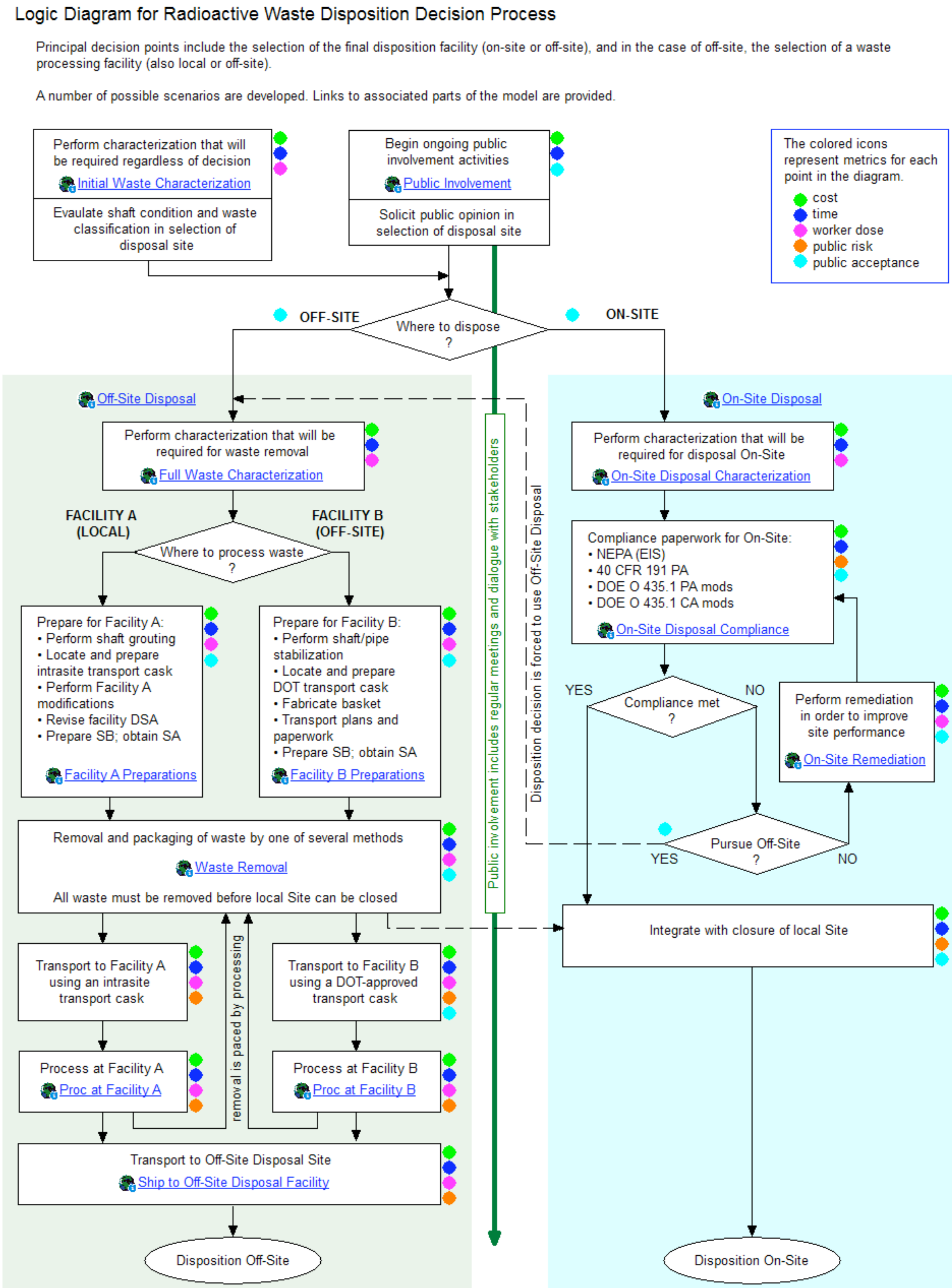

Fig. 2. Logic Diagram for the Decision Process

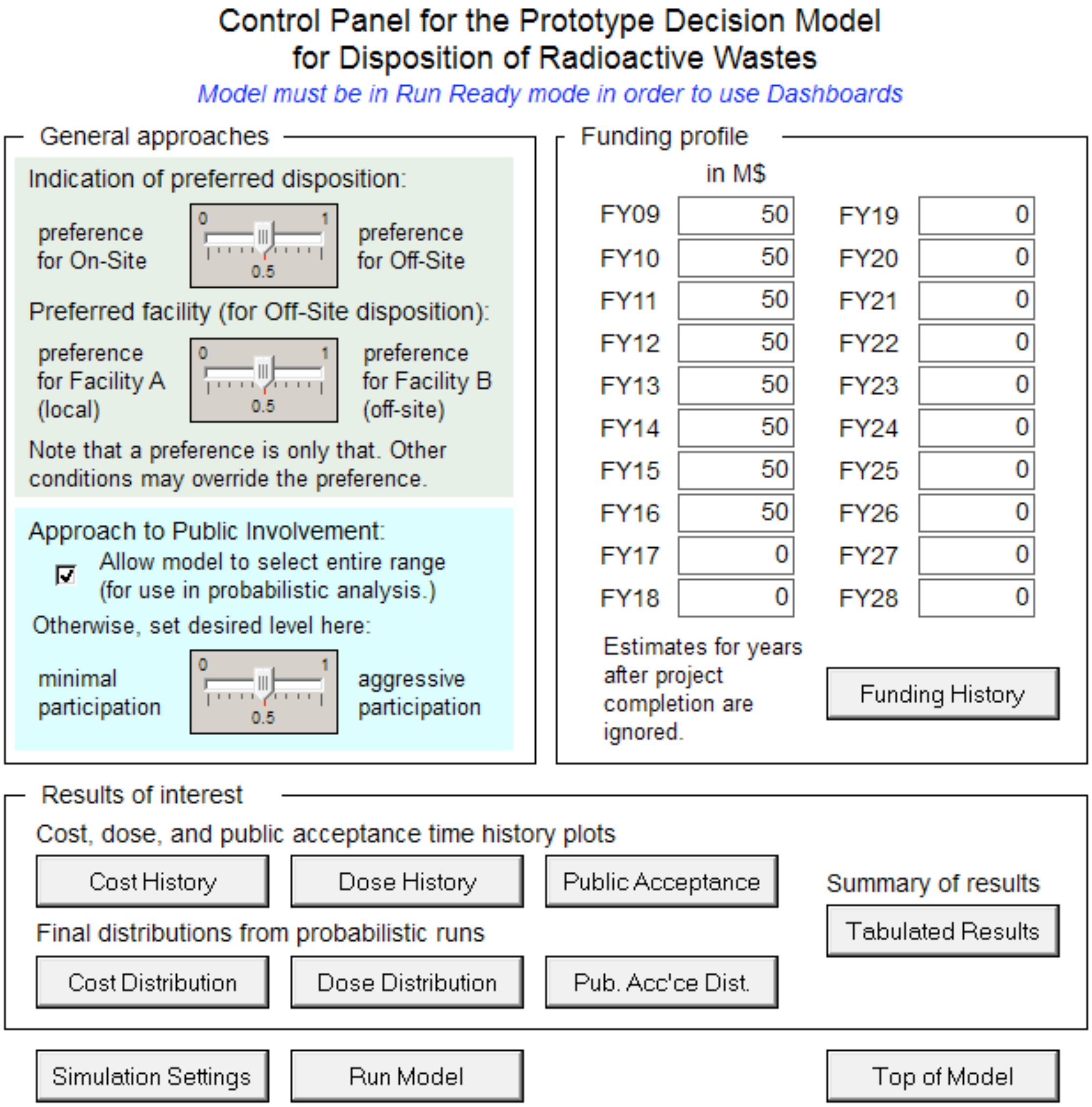

Fig. 3. Control Panel for selecting user-definable options.

of the waste, one or both of these facilities may require upgrading, at additional cost. The decision about which treatment facility to use is also part of the overall scenario.

Each activity in the model, from waste characterization to removal to transportation, incurs uncertain costs, worker risks, risks to the public, and acceptance by the public. Preliminary estimates of each of these parameters are made, and can be updated at any time as more information becomes available, and to the extent that each of these inputs is deemed significant in influencing the model results, and hence the final decisions. The estimates of uncertain parameters are encoded as probability distributions. For example, the cost of revising the local EIS may be as low as $100,000, as high as $1,000,000, with a most likely value of $450,000. Such estimates can be developed by using costs of similar work, or by eliciting information from subject matter experts.

Once all the possible scenarios and contingencies, as well as their associated costs, risks, and public acceptance outcomes have been incorporated into an SPD (such as Fig. 2), they are programmed quantitatively into the GoldSim model. The model is then run in a probabilistic fashion, wherein all input distributions are sampled throughout their ranges and combined in a large number of realizations – typically hundreds or thousands of them. The results show the effects of specific decision options, in terms of costs, doses to workers and to the public, and public acceptance. Using this information, a decision-maker can assess, quantitatively, the predicted risks and outcomes of specific decisions.

One particularly informative result is shown in Fig. 4. Here, we can see the outcome, in terms of overall project cost at completion, of the various decision paths, having run 100 different realizations. The final costs of the various scenarios fall into five distinct bands, corresponding to the outcomes of various combinations of decisions. The least expensive scenario is identified in the lower band, and corresponds to the situation where on-site disposal is acceptable and no special waste treatment is required. The next cheapest option is the selection of off-site treatment (at Facility B, which did not require the expensive upgrades that would be necessary at Facility A) and off-site disposal. Following that is off-site disposal, with treatment at Facility A,

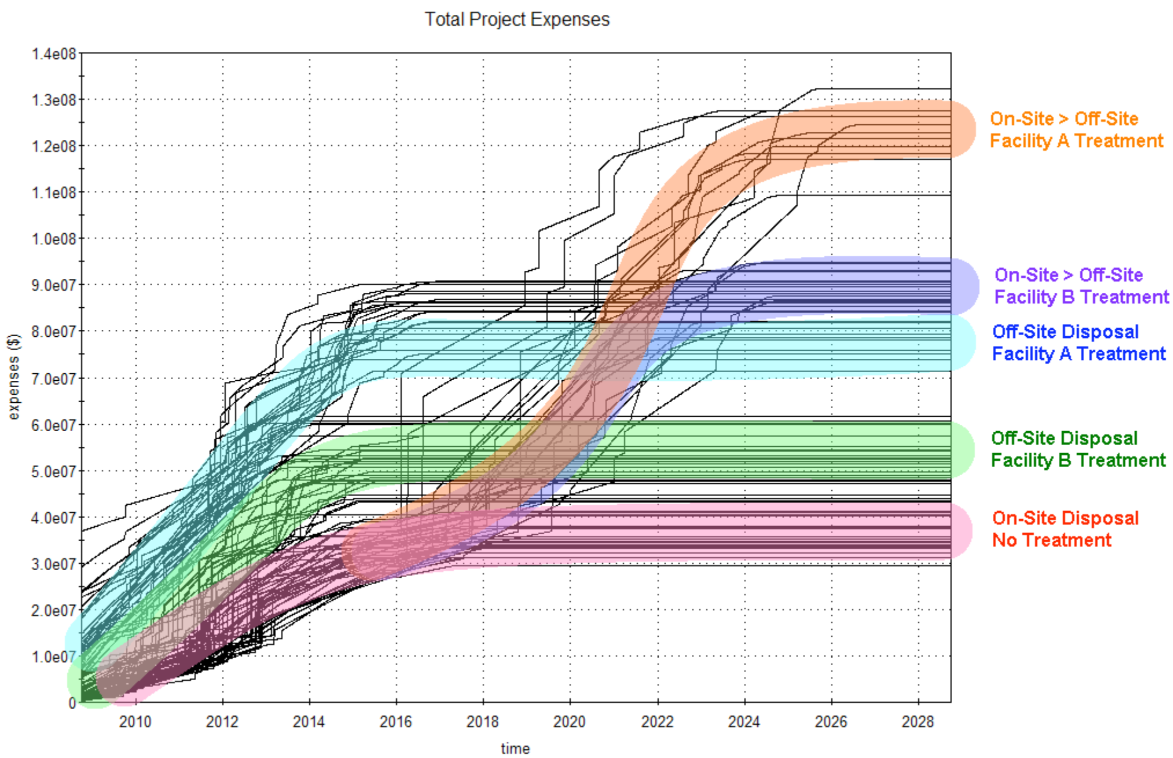

Fig. 4. Sample output of realizations from the decision model, showing the final costs related to various decision paths.

including its expensive upgrades. The two most expensive outcomes are the result of an initial decision to pursue on-site disposal, but being thwarted by an inability to meet compliance, forcing a change in final disposal sites. These are the most expensive because they include both the costs of developing a local EIS and PA, as well as all the costs involved in treatment and off-site disposal.

Note that in addition to examining overall cost, a decision-maker would typically be interested in the results for worker and public risks, and the degree of public acceptance for various decision scenarios. The model would also be run for many more than the few realizations shown in Fig. 4, where just 100 are shown for clarity.

This example illustrates that although the decision to dispose of the wastes on-site may at first seem to be the most expedient choice, the possibility of having to nevertheless abandon this option in favor of off-site disposal is significant. The final costs of the decision path to dispose on-site can be either the least expensive or most expensive, in the end, depending on the feasibility of on-site disposal. That feasibility is not fully known at the time of making the initial decision, since it would be determined by the results of a site-specific radiological performance assessment, which will not be known for some time. While this information may not make the decision-maker’s job easier, it certainly does make the risks and options clearer.

An appropriate path forward for the decision-maker would be to identify what information is needed to help with the initial decision of whether to pursue on-site disposal at all. In this example, that information would come from improved waste characterization, so that work should proceed regardless. Based on the results of that exercise, it is likely that the probability of success for on-site disposal will become clearer. In this fashion, the model is a useful tool in identifying the appropriate path forward at any juncture in the decision process. Along the way, the cost/benefit of acquiring needed information can also be assessed.

CONCLUSIONS

Risk-informed decision-making thrives on information – especially on clear, defensible information that can be easily communicated. Decision-support models like the one presented in this example have great utility in demonstrating probable outcomes quantitatively. In the end, the decision-maker still must balance costs, risks to human health, and public opinion, but the information provided by the model is invaluable.

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