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Risk D&D Rapid Prototype: Scenario Documentation and Analysis Tool

Report to DOE EM-23 under the D&D Risk Management Evaluation and Work Sequencing Standardization Project

SD Unwin
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May 2009



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Pacific Northwest National Laboratory
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1.0 Background

The objective of the Decontamination and Decommissioning (D&D) Risk Management Evaluation and Work Sequencing Standardization Project under DOE EM-23 is to recommend or develop practical risk-management tools for decommissioning of nuclear facilities. PNNL has responsibility under this project for recommending or developing computer-based tools that facilitate the evaluation of risks in order to optimize the sequencing of D&D work. PNNL's approach is to adapt, augment, and integrate existing resources rather than to develop a new suite of tools.

Methods for the evaluation of H&S risks associated with work in potentially hazardous environments are well-established. Several approaches exist which, collectively, are referred to as process hazard analysis (PHA). A PHA generally involves the systematic identification of accidents, exposures, and other adverse events associated with a given process or work flow. This identification process is usually achieved in a brainstorming environment or by other means of eliciting informed opinion. The likelihoods of adverse events (scenarios) and their associated consequence severities are estimated against pre-defined scales, based on which risk indices are then calculated.

A similar process is encoded in various project risk software products that facilitate the quantification of schedule and cost risks associated with adverse scenarios. However, risk models do not generally capture both project risk and H&S risk. The intent of the project reported here is to produce a tool that facilitates the elicitation, characterization, and documentation of both project risk and H&S risk based on defined sequences of D&D activities. By considering alternative D&D sequences, comparison of the predicted risks can then provide a basis for identification of the optimal sequences.

2.0 Overview

Under this project PNNL has developed a rapid prototype tool to support the systematic analysis of risks associated with project cost variances, schedule variances, and H&S impacts. Oracle's Primavera Risk Analysis® Tool (known formerly, and hereafter referred to as Pertmaster), is risk analysis software used across the DOE complex to analyze project risks. Pertmaster focuses exclusively on risks associated with project schedule and cost variances, where schedule data are supplemented with assessments of schedule/budget uncertainties and risks at the level of individual activities. Monte Carlo methods are then used to integrate activity-

level uncertainties/risks to produce the aggregate project-level schedule/budget projections.

In this project we have produced a custom risk register that interfaces with Pertmaster, incorporating not only project risk data, but also H&S risk information. A risk register is a documentation structure in which hypothetical adverse scenarios are defined along with their prospective impacts (schedule, cost, H&S), likelihoods of occurrence, protective measures, and risk-reduction opportunities.

This document outlines our approach to integration of project and H&S risk data, as well as providing instructions for the installation and use of the tool we have developed.

3.0 Approach

An integrated H&S and project risk register application we have named *Risk D&D* was created to accommodate the documentation of parameters governing project and H&S risks associated with hypothetical adverse scenarios. A user interface was developed using Microsoft Visual Basic for Applications (VBA) within the Pertmaster software. Microsoft Access was used to store the register data.

Prior to defining risk scenarios, a project schedule is loaded into Pertmaster from Primavera or Microsoft Project - both are standard scheduling tools across the DOE complex. Once a schedule is in-place, Risk D&D is used to support systematic elicitation of risk data and associated impact scenarios to provide the basis for subsequent risk calculations.

Following elicitation of input information, project risk data are extracted from the risk register and processed via Pertmaster, while H&S risk data are processed through a parallel set of algorithms. Finally, project and H&S risk outputs from the two parallel analyses are integrated to produce an overall display of the risks associated with the D&D project.

4.0 Risk D&D Installation

Risk D&D operates as a custom macro within Pertmaster Risk Expert. Microsoft Office 2007 is used to support reporting functionality. These third party tools must be installed prior to using Risk D&D.

Risk D&D was developed using Pertmaster v8.2 but is also supported by the newly released v8.5. A 30-day trial of Pertmaster Expert v8.5 may be downloaded from <http://edelivery.oracle.com>. Instructions are included in Appendix C.

The following files have been sent with this report:

- RiskDnD.menu – custom Pertmaster menu
- Sample_Schedule.plan – sample Pertmaster plan (schedule)
- RiskDnD.accdb – sample scenario (risk) register database.

Begin by copying the *Risk D&D* custom menu file (RiskDnD.menu) to your local Pertmaster directory (assumes default installation directory):

- “C:\Program Files\Pertmaster Software\Pertmaster8x\Macros” (v8.2).
- “C:\Program Files\Pertmaster Software\Pertmaster8x\Others” (v8.5).

Next, copy the sample Pertmaster plan file (Sample_Schedule.plan) and the sample database (RiskDnD.accdb) to a working directory of your choice.

5.0 Opening Sample Case

Follow these steps to explore the sample project:

- Launch Pertmaster Risk Expert. Open the sample plan by navigating to the Sample_Schedule.plan file
- Enable macros
- Set the location of the sample database using the Set Project Database tool in the Risk D&D menu.
- Launch the Elicitation Tool from the Risk D&D menu.

6.0 Basic Functionality

The description of system functionality to follow is not intended as a guide to the use of Pertmaster. For that, the Pertmaster user’s manual should be consulted. Rather, this section outlines the incremental functionality associated with the custom risk register into which we have now incorporated H&S risk.

6.1 Sample Schedule & Gantt Chart

Pertmaster offers two basic schedule views, a table view (below left) and a classic Gantt Chart view (below right). The sample schedule represents a simplified hypothetical D&D project.

WBS	Parent	ID	Description	Rem Duration	Preceding Tasks	Jun '09				
						1	8	15	22	29
1		1	Sample D&D Schedule	32						
1	1	001	Deactivate	6						
1	001	001.1	Remove all staff and equipment	2						
1	001	001.2	Disconnect all utilities and services	2	001.1					
1	001	001.3	Establish safety perimeter	2	001.2					
1	1	002	Decontamination	6						
1	002	002.1	Identify sources of hazardous waste	2	001.3					
1	002	002.2	Dispose of hazardous waste	2	002.1					
1	002	002.3	Obtain approval for decon completion	2	002.2					
1	1	003	Decommission	4						
1	003	003.1	Submit necessary documentation	2	002.3					
1	003	003.2	Obtain approval to begin demolition	2	003.1					
1	1	004	Demolition	8						
1	004	004.1	Debris removal	2	003.2					
1	004	004.2	Confirmatory sampling	2	004.1					
1	004	004.3	Apply clean fill	2	004.2					
1	004	004.4	Establish permanent institutional controls	2	004.3					

6.2 Set/View Project Database

This utility provides a mechanism for informing the software as to the location of the risk register database. Navigate to the sample database and click OK. The file path is then saved as an encoded variable in the plan file.

6.3 Build Risks

The Build Risk utility extracts the project risk parameters from the sample database and automatically builds the appropriate risk structures directly in the Pertmaster schedule (see Appendix A).

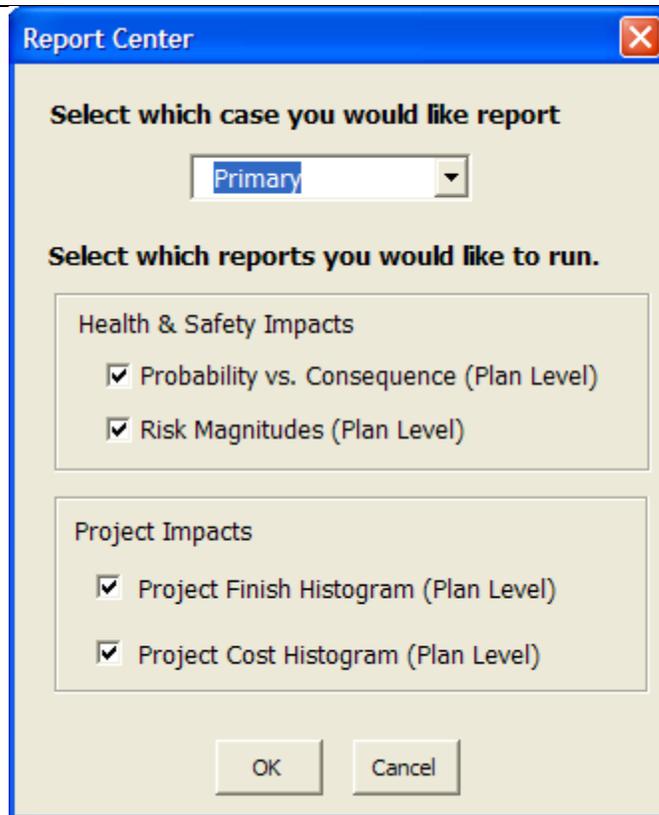
The rapid prototype tool only supports the standard threat model within Pertmaster. Accordingly, a :B task is created for each activity, and risks (customized normal type tasks) are linked as successors to the :B, as is standard in Pertmaster.

The risks are parameterized using the probabilistic and consequence information in the database.

Once the structures are built, users may execute a risk analysis in the usual manner. The results of the risk analysis are used to support the integrated risk report.

6.4 Reports

Risk D&D is capable of reporting both H&S and project impacts. A single interface is provided to manage reporting.



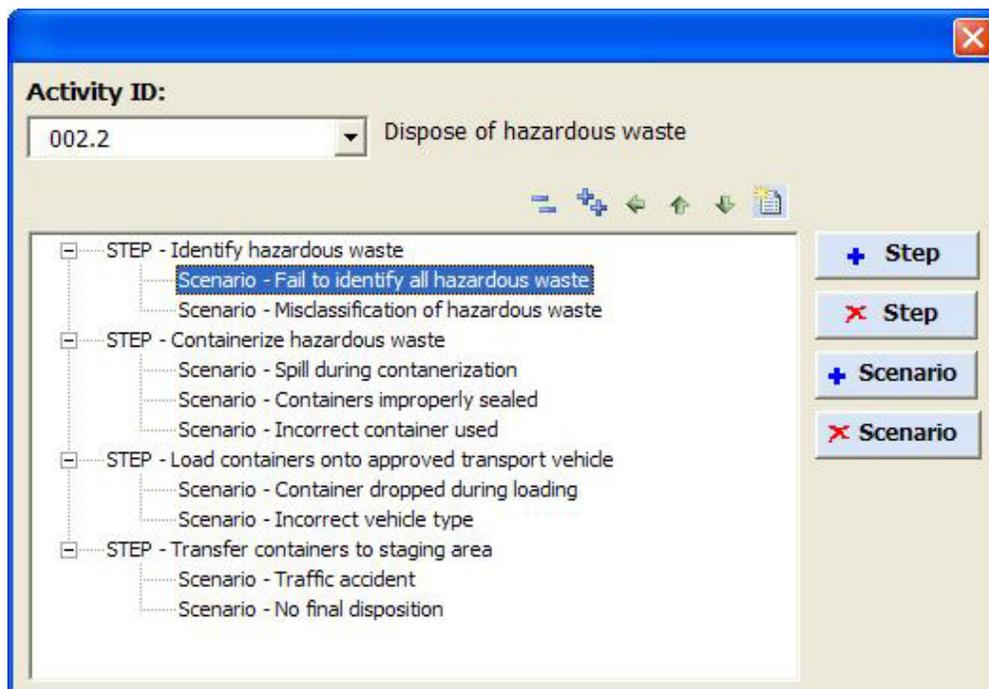
Users may choose to print individual graphs (i.e., risk representations for project risk and/or H&S risk, to be described in Section 8) or all of the graphs in an integrated risk report.

The reports are auto-generated using Microsoft Word 2007 with Excel as a back-end for H&S charting.

6.5 Elicitation Tool

The main component of the *Risk D&D* application is the Elicitation Tool which allows the user to define risk scenarios. Scenarios, that is, adverse deviations from project and/or operational intent, may be associated directly with the activities defined in the schedule. This is the approach to project risk characterization conventionally used in Pertmaster. However, we have added the option of defining individual steps within an activity to more closely reflect the level at which operational deviations are usually defined in a process hazard analysis (PHA); that is, scenarios may now be associated with individual steps. This augmented resolution will facilitate completeness of the scenario identification process. *Risk D&D* will automatically roll-up the risks from the step level to the activity level.

In what follows, a series of screen shots from *Risk D&D* shows the elements of the risk register elicitation form. The activity reference identifies the schedule activity with which the scenarios are associated (either directly or via a constituent step). The tree view of scenarios summarizes all the scenarios associated with the selected activity. Basic tools are provided to allow users to navigate the tree and add or remove steps and scenarios. Scenarios may be nested under steps by adding a new scenario, then dragging it onto the step. The green arrows are used to promote a scenario to the activity level or to re-order the steps or scenarios within a step.



The Scenario Detail section is a multi-tab data entry form with the following tabs:

- **Define** - general scenario attributes

The screenshot shows a web-based form with a tabbed interface. The 'Define' tab is selected, and the form contains the following fields and text:

- Define** | *Project* | *H&S* | *Recommendations*
- Name (40 character limit): Scenario - Fail to identify all hazardous waste
- Status: Active
- Activity ID: 002.2
- Step Name: STEP - Identify hazardous waste
- Cause: Operator conducts incomplete survey of hazardous materials or HAZCOM database incomplete.
- Consequences (Cost, Schedule, H&S):
H&S - significant operator exposure to hazardous materials during demolition
Cost - clean-up and compensation, new equipment, worker training, penalties
Schedule - delays due to clean-up and to obtaining work authorization

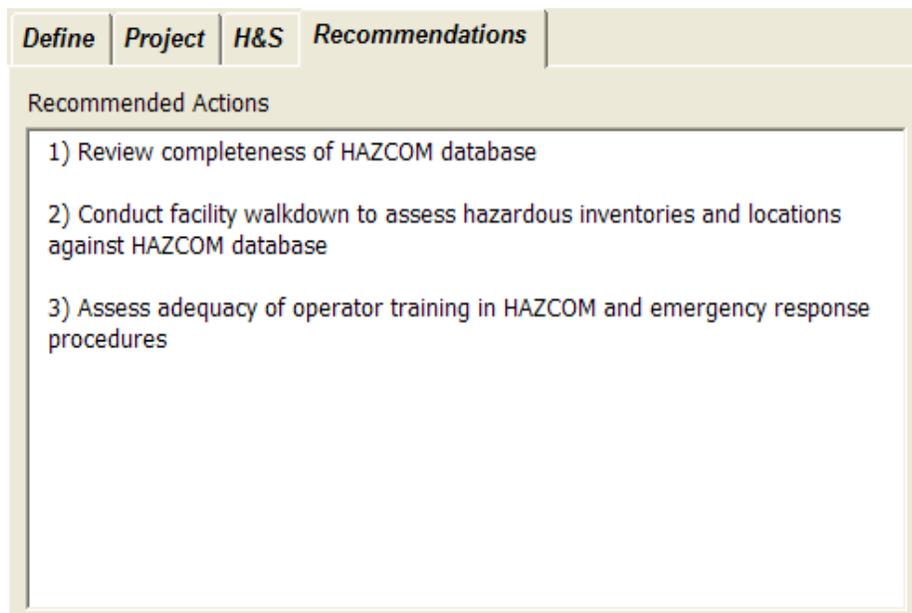
- **Project** –project risk impact parameters (cost and schedule)

Define	Project	H&S	Recommendations			
Primary						
Likelihood	L	0.18	<input checked="" type="radio"/> Linear <input type="radio"/> Log			
Cost	M	1	1.5	2	10 ⁶	Fixed
Duration	M	60	150	240		Days
Residual						
Likelihood	N	0	<input checked="" type="radio"/> Linear <input type="radio"/> Log			
Cost	N	0	0	0	10 ⁶	Fixed
Duration	N	0	0	0		Days

- **H&S** – contains health and safety impact parameters (onsite and offsite impacts, likelihoods, and protection reliabilities)

Define	Project	H&S	Recommendations		
Primary					
Like.	L	0.18	<input checked="" type="radio"/> Linear <input type="radio"/> Log		
	Protection	On-Site	Off-Site	Risk (on)	Risk (off)
Kinetic	VH	Negligible	Negligible	0.0 e+0	0.0 e+0
Chem	L	Significant	Minor	1.8 e+0	1.8 e-1
Rad	L	Minor	Negligible	1.8 e-1	0.0 e+0
Protective Safeguards currently in place					
PPE, environmental monitoring, emergency response procedures					
Residual					
Like.	N	0	<input checked="" type="radio"/> Linear <input type="radio"/> Log		
	Protection	On-Site	Off-Site	Risk (on)	Risk (off)
Kinetic	VH	Negligible	Negligible	0.0 e+0	0.0 e+0
Chem	VH	Negligible	Negligible	0.0 e+0	0.0 e+0
Rad	VH	Negligible	Negligible	0.0 e+0	0.0 e+0

- **Recommendations** – records suggested actions to reduce risks



The "residual" fields accommodate risk data modified to reflect the benefits of a prospective engineering or administrative control action.

Help buttons are provided to document the default ranges for various impact scales. Tool bars are provided to perform tasks such as adding and removing steps or scenarios, re-ordering the steps and scenarios, and manipulating the tree view.

Default scales for scenario likelihood, safeguard protection factors, and impacts (cost, duration, and H&S) are as follows:

- **Likelihood** (linear version: a logarithmic scale can also be selected)

	Probability	(default)
VH	0.95 - 1.0	0.98
H	0.75 - 0.95	0.85
M	0.25 - 0.75	0.50
L	0.1 - 0.25	0.18
VL	0.01 - 0.1	0.05

- Total Cost Impact (spread resource) or Incremental Cost (normal resource)

Help - Cost Impact Scale

	\$ Million	Default (min, ml, max)		
VH	> 100	100	300	500
H	10 - 100	10	50	100
M	1 - 10	1	5	10
L	0.1 - 1.0	0.1	0.5	1
VL	0 - 0.1	0	0.05	0.1
N	0	0	0	0

- Duration Impact

Help - Duration Impact Scale

	Days	Default (min, ml, max)		
VH	> 360	360	420	500
H	240 - 360	240	300	360
M	60 - 240	60	150	240
L	30 - 60	30	45	60
VL	1 - 30	1	15	30
N	0	0	0	0

- **H&S Impacts (on and off-site: chemical, radiological, kinetic)**

Help - Health & Safety Impact Scales			
Category	Relative Score	On Site (Worker)	Off Site (Public)
Major	1000	Chem: ERPG 3 Rad: > 10 rem Kinetic: Severe short term effects disability, death	Chem: ERPG 2 - ERPG 3 Rad: > 1 rem Kinetic: Injuries
Significant	100	Chem: ERPG 2 - ERPG 3 Rad: 0.1 - 10 rem Kinetic: Lost time injury	Chem: ERPG 1 - ERPG 2 Rad: 0.01 - 1 rem Kinetic: none
Minor	10	Chem: TLV/TWA - ERPG 2 Rad: 0.001 - 0.1 rem Kinetic: Injury	Chem: 0.1 x TLV/TWA - ERPG 1 Rad: 0.001 - 0.01 rem Kinetic: none
Negligible	0	Chem: <TLV/TWA Rad: < 0.001 rem Kinetic: Not reportable	Chem: < 0.1 x TLV/TWA Rad: < 0.001 rem Kinetic: none

- **Safeguard protection factor (on-demand reliability)**

Help - Protection Factor		
VH	$1 - (e^{-4})$	Highly effective safeguards
H	$1 - (e^{-3})$	
M	$1 - (e^{-2})$	
L	$1 - (e^{-1})$	
N	$1 - (e^0)$	

7.0 Health & Safety Risk Calculations

The Risk Register provides the necessary information to perform both the project risk and the H&S risk calculations. Project risk calculations are performed within Pertmaster using Monte Carlo methods. The H&S risk calculations are performed within Risk D&D. There are six sets of H&S risk calculations for each identified scenario, corresponding to three impact types. These are:

-
- chemical exposure
 - radiological exposure
 - kinetic impacts

where each is calculated both for onsite and offsite receptors. Each scenario is assigned a likelihood (probability) of initiation (over the project duration) by the user which can be defined on either a linear or a logarithmic scale. The user can then define a protection factor relative to each of the three impact types. The protection factor is related to the probability that the impact/consequence will be averted or mitigated given that the scenario has been initiated, and is based on consideration of the safeguards in place. Note that it is appropriate to allow each impact type to have its own protection factor since safeguards may not protect against all impact types (e.g., PPE for protection against kinetic hazards, such as a hard hat, will not protect against radiological hazards).

Finally, a common set of impact scores is defined across the impact types to facilitate numerical analysis (see previous section). The purpose of the scores, which can be adjusted from the preset scale, is to provide the basis for risk prioritization and comparison between D&D sequencing options rather than to characterize absolute risk. Onsite and offsite impacts are assessed separately.

Relative to these parameters, each H&S risk score is calculated as

$$R = L \times (1-F) \times I$$

where R is the risk score, L is the initiator likelihood/probability, F is the protection factor, and I is the impact score. Since these calculations are performed within the Risk D&D, they are displayed immediately to the user once the inputs are provided (see previous section).

8.0 Integrated Risk Report

A unique aspect of this rapid prototype tool is the ability to integrate the characterization, analysis, and management of risk data drawn from two different forms of risk analysis, PHA (H&S risk) and schedule-based Monte Carlo analysis (project risk). The Risk D&D elicitation tool provides the unified interface for managing the input parameters, while the integrated risk report provides a unified platform for viewing results from the PHA and Monte Carlo elements.

To demonstrate this capability, a sample integrated risk report format was developed that displays the following risk quantities at the overall project plan-level.

-
- Total occurrence probability of each H&S impact level
 - Risk magnitude associated with each H&S impact type
 - Schedule variance (Pertmaster histogram)
 - Cost variance (Pertmaster histogram).

These are displayed in Appendix B. The first two charts (H&S risk) are generated directly by the Risk D&D application while the last two charts (project risk) are captured from Pertmaster output. These charts are generated from a single risk register that captures all necessary input data (pseudo data in this case) relative to a single set of activities, constituent steps, and associated scenarios.

The first plot shows the probability that each H&S impact level (for each impact type) will occur during the lifetime of the project. It is calculated as (for each impact type / impact level combination):

$$P = 1 - (1-P_1)(1-P_2) \dots(1-P_n) \dots(1-P_N)$$

where P_n is the probability of the n'th scenario (of total number N) with the given impact level. Note that P_n is calculated as $L_n \times (1-F_n)$ (see previous section).

This chart allows the user to quickly assess the overall probability that a major H&S event will occur.

The second chart displays the risk associated with each impact type, where this risk is the sum of the risk from each scenario (see risk formula in previous section) that contributes to the specified risk/impact type. This chart provides a sense of the relative magnitude of each H&S risk type associated with the project (based on the assumptions of the impact scales): onsite versus offsite - chemical exposure, radiological exposure, and kinetic impacts.

Combining these two H&S charts with the plan-level histograms from Pertmaster for project finish and project cost provides Risk D&D users with a single, integrated view of both H&S and project risk exposure for a given sequence of D&D activities.

Only plan-level reporting was included in the rapid prototype, although additional levels of risk resolution at the activity, step, or scenario level could be supported for H&S risk, while Pertmaster project risk graphs are already available down to the activity level.

9.0 Concluding Remarks

Risk D&D is a rapid prototype tool intended to demonstrate a capability to produce and document an integrated characterization of project risk and health & safety risk associated with specified decontamination and decommissioning (D&D) work sequences. This integrated characterization provides the basis for assessing the wider risk implications of alternative work sequences. As a rapid prototype, the current version of this tool is not intended for deployment in a production environment.

There are several areas in which the capabilities of the current version of the tool could be expanded. For instance, incorporation of a risk-importance analysis would allow the user to rapidly identify those factors and scenarios that are predominantly governing the risk, and therefore determine what procedural or sequencing changes are likely to have the greatest risk-reduction impact. Also, the integrated risk display could be expanded to graph risk hierarchically, showing absolute and percentage risk contributions from individual scenarios, steps, and activities to higher-level elements of the analysis. Such enhancements would produce greater risk insight and facilitate management decision-making.

A prospective step forward would be the conduct of a workshop in which PNNL could demonstrate the functionality of Risk D&D and elicit suggestions on where expanded capability or enhanced usability of the tool would be of greatest value. The rapid prototype could then be converted into a robust software application that is capable of supporting EM-23 on a production basis.

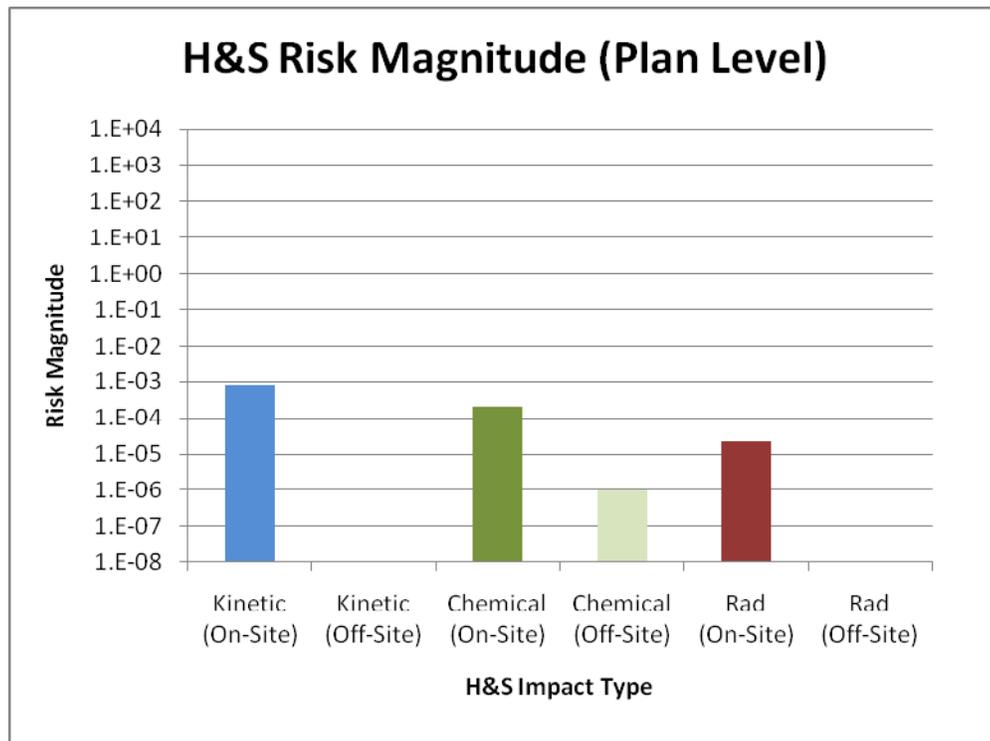
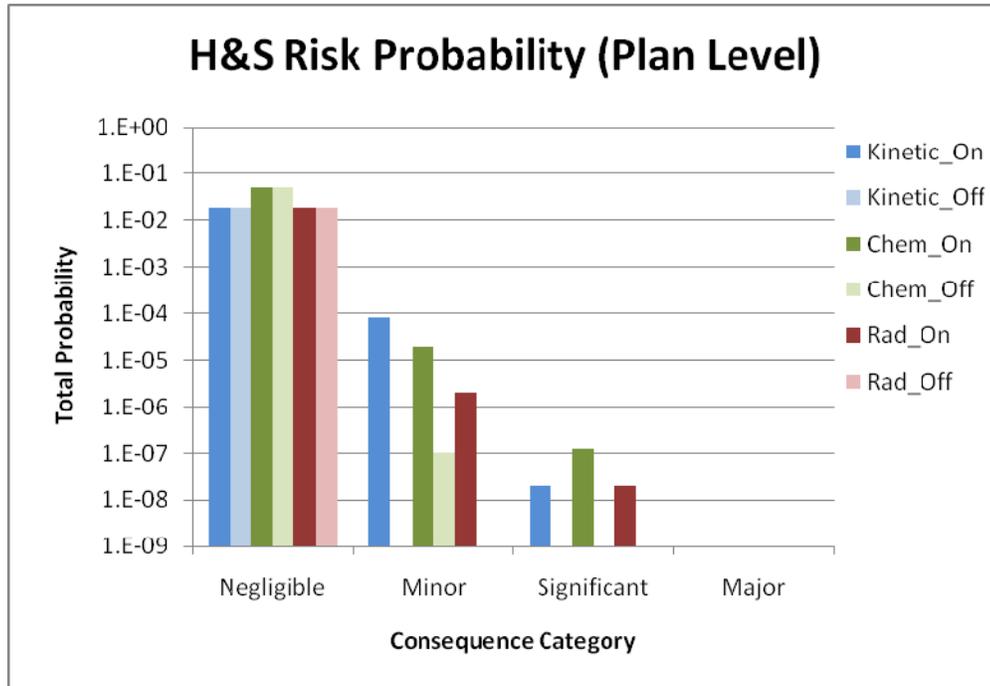
Appendix A: Sample Schedule

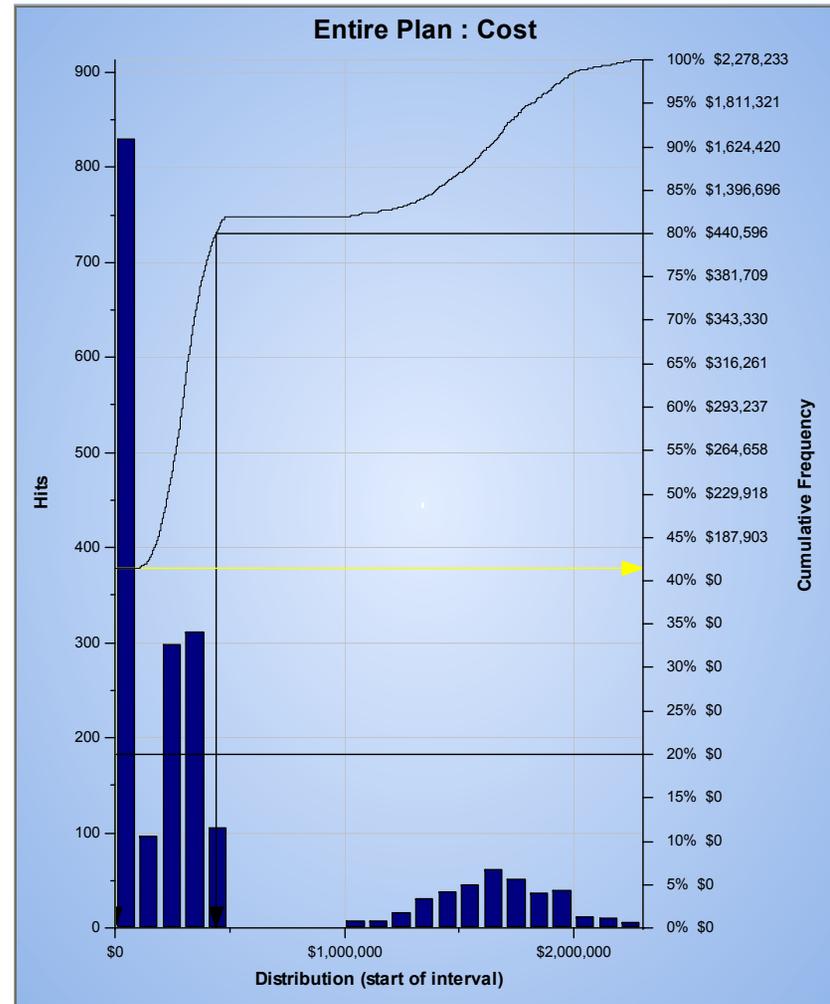
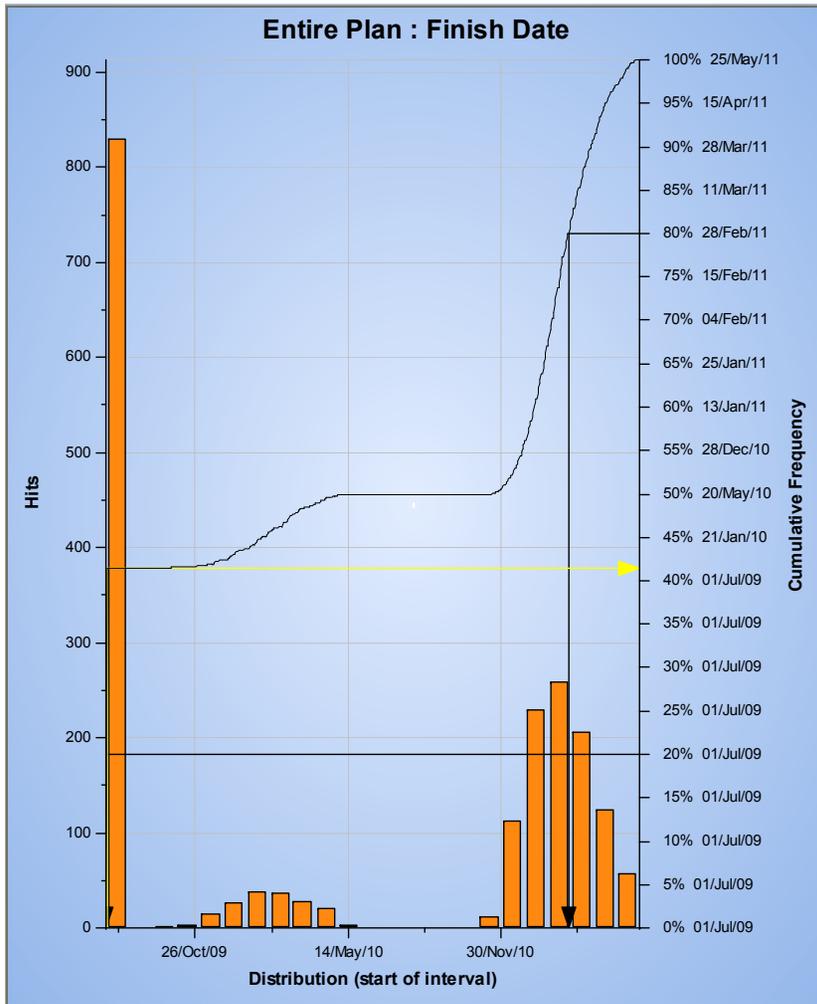
Sample schedule after building risk structures

Parent	ID	Description	Rem Duration	Preceding Tasks	Task Existence %	Resource Risk Functions	Duration Function	Jun '09				
								1	8	15	22	29
	1	Sample D&D Schedule	31									
1	001	Deactivate	6									
001	001.1	Remove all staff and equipment	2									
001	001.2	Disconnect all utilities and services	2	001.1								
001	001.3	Establish safety perimeter	2	001.2								
1	002	Decontamination	5									
002	002.1	Identify sources of hazardous waste	2	001.3								
002	002.2	Dispose of hazardous waste	1	002.1								
002	002.2:B	:B for 002.2	1									
002	R24	Scenario - Fail to identify all hazardous waste	0	002.2:B	18%	TOTAL[Triangle(1,000,000;1,500,000;2,000,000)]	Triangle(60;150;240)					
002	R26	Scenario - Spill during containerization	0	002.2:B	50%	TOTAL[Triangle(100,000;300,000;500,000)]	Triangle(360;420;500)					
002	002.3	Obtain approval for decon completion	2	002.2								
1	003	Decommission	4									
003	003.1	Submit necessary documentation	2	002.3								
003	003.2	Obtain approval to begin demolition	2	003.1								
1	004	Demolition	8									
004	004.1	Debris removal	2	003.2								
004	004.2	Confirmatory sampling	2	004.1								
004	004.3	Apply clean fill	2	004.2								
004	004.4	Establish permanent institutional controls	2	004.3								

Appendix B: Integrated Risk Display

Sample Integrated Risk Report based on sample data delivered with Risk D&D





Appendix C: Pertmaster Download Instructions

1. Navigate to <http://edelivery.oracle.com/>
2. On the welcome page choose your language & then in the first paragraph click continue.
3. If this is your first time downloading the software you will be prompted for your Full Name, Company Name, Email Address, Country & will need to read & accept the Trial License Agreement & the Export Restrictions Agreement by ticking the required boxes. Once this is done click Continue.
4. On the search page choose : **Product Pack ‘Primavera Project Portfolio Management Products’ & Platform ‘Microsoft Windows (32-bit)’** from the drop down menu’s then click Go.
5. Results should show a list of products. Select **‘Primavera Risk Analysis (v8.5) Media Pack for Microsoft Windows (32-bit)’** & then click Continue.
6. You will be given 2 files to download. First of click to download the **‘Primavera Risk Analysis Quick Install Guide’** for help with installing the application. Save this on your machine & unzip the file to view.
7. Then click download for the application file **‘Primavera Pertmaster v8.5 for Microsoft Windows 32-bit’** once downloaded unzip the file & run the setup.exe file to install.