Project Risk Analysis Model

User's Guide

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Terms

Base Cost Estimate	The reviewed or validated project cost estimate used in quantitative risk analysis. It represents the expected cost if the project materializes as planned, including PE, RW, and CN costs. It is unbiased and neutral (neither optimistic nor conservative).
Base Variability	The ordinary quantity and price variations about the estimated base. It is captured as a modest symmetric range about the estimated value, of the form: base value ±x% — typically from ±5% to ±15% depending on level of project development and complexity of the project.
Estimate	A quantitative assessment of the likely amount or outcome. Refers to project costs, and durations – typically preceded by a modifier (i.e. preliminary, conceptual, order-of-magnitude, etc.). An indication of accuracy (e.g. ± x percent). An estimate has two components: the base cost estimate component and the risk/uncertainty component. An estimate is best expressed as a range, not a single number.
Impact	A consequence of a risk occurring in terms of cost ($) or months (mo); expressed as a range defined by three values: minimum, maximum, and "most-likely". A threat impact adds cost or delay; an opportunity impact adds value or reduces cost.
Mitigation	Action taken to reduce the impact or likelihood of an undesirable risk event or events.
Opportunity	An event risk that has the potential to positively impact project objectives.
Probability	An estimated likelihood that a particular risk event will occur. Often expressed on a scale of 0 to 10 or 0 to 100 percent. Estimates of probability are often subjective, as the combination of tasks, people and circumstance varies among projects.
Qualitative assessment	An assessment of risk relating to the qualities and subjective elements of the risk — those that cannot be quantified accurately. Qualitative techniques include the identification of risk, recording risk details and relationships, categorization and prioritization of risk relative to each other.
Quantitative Analysis	Modeling of numerical outcomes by combining actual or estimated values with an assumed or known relationship between values, using arithmetic or statistical techniques, to determine a range of likely outcomes of a variable or to understand how variance in one or more values is likely to affect others.
Risk	Effect of uncertainty on objectives.
Risk Events	Uncertain events that affect the project resulting in impacts to cost, schedule, safety, performance or other characteristic but do not include the minor variance inherent in Base Costs.
Risk Register	The risk register serves as a repository for identified project risks. The risk register includes detailed information about the risk and is a "living" document that evolves as the project evolves.
Risk Response	The process of developing response actions to identified risk events that enhance opportunities and reduce threats to project objectives.
Threat	An event risk that has the potential to negatively impact project objectives.
Uncertainty	The lack of knowledge of the outcome for a particular element or value.
YOE	Year Of Expenditure. The estimated year that money will be spent to complete project work elements. Base costs reported to program management shall be in current-year dollars (the un-inflated estimate).
Additional terms for Risk Management may be found in the WSDOT Glossary for Cost Risk Estimating Management	

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Project Risk Analysis Model: Overview

A Risk model simulates events that may occur in the real world. For project risk analysis, attention is focused on events that can affect project objectives such as cost and schedule.

The Project Risk Analysis Model (PRAM) uses Monte Carlo simulation to generate cost and schedule probability distributions from user input cost, schedule, risk and uncertainty information. It produces quantitative risk analysis outputs that provide actionable information to project managers and teams.

The model runs thousands of simulations or "project realizations" that virtually execute the project under the influence of all input uncertainties and risks. For each realization some risks occur, some do not; some impacts are high and others are low. The output provides an estimated range of project cost and schedule outcomes. Few realizations reach the extreme limits of the distribution, most aggregate toward the middle.

Up to 24 individual risks may be entered into the model. The outputs present statistical summaries, graphically as a distribution histogram, a cumulative distribution function S-curve, and as a percentile table. The model reports cost distribution forecasts for Preliminary Engineering (PE), Right of Way (RW), and Construction (CN) as well as total project cost. Results are provided in Current Year (CY) dollars and as inflated to Year of Expenditure (YOE) dollars. There are two schedule distribution forecasts, contract advertisement date and end of construction date. There are also tornado diagrams, sorting risks by expected value (EV), by cost and schedule impact.

The model accommodates two analyses. The first is for analyzing project estimate exposure to risks as initially identified and assessed, and the second is for analyzing the response to those risks. Comparing the pre-mitigated and post mitigated results offers users a quantified measure of the value added by proactive project risk management. The Base Estimate and Risk input forms serve both analyses. Color-coding is used throughout the model to promote instant recognition of which analysis inputs or results are which:

ORANGE = Risk Analysis (pre risk-response: pre-mitigated risk analysis)

BLUE = Risk-Response Analysis (post risk-response: post mitigated risk analysis)

Two-in-One

The following illustration shows the two analyses available in the model, how they are color-coded, and how single input sheets are used for each:

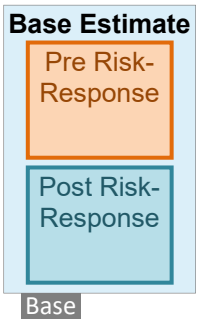
Basic Parts

Workbook Sheets

The PRAM workbook contains sheets for data input and for output reports of simulation results. These sheets serve to record the Risk Analysis — pre risk-response — and the Risk-Response Analysis entries and results. The respective zones are clearly labeled and color-coded.

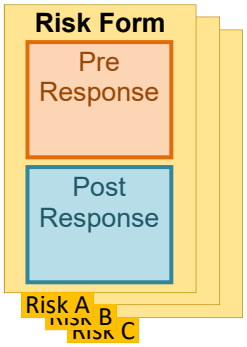
Inputs

BASE Estimate (Sheet: Base)



Users enter the expected cost as if the project goes as planned. The BASE Cost is an unbiased neutral estimate of cost and schedule; care should be taken that information entered is neither conservative nor optimistic. The BASE estimate captures the total estimated project costs including, preliminary engineering, right-of-way, construction, Mobilization, Construction Engineering, Tax, Change Order Contingency, and below the line items (700/800 items). (WSDOT standard construction contingency amount is based upon historical usage). The upper portion is for the initial Project Risk Analysis. The lower portion accounts for any base estimate adjustments due to risk response strategies — the Risk Response Analysis.

Values are entered in Current Year (CY) dollars.



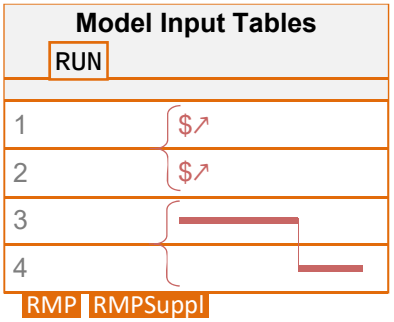
RISK (Sheets: identifications vary)

The simulation handles up to 24 discrete risks. Each Risk sheet records an identified risk associated with the project under study: the phase it affects, its details, probability and quantified consequences. The upper portion of the form is about the risk as it is first identified, with no regard to doing anything about it, i.e., before any response strategy — pre risk-response values, or pre-mitigated risk. The lower portion details the proposed response strategy with any expected change to likelihood or impact due to implementing the strategy — the post risk-response values, or Post-mitigated Risk.

Project risks can pose a **Threat** of negative impacts to project objectives, *or* present an **Opportunity** that has a positive impact.

Model Input Tables: Inter-Risk Conditionality / Model Input Synopsis

RMP (Risks ordered 1 – 12) & **RMPSuppl** (Risks ordered 13 – 24)

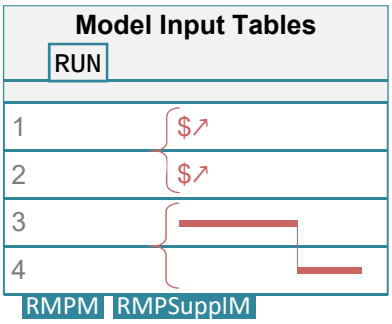


Data entered in the individual forms for Risk Analysis (pre risk-response) appear in these tables. The first twelve risks (1 – 12), in the same order as workbook sheet tabs, are in one, the second twelve (13 – 24), are in the other. At the top of each table is a summary of (pre risk-response) Base Estimate inputs.

This is where to Indicate conditionality between risks, to model basic correlations, dependencies, and duration links. See later section for more details.

The model-engine uses the inputs from these sheets. Review the inputs before running.

RMPM (Risks ordered 1 – 12) & **RMPSupplM** (Risks ordered 12 – 24) Data entered in the individual forms for Risk-Response Analysis appear in these tables. The first twelve risks (1 – 12), in the same order as workbook sheet tabs, are in one, and the second twelve (13 – 24), are in the other. At the top of each table is a summary of (post risk-response) Base Estimate inputs.



Revise or indicate conditionality between risks accordingly, to reflect the effects of response strategies (more detail provided later in this guide).

Review the model inputs here before running.

Outputs

Expected Value (sheet: EV)

Graphs on this sheet sort entered risks by Expected Value (EV) as an aid for optimizing the risk-response effort. Typically, risks at the top warrant the most attention, with a diminishing rate of return on effort as we descend on the diagram. Limited risk management resources should be applied proportional to a risks likelihood and impact. To that end, expected value combines factors to one convenient, probability-weighted number. When using, however, be aware that this calculation could de-emphasize a high impact risk that has low probability. Project Managers are advised to look for these events (known as "Black Swans"), and give them due attention.

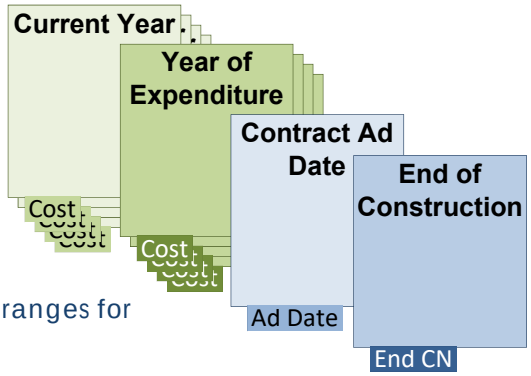
The expected value of individual random variables is the probability-weighted average of input values.

$$Expected\ Value\ = Probability \times \left(\frac{min\ +\ 4(most\ likely)\ +\ max}{6}\right)$$

There are four diagrams in the sheet. The top two show pre risk-response ranking, one for cost and another for schedule. The bottom two are for after risk-response adjustments. The simulation need not run before viewing the Expected Value summary. This diagram is available as soon as all risks have been entered/quantified. "Click" the launch button on the sheet after risk entry; "click" to update after any risk entry revision. Do the same after recording risk-response values to note any changes in standing.

Outputs: Analysis Results

Risk model forecast results are presented in 8 sheets for cost, and 2 for schedule. There are reports for Preliminary Engineering, Right-of-Way, and Construction cost, as well as total project cost. Costs are provided in Current Year (CY) dollars, for reporting to Program Management, and in Year-of-Expenditure (YOE) dollars. Schedule reports give date ranges for contract advertisement and end of construction.



Result Sheets		
Cost		
Project Phase	Current Year (CY) dollars	Year-of-Expenditure (YOE) dollars
Preliminary Engineering	**PE-Cost (CY)**	**PE-Cost (YOE)**
Right of Way	**ROW-Cost (CY)**	**ROW-Cost (YOE)**
Construction	**CN-Cost (CY)**	**CN-Cost (YOE)**
Total	**Total-Cost (CY)**	**Total-Cost (YOE)**
Schedule		
Contract Advertisement	**Ad Date**	
End of Construction	**End CN**	

Below is an example Result Sheet:

See: *Viewing the Results*

Using the PRAM: Basic Steps

Before Using

The correct application of the Project Risk Analysis Model assumes familiarity with basic risk management theory and technique. Please review WSDOT's Project Risk Management Guide before using the model:

http://www.wsdot.wa.gov/publications/fulltext/cevp/ProjectRiskManagement.pdf

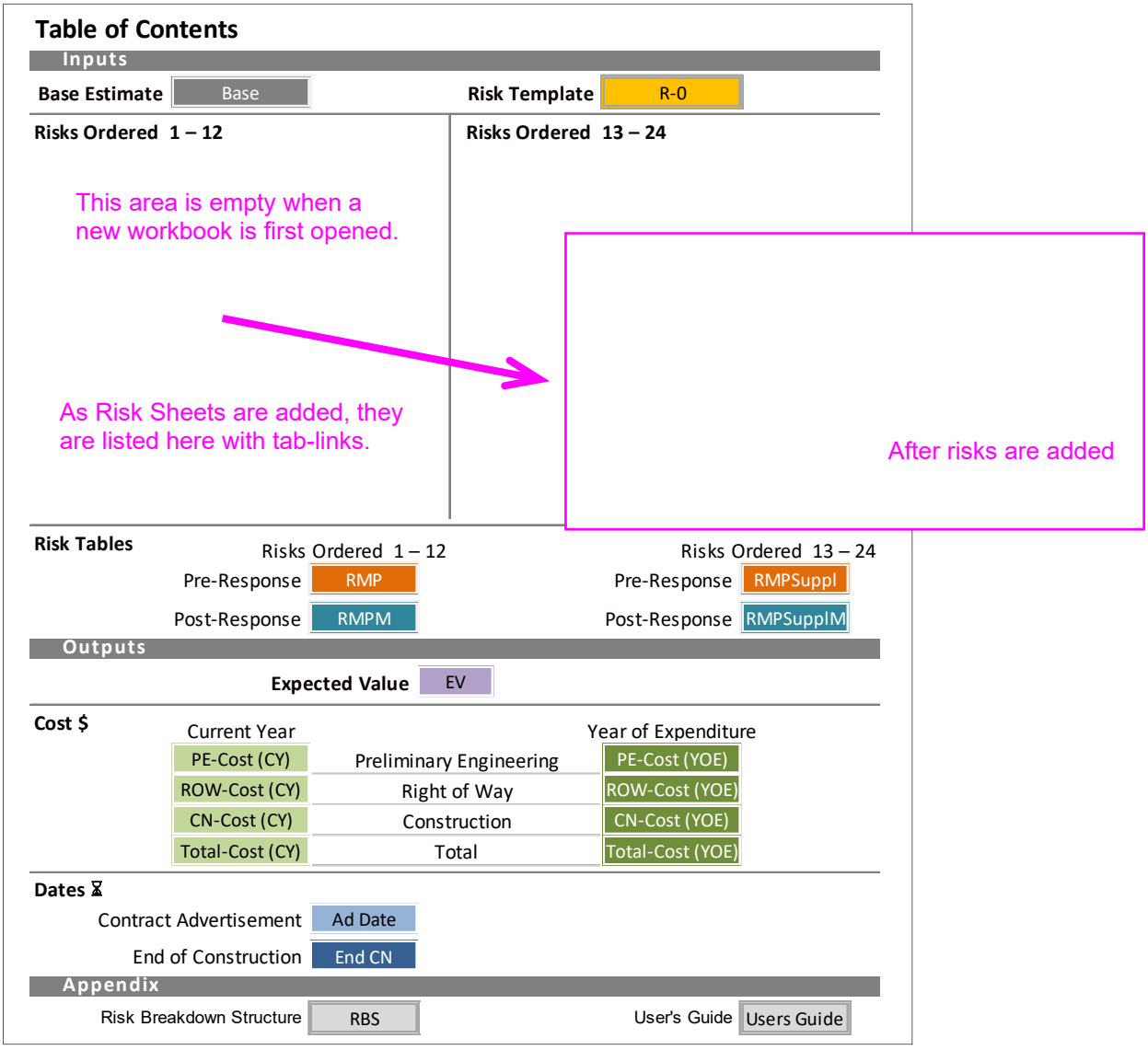
Get the Workbook

The Project Risk Analysis Model workbook is available online here:

http://www.wsdot.wa.gov/publications/fulltext/CEVP/PRAM.xlsm

Open the Workbook / Table of Contents / Navigation

The Project Risk Analysis Model workbook should open at the Table of Contents (TOC) sheet.



Notice the variously colored rectangles that look like the sheet tabs; these are links to respective sheets in this workbook. The user may navigate to sheets in the usual way by selecting tabs at the bottom of the workbook, or go to any sheet in the workbook from the TOC by clicking on these tab-links.

Each destination sheet has at least one TOC tab-link to return the user to the Table of Contents.

Most sheets have tab-links to provide a direct route to other sheets, as well.

The exception is when in one of the Model Input Tables:

Model Input Tables	Risks Ordered 1 – 12	Risks Ordered 13 – 24
Pre-Response	RMP	Pre-Response RMPSuppl
Post-Response	RMPM	Post-Response RMPSupplM

From the Model Input Tables, along the left edge of the table, notice that for each risk entry there are two tab-links. The upper one goes to the risk sheet, the lower one goes to the Table of Contents.

All of these navigational shortcuts have some advantage over the traditional sheet selection-by bottom-tab. There are over 40 sheets to negotiate in a model fully loaded with project risk sheets (up to 24 risks). Getting from one sheet to another can be difficult when limited to scrolling and selecting from a wide array of bottom sheet tabs.

Reordering Risk Sheets

Risks may be entered in any order, but later it may be desired or necessary to change the sequence as they list in the Table of Contents and/or in the Model Input Tables. For purposes of modeling inter-risk conditionality (see later section) the sequence of risk entries is crucial; but even for purely esthetic reasons, reordering risks is a simple matter of dragging their respective tabs (at bottom) to the required sequence.

Be careful when reordering tabs in a workbook that already has inputs for inter-risk conditionality.

The user may reorder risk sheets by dragging their respective sheet tabs, but conditionality indicators will not automatically update to suit a new order. Any that were set before a reordering should be checked afterwards to ensure risks are still connected as intended.

Entering Data

There are two parts to each input worksheet. The first records the values required for a Risk Analysis (pre risk-response) simulation. The second is for Risk-Response Analysis, to model the effect of response strategies. Combining these in one workbook allows for ready comparison and quantification of the value added by active risk management.

Data may be entered live during a workshop, before, or sometime after active or collaborative risk assessment. It may be copied-in from a list, from separate sheets, imported, or received from remote collaborators, etc. Risk response strategizing may lag the risk analysis, or it may take place on the heels of initial risk elicitation and assessment. Data for each analysis, pre or post response, does not need to be entered in a particular sequence, but care must be taken to assure that it is complete for an analysis, and that it is entered in the right section.

For the purpose of orderly presentation in this guide, we will assume a workflow where Risk Analysis data is entered first, then we will return to make Risk Response Analysis entries. This guide follows the diagram **Using the PRAM: Basic Steps**.

Base Estimate

Go to the Base sheet.

Enter data in the fields of the upper portion of the sheet, for Risk Analysis (with Pre-mitigated Risks). The orange outlined boxes are critical for the model to calculate results. Leave blank when there is no associated value.

Do not enter zero"0" in the entry fields.

Important, but less critical for modeling, are the lighter-outlined boxes. Hatched fields are for a more complex analysis — see the section, Non-WSDOT Inflation Rates, for more information. Underlined fields are calculated values or information referenced from elsewhere and are auto-filled.

Make cost entries in million dollar units, and durations in months.

NOTE: Values are displayed in "Millions of dollars" ($M) and "Months" (mo). Less than a million dollars or less than a month is entered as a decimal. Examples:

$200,000 enter as .2 it is displayed as 0.20 $M	*1 week enter as .25 it is displayed as 0.3 mo*
$2,689,123 enter as 2.69 it is displayed as 2.69 $M	*3 months and three weeks enter as 3.75 displayed as 3.8 mo*
$23,000 enter as .023 it is displayed as 0.02 $M	*one and a half years enter as 18 it is displayed as 18.0 mo*

Project information is at the top.

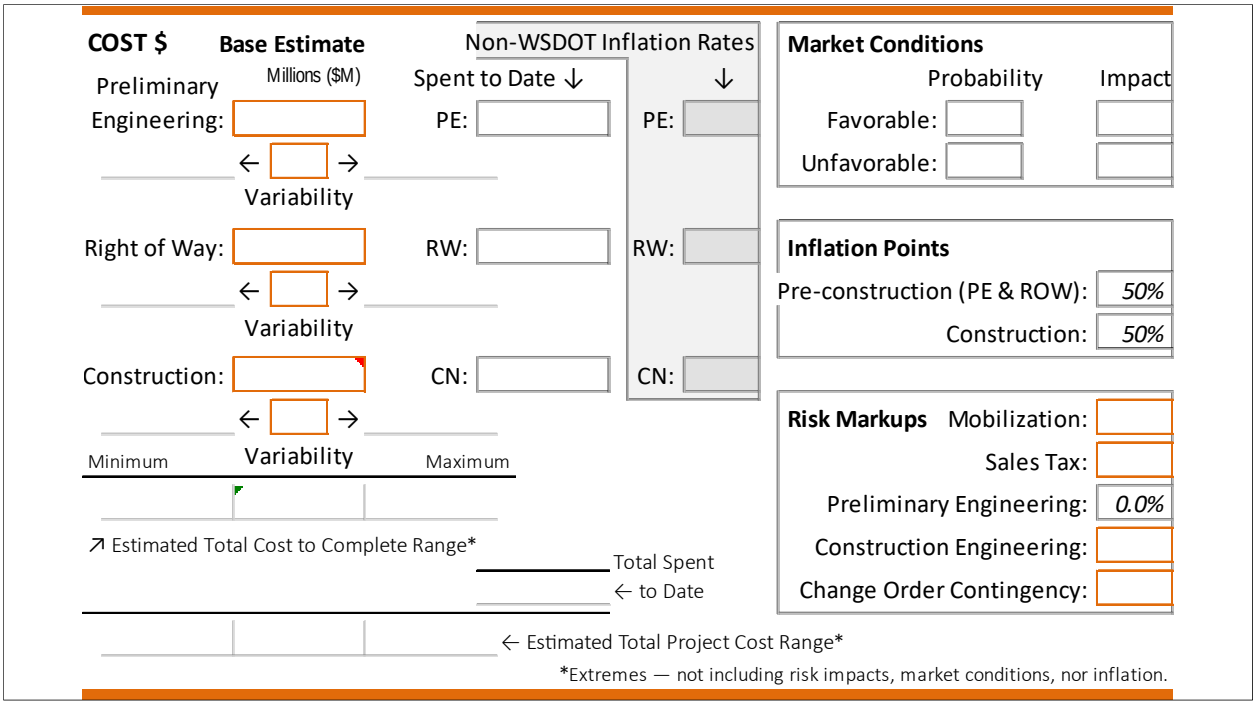
Critical fields include:

- Project Title, Enter the complete project title as programmed.
- Estimate Date: Enter the date of the current project estimate. This is the critical base date entry for modeled contract advertisement and end of construction forecasts.

Less critical:

- Model Date: A project may be analyzed several times over the course of its development. Enter the date of this model to place it in history with others.
- State Route: Enter the route identifier(s) if they are not already in the project title.
- Mileposts: Enter the project milepost limits if they are not already in the project title.
- Project Manager: Enter the name of the project manager.
- PIN #: Enter the Program Item Number.
- WIN #: Enter the Work Item Number.
- Estimate Prepared by: Enter the name of the person who prepared the estimate.
- Last Updated: Enter the date that the estimate was last updated.
- Basis of Estimate Date: Enter the date of the Basis of Estimate form.
- Review Date: Enter the date that the estimate was last reviewed.

The next section is for Base Estimate Cost values:



- **Base Estimate:** Enter base cost for each project phase: Preliminary Engineering (PE), Right of Way (RW), and Construction (CN). Do not include ANY misc. allowances in these. The construction figure should already reflect the cost of all Bid Items, Mobilization, Sales Tax, Change Order Contingency, Construction Engineering, 700 & 800 Level Items, etc. — the Total Cost to Complete minus RW & PE costs.

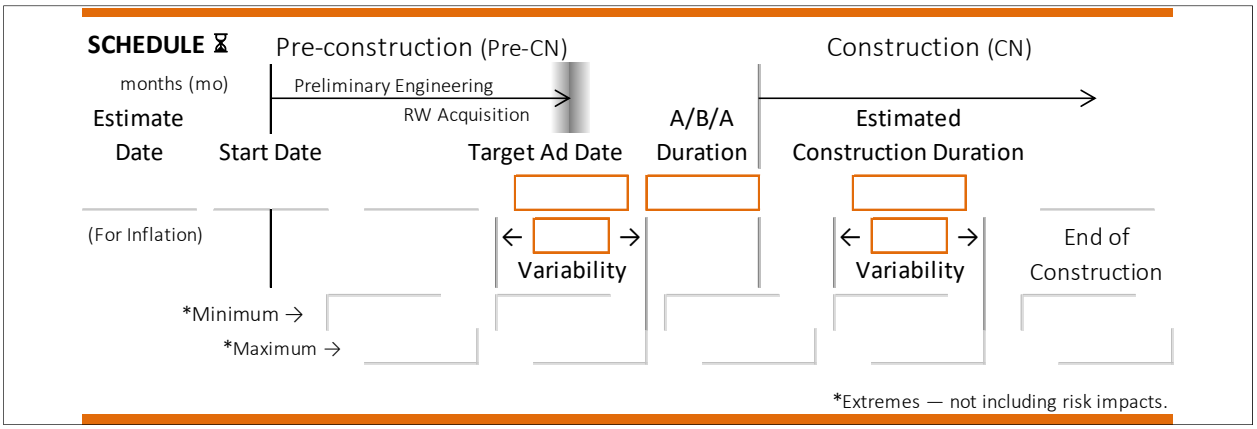
Cost and Schedule Variability: Below each project phase cost and schedule estimate is an input for inherent variability — not caused by risk events. Base variability captures a modest symmetric range (of the form: base value ± x%) about the estimated value, typically from 5% to 15% depending on level of project development and complexity. Cost variability represents quantity and price variations about the estimated base.

- Spent to Date Project dollars already spent may be accounted for in this column.
- Non-WSDOT Inflation Rates By default, the model refers to an internal inflation rate table developed by a third party. The user may opt-out of the table by entering an inflation rate that better suits conditions.
- **Market Conditions**: Enter percentages that reflect characteristics or trends in the market. Cost and availability of labor and materials, or the number of contractors available to bid the work, will all effect the market conditions.
  Values reflect the opinion of the project team, an assessment of the bidding environment.
  Enter a Probability for Favorable: (likelihood of better than planned) and Unfavorable: (likelihood of worse than planned). Enter a percentage of construction cost representing the Impact of how much better, or worse the project cost might be due to market conditions, primarily the bidding environment.

- **Inflation Points**: 50% by default; this directs the model to inflate costs to the midpoint of each phase duration, i.e. 0.5. Inflation point fields are provided for Pre-Construction (Preliminary Engineering and Right of Way acquisition) and Construction activities.
  Please contact the Strategic Analysis and Estimating office (SAEO) for assistance.

- **Risk Markups**: These are applied to the risk cost impact result per simulation. Values are typically the same as those used in calculating the construction base cost estimate. Enter Project Markup percentages for:
  - → Mobilization
  - → Local Sales Tax Rate
  - → Construction Engineering
  - → Preliminary Engineering — this is a calculated field, assuming the user expects the same ratio as entered for estimated PE/CN for any simulated total risk cost impact (users may override if desired).
  - → Change Order Contingency

The next section is for Base Schedule values:

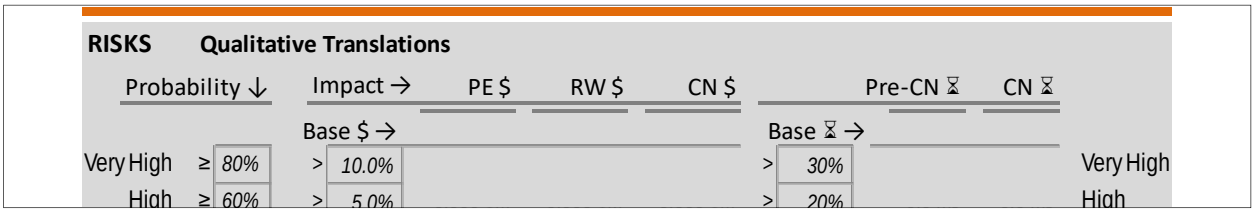


- Target AD Date, Enter the planned Advertisement Date of the project.

- Ad/Bid/Award (A/B/A) Duration, Enter how many months from the AD date until it is awarded.

- Estimated Construction Duration, Enter how many months the project will be in Construction.

Risks: Qualitative Translations — informational (no entries required, advanced feature)
This section shows and controls how the model translates risk probability and impact (quantitative) values into qualitative terms relative to base estimate entries. This governs the Heat Map display in each risks Qualitative Rendition section. In reverse, it serves as an aid in quantifying risk probability and impact when starting from qualifying terms like "High", "Very Low", etc.



Risk sheets

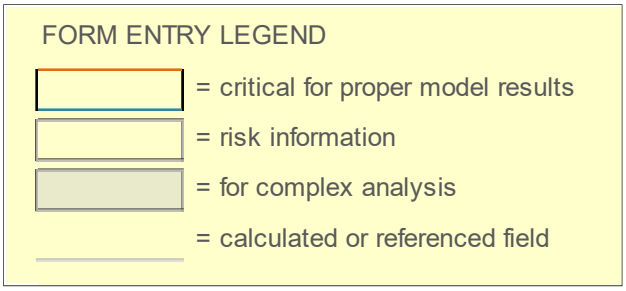
Go to the Risk Form template sheet.

Make a Form for your risk by copying the template "**R-0"**.

This can be done several ways, but the easiest is to hold down the Ctrl key and drag the "R-0" tab. This will result in a new tab named "R-0 (2)", which you will rename a little later.

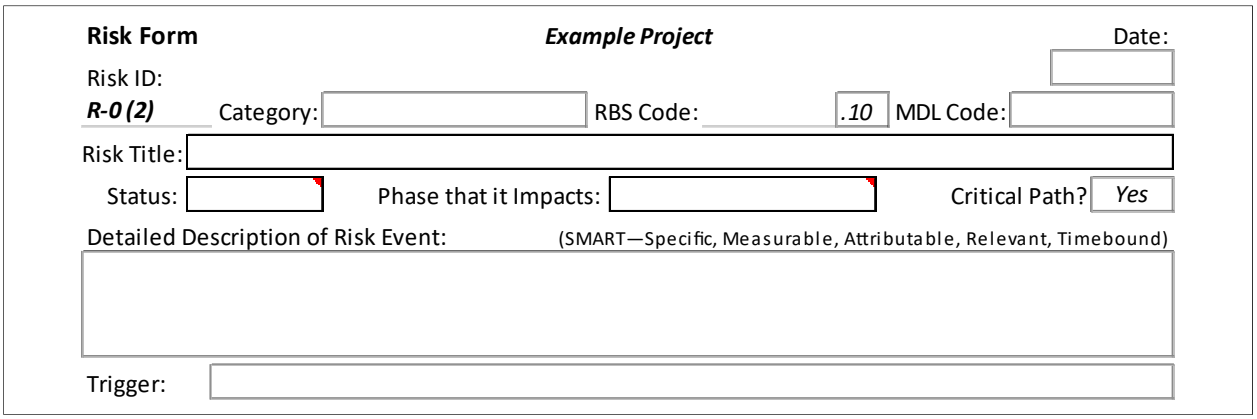
You may repeat this as many times as you have known risks already identified.

When adding more risks later, after previous forms have been filled-out, always start by making a copy of a blank template "R-0". This prevents unintentionally using values from a pre-existing (copied) risk form.



Now go back to tab "R-0 (2)". Enter risk analysis (pre risk-response) values in the upper portion of the Risk Form. Notice that critical entries for simulation are in solid, black or orange outlined boxes. Important, but less critical for modeling, are the lighter-outlined boxes. Hatched fields are for a more complex analysis — see the section on Conditionality for more information. Underlined fields are calculated values or information referenced from elsewhere and are auto-filled.

The top portion is for risk identification information and is common to both pre and post mitigated risk analyses.



The title of the project is automatically copied from the Base Estimate form.

Date: Enter date the risk was identified and assessed.

Risk ID: (auto-filled) copies what you enter as the tab name. Recommendation — use a Risk Breakdown Structure (RBS) code as a Risk ID / tab name. Build one by first selecting a general Category, then pick a specific from the drop-down in the upper-right form-corner. The result will appear in the RBS Code field. Change the decimal place if the ID is the same as a previously entered risk. Enter this unique ID as the tab-name for this sheet/risk. (See later section for more details about RBS).

Risk ID examples:

Category: (drop-down) Select from among the following:

Environmental / Hydraulics	Structures / Geotech	Design / PS&E
Right-of-Way	Utilities	Railroad
Partnerships / Stakeholders	Management / Funding	Contracting / Procurement
Construction	Enterprise Risk	

After choosing a category, specify by selecting a subcategory from the drop-down in the upper-right corner of the sheet. Example (Right-of-Way):

RBS Code: (auto-filled) See Risk ID: above. This is auto-filled, but it may be over-written.

MDL Code: (optional) is the Master Deliverable List ID.

Risk Title: Summary Description. Enter a concise descriptive title for the risk.

Status: (drop-down) marks a change of the risks potential in relation to project progress. Select:

Active – The risk is included in the simulation; it should get a response; it should be monitored and controlled.

Dormant – Low priority risk; is excluded from the simulation; could become active in the future if conditions change.

Retired – The risk is excluded from the simulation; it is no longer relevant; it poses no real threat (or opportunity) to the project.

Phase that it Impacts: (drop-down) select the phase which the risk is likely to affect:

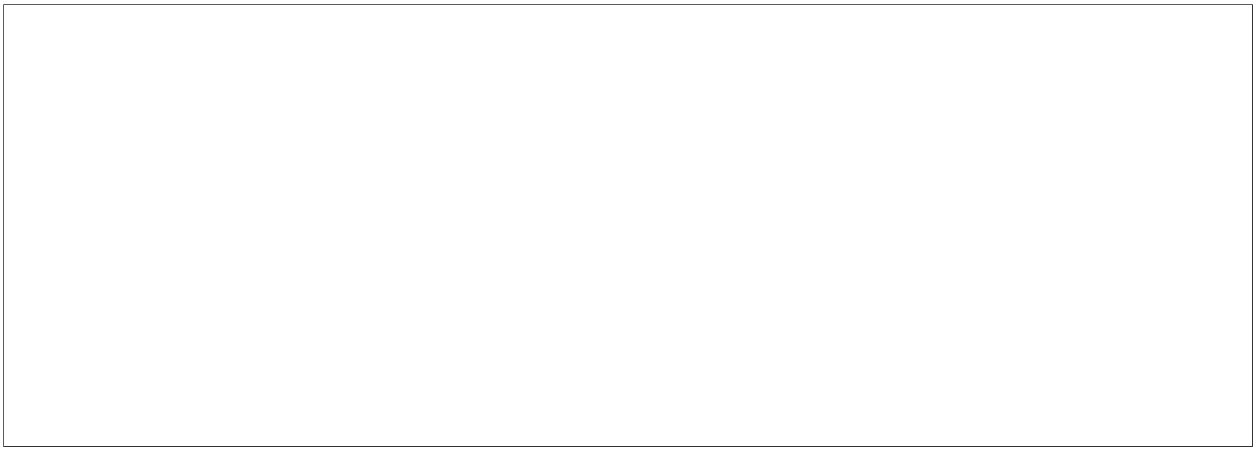
Pre-construction
ROW
Construction

Critical Path? (drop-down) The default is "Yes". Select Yes or No to indicate whether or not this risk affects an activity that has impact on the critical path of the project schedule.

Detailed Description of Risk Event: Concisely describe the risk with enough detail so that its nature is clear to later readers. Description of risks are: Specific, Measurable, Attributable, Relevant, and Time-bound (SMART). The note fields at the bottom half of the worksheet can be used for additional details.

Trigger: Enter a brief description of any event that must occur to initiate the risk's potential.

The next section is for entering data for the initial risk analysis:



Pre-Response: Quantitative Assessment

Nature: (drop-down) select whether the risk poses a:

Threat – If the risk occurs, it will negatively affect project objectives.
Opportunity – If the risk occurs, it will positively affect project objectives.

Probability: Quantify the likelihood of the risk occurring. Enter a percentage %. Of course, 100% means the risk should be part of the Base Estimate, 50% is a coin toss — it could go either way, and 0% means there is no risk at all. The following guide offers qualitative renderings of probability ranges:

0%—Very Low—**20%**—Low—**40%**—Moderate—**60%**—High—**80%**—Very High—**100%**

Make the following entries for Cost and Schedule in million dollar units, or in months, respectively.

NOTE: Values are displayed in "Millions of dollars" ($M) and "Months" (mo). Less than a million dollars or less than a month is entered as a decimal. Examples:

$200,000 enter as .2 it is displayed as 0.20 $M	*1 week enter as .25 it is displayed as 0.3 mo*
$2,689,123 enter as 2.69 it is displayed as 2.69 $M	*3 months and three weeks enter as 3.75 displayed as 3.8 mo*
$23,000 enter as .023 it is displayed as 0.02 $M	*one and a half years enter as 18 it is displayed as 18.0 mo*

**COST $** — Expected impact range if risk occurs, in millions of dollars ($M). If the risk presents only a schedule impact, leave these blank.

Minimum: Quantify and enter the value of the least cost impact.

Most Likely: Quantify and enter the value of the most likely cost impact.

Maximum: Quantify and enter the value of the greatest cost impact.

SCHEDULE ⧗ — Expected impact range if risk occurs, in months (mo). If the risk presents only a cost impact, leave these blank.

Minimum: Quantify and enter the value of the least schedule impact.

Most Likely: Quantify and enter the value of the most likely schedule impact.

Maximum: Quantify and enter the value of the greatest schedule impact.

Pre-Response: Qualitative Rendering

This section plots a qualitative depiction of probability and impact in an intuitive and familiar visual.

Impact Relative to: (auto-filled & drop-down) by default this plots the risk impacts relative to the phase selected in Phase that it impacts entry (above). The user may select "Project" from the drop-down to scale this risk's potential to the entire project instead of just a phase. The selection has no effect on the simulation.

$↔⧖ Impact Correlation: (drop-down) selection is for a more complex analysis; informs the simulation of correlation between the risk's cost impact and its schedule impact. See the later section on Conditionality for more information.

Supplemental Risk Information: (This box is located lower down on the form). Enter further notes or clarifications about the risk, its trigger(s), etc.

STOP!

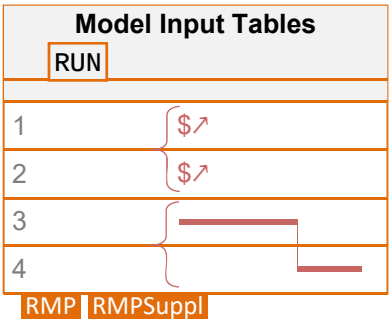
In practice, the user may continue to the Post-Response half of the Risk Form if data is available, but for orderly presentation in this guide, we will assume a project execution modelling workflow that focuses on a complete project risk analysis first, followed by a complete risk response analysis. This guide follows the diagram **Using the PRAM: Basic Steps**.

Enter the Next Risk

Go to the next blank Risk Form, or make another copy of the Risk Form template sheet, "**R-0"**. Follow the same data entry instructions as above. Do this for each identified/assessed risk (up to 24). After all risks have been entered to the extent required for risk analysis, go to the following step.

Model Input Tables

Go to the **RMP and RMPSuppl** sheets - this is where the model retrieves data, and from where the simulation is launched. All of the values necessary for modeling project execution are gathered from the various input forms and presented here in tables. This layout lends easy scanning for input errors, and it is recommended to do so before running the model. Base Estimate inputs are at the top of each sheet. The sheet titled **RMP** holds risks 1 – 12, and the sheet titled **RMPSuppl** holds risks 13 – 24. (If there are less than 13 risks, then only the RMP sheet is used.)



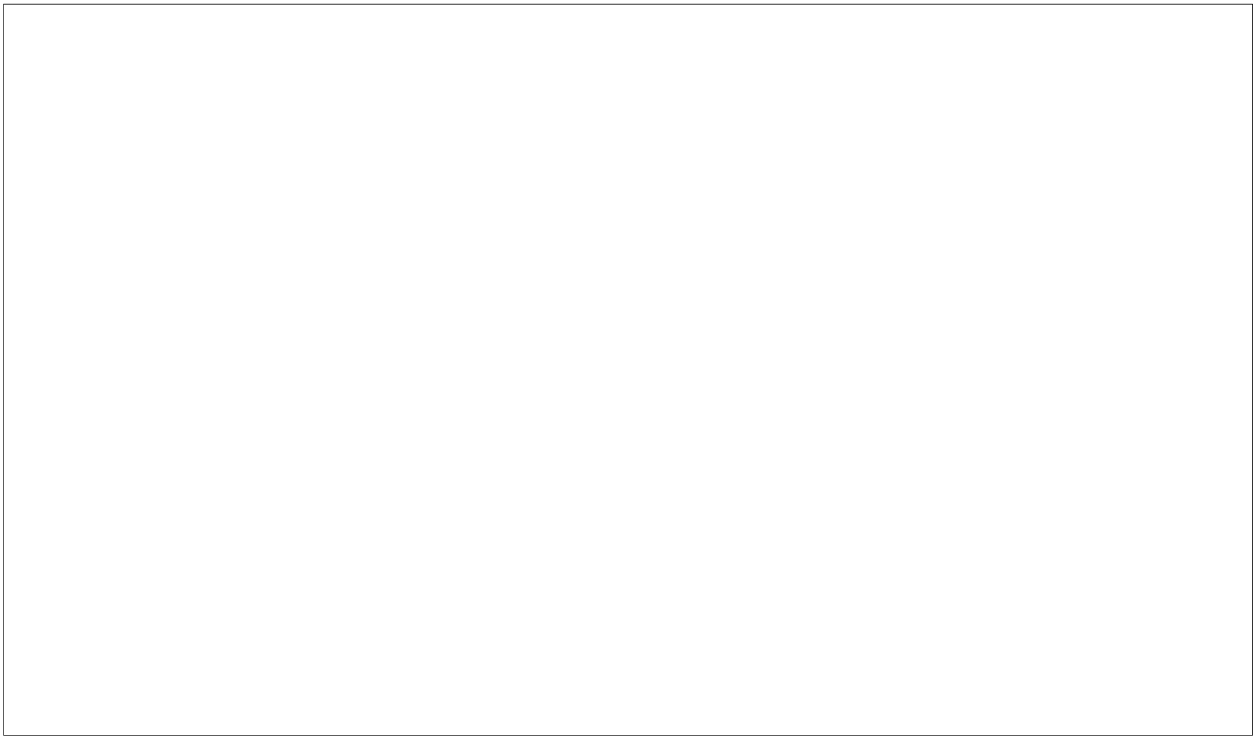
If for some reason the order of risks as they appear here, and in the table of contents, is not as desired, it may easily be changed.

Conditionality (between risks)
Although not crucial to generating meaningful results in many cases, at this point the user may consider setting risk conditionality. See the later section on this topic for more details. The risks need to be in a particular order to suit conditionality.

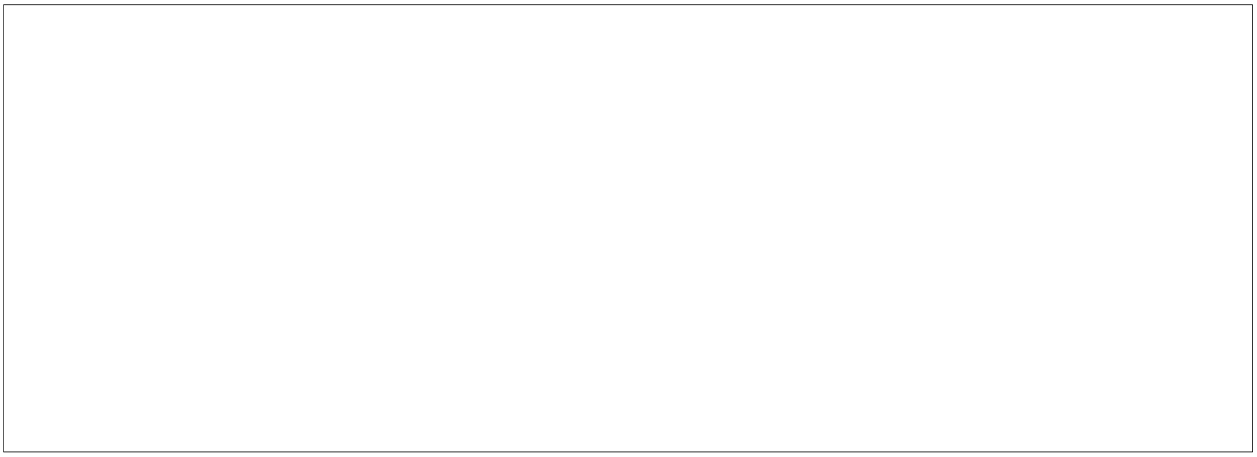
The user may reorder risk sheets by dragging their respective sheet tabs, but conditionality indicators will not automatically update to suit a new order. Any that were set before a reordering should be checked afterwards to ensure risks are still connected as intended.

Run the Project Risk Analysis Model

After setting conditionality and checking the entries, find the **Run Model** button near the top of the RMP sheet, "click" the button. Expect that the program will calculate for a minute or two.

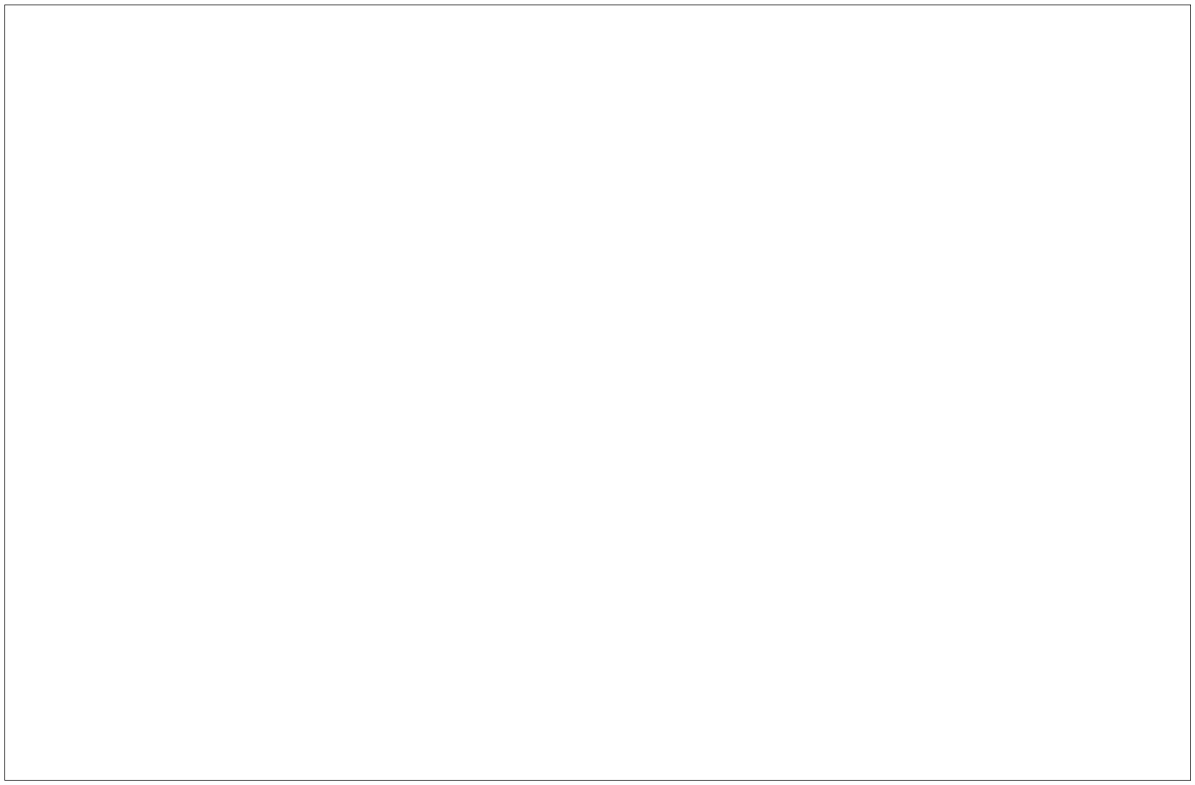


After running, the view should orient on a basic output presentation at the top-right of the sheet:



"Clicking" one of the green or blue tab-links near the top takes you to the respective output sheet:

Example pre risk-response (pre-mitigated) results graph and table:



Viewing the Results

The model simulates 10,000 project realizations, under the influence of entered risks, with resulting phase costs and dates. It renders these results into frequency distribution histograms of cost and date ranges. It does this by collecting resultant values into uniform bins (incremental ranges), then graphing them as columns, each with a height relative to the number of total outcomes that fall within the bin bounds. Bin maximums, in dollars or dates, mark the horizontal axis.

A typical graph looks like a mound, implying that the actual, real-life outcome will itself be somewhere near the middle of the mass. The report tempers this notion by listing outcome-pool percentile values, suggesting a confidence level that the actual value will not exceed that shown.

The results are also depicted with a Cumulative Distribution Function S-curve, which is the running total number (y) of outcomes with values at or below each upper bin limit (x). This shape provides insight into the aggregate project estimate simulated outcome.

For reference, the original base estimate appears as a vertical, dashed line.

After running the risk-response analysis — the second part of this comprehensive risk management process — using the initial risk analysis result as a backdrop, the tool displays pre and post results in the same report. This facilitates ease of comparison, the difference being the value of active risk management. Color-coding allows instant recognition of pre-response and post-response results:

ORANGE = Risk Analysis (pre risk-response) results

BLUE = Risk-Response Analysis (risk management) results

The following example shows results of pre and post risk response analysis:

Notes

Tabular minimum and maximum values are not the limits of what is possible, but are the range of this particular model run. The program replicates risk by generating random numbers. It does this fresh each run, so no two outcome sets will be the same; but the governing input bounds are the same, so the outputs will be similar. A subsequent run will likely show slightly different values.

It is expected that the graph of the risk analysis results alone will look somewhat different after the risk-response analysis run. Besides the obvious addition of another histogram and S-curve, the bin limits will adjust to cover the whole outcome spectrum of both runs, likewise the y-axis/% labels. This is because the report uses the same number of bins to cover a different range. This graphical artifact makes no difference to the validity of the statistics presented in either set.

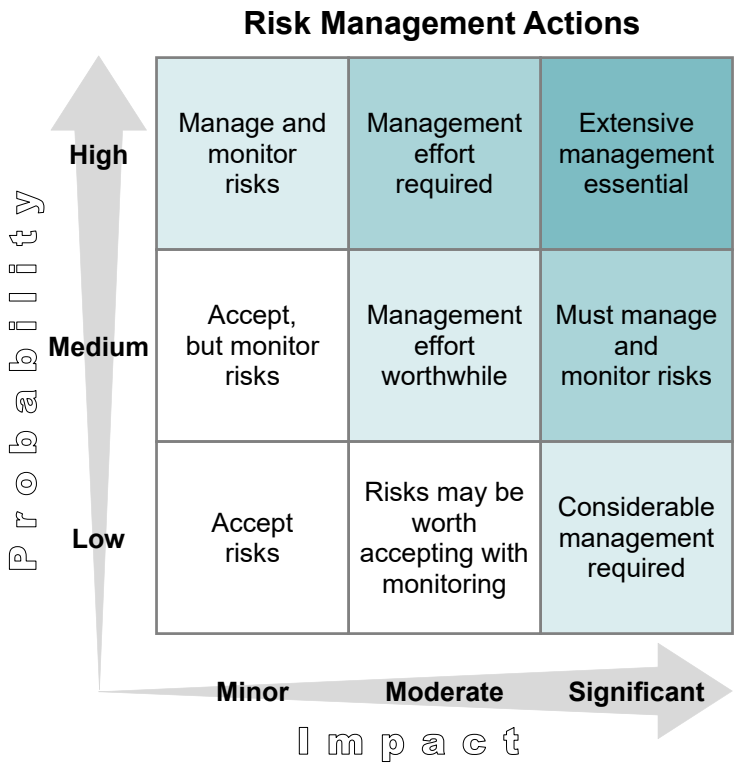
The risk-response result plots on top of the risk analysis. In many response scenarios, the base estimate does not change. In that case the base estimate appears as only a dashed, blue, vertical line (the orange is underneath it at the same value).

Risk Response

Risk response is where the true value of project risk management is realized. The Expected Value (EV) diagram sheet suggests how to prioritize and allocate risk management effort and resources.

Right-sizing the Risk Response

Response to a risk should be proportional to its likelihood and consequence.

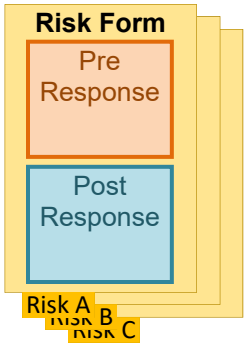


While much of the brainstorming and ideas about how to respond to a risk naturally flow on the heels of identifying the risk in the first place, this guide assumes a workflow where risk response is deferred to a discrete phase. This activity is dedicated to risk response strategizing, and the orderly recording of the decisions, plans, and actions intended to counter the risks, either to lessen detrimental effects and likelihood of threats, or by taking advantage of opportunities.

Risk Response Strategies	
Threat Responses	**Opportunity Responses**
Avoid – actions to eliminate the risk and protect project objectives from risk impact. Examples: • Change scope • Change requirements • Revise resources allocations such as cost or time.	**Exploit** – response actions taken to ensure the benefits of the opportunity are realized. Examples: • Change timing of ad or construction • Modify work restrictions • Employ expertise that can make sure the opportunity is realized
Mitigate – reduce probability of occurrence or intensity of the impact. Mitigation is risk and project specific. Examples: • Look at work activities and schedule • Change requirements • Additional investigation	**Enhance** – actions take to enhance an opportunity; actions that can increase probability or beneficial impacts. Examples: • Look at work activities and schedule • Change requirements • Add features to trigger opportunity
Transfer – transfer activity to other responsible parties best able to address the risk and associated work. Examples: • Contract work • Assign to other stakeholders • Insurance	**Share** – opportunity risks may be shared with parties positioned to help secure the benefits of the opportunity risk. Examples: • Share ownership and allocate benefits among parties best able to make sure the opportunity is realized.
Acceptance of the risk All projects live with some level of risk and uncertainty. In many cases, even for identified risk events, the decision is made to accept the risk. The planned project is not changed due to the possibility of the risk occurring, nor is any response strategy adopted other than agreeing to address the risk if it occurs. Project managers should always monitor risks and project health during execution. If a risk appears imminent, communicate with leadership.	

Just as in quantifying risk analysis, the model needs numerical values to input, so the response activity includes quantifying changes resulting from response actions. The post risk-response probability and impacts are entered in the model, and after running, will quantify the value of the risk (management) response itself.

Risk-Response Analysis Inputs



Risk Forms

Use the same Risk Forms used for input to the risk analysis, to input for analyzing risk-response.

Return to the risk sheets and go down to the **Post-Response** section. Make entries in fields as performed previously for the risk analysis.

Risk Response: (drop-down) select from the following:

If a Threat:	If an Opportunity:
Avoid	Exploit
Transfer	Share
Mitigate	Enhance
Accept	Accept

Selecting "Accept" automatically populates the quantitative assessment fields with the values from the above, pre-response section.

Risk Owner: Enter the name of the person responsible for managing this risk.

Response Description: Enter a concise description of the response and reason for the strategy.

"Action by" date: Enter the date that the management action should be engaged.

Post-Response: Quantitative Assessment

Nature: (drop-down) this is usually the same as above — Threat or Opportunity.

Probability: Adjust the probability according to the response strategy. Passive acceptance should not lead to changing probability, but if circumstances have changed outside of any active strategy, consider running the initial risk analysis with the latest probability.

COST $ — Adjust the expected Minimum, Most likely, and Maximum cost impact values according to the proposed response strategy.

SCHEDULE ⧖ — Adjust the expected Minimum, Most likely, and Maximum schedule impact values according to the proposed response strategy.

Post-Response: Qualitative Rendition: This provides a qualitative, visual interpretation of risk probability and impact. The user may compare this heat map with the one above to observe difference in symbol placement proportional with anticipated post-response probability and impact quantifications.

Impact Relative to: (auto-filled & drop-down) by default this follows the Phase that it impacts: entry (above) and governs the Quantitative Rendition Heat Map to graph impacts relative to the phase. One may select "Project" from the drop-down to scale this risk's potential to the entire project instead of just the phase. The selection has no effect on the simulation.

$↔⧖ Impact Correlation: (drop-down) selection is for a more complex analysis; informs the simulation of correlation between the cost impact and the schedule impact of the risk. See the later section on Conditionality for more information. Revise this entry if affected by the response strategy.

Response Action(s) to be taken: Detail the action you will undertake in response to the identified risk.

Action by date: Enter the date by which response action(s) need to be taken.

Supplemental Risk Information:

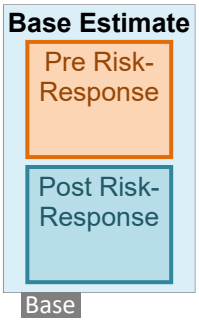
Response Details: Enter further notes or clarifications about the risk response strategy, basic outline of the practical steps involved with monitoring and controlling the risk, etc.

Risk Monitoring and Control: As project execution progresses, journal the actions taken, status, and review comments regarding this risk. Date and stack entries on top of one another to retain history.

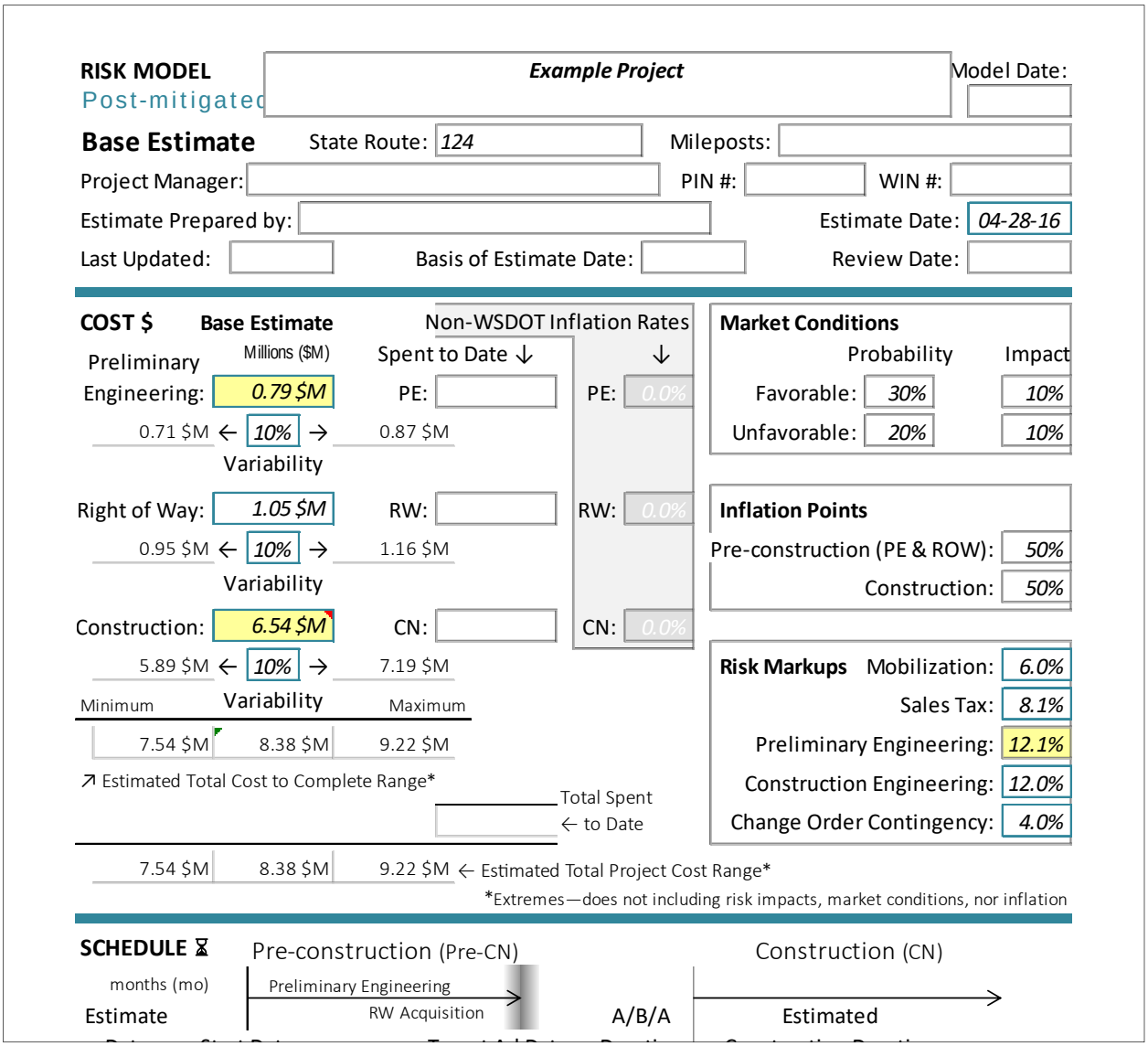
Next review date: Enter the date when the risk is due for review as part of risk monitoring and control.

Base Estimate sheet

The same worksheet used to input for project risk analysis also handles inputs for risk-response — on the second part or page. After carefully developing a response strategy for all risks as warranted, and quantifying the expected probabilities and impacts, one may find that some of the responses, however beneficial in the long run, come at a price up-front. The total of all these (per project phase) should be added to the estimate. There may also be instances where brainstorming about risks and risk-response has led to some impromptu Value Engineering (VE) — or VE may be integrated and result in quantified costs or savings to the project. The second base estimate is to account for any changes to the first. This is an appropriate backdrop for the second simulation, which actually analyzes the value of the risk-response (and VE) itself and reflects updates to the estimate.



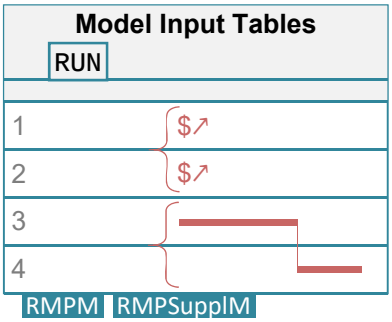
There might not be any changes, and the worksheet automatically populates the Post-mitigated Base Estimate with the values entered from the initial estimate. These may be over-written; doing so automatically highlights the changes for ease of comparing the two estimates.



RMPM and RMPSupplM sheets

At this point, go to the post risk-response Model Input Tables and adjust any inter-risk conditionality that may have changed due to response strategies involving one or more of the associated risks.

It is also possible that response strategies now anticipate a significant conditionality between risks. Read the Conditionality section, later in this guide, before making these settings.



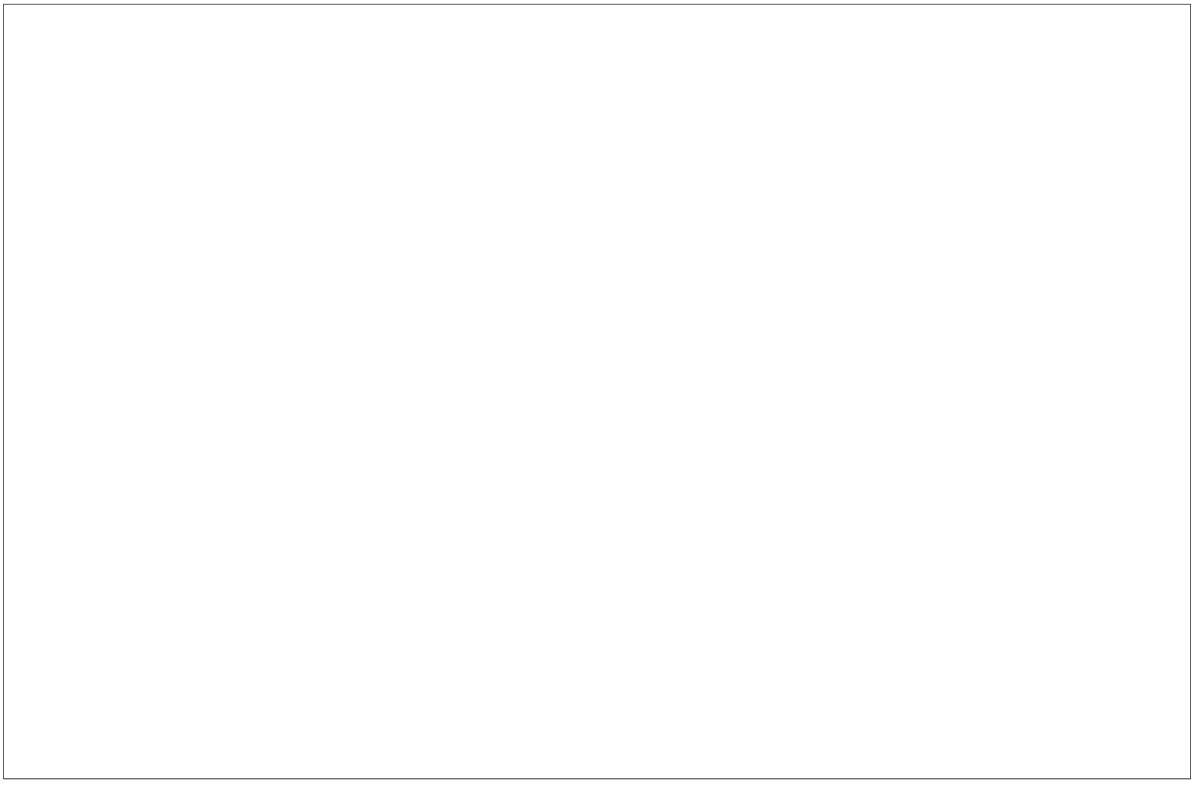
Running the Risk Response Model

After adjusting conditionality and checking the Base and Risk entries, find the **Run Model** button near the top of the RMPM sheet, "click" the button. Expect that the program will calculate for a minute or two.

After running, the view orients on a basic output presentation at the top-right of the sheet:

“Clicking” the green or blue “buttons” near the top, will take you to the respective output sheet:

Example:



Appendix: Risk Breakdown Structure (RBS)

The Risk Breakdown Structure (RBS) provides a consistent approach for organizing risks.

The RBS is a list of common transportation project risks organized in a hierarchical matrix, by category and subcategory. Besides promoting a consistent risk identification system, it can serve as a prompt for risk elicitation.

The RBS provides several functions and benefits to the project team and to management, including:

1) Consistency with taxonomy (wording)
2) Organizes risk events into common categories
3) Helps identify trends with respect to common usage of risk event categories and event types, along with their probability and impact values
4) Helps to identify common risk events among projects that the Region and Headquarters offices should be aware of due to their potential cumulative effects; e.g. negotiating agreements with agencies or other municipalities
5) Provides a basis to work from for risk assessment and risk elicitors during workshops
6) Provides a basis for development of independent risk surveys for those unable to attend a workshop

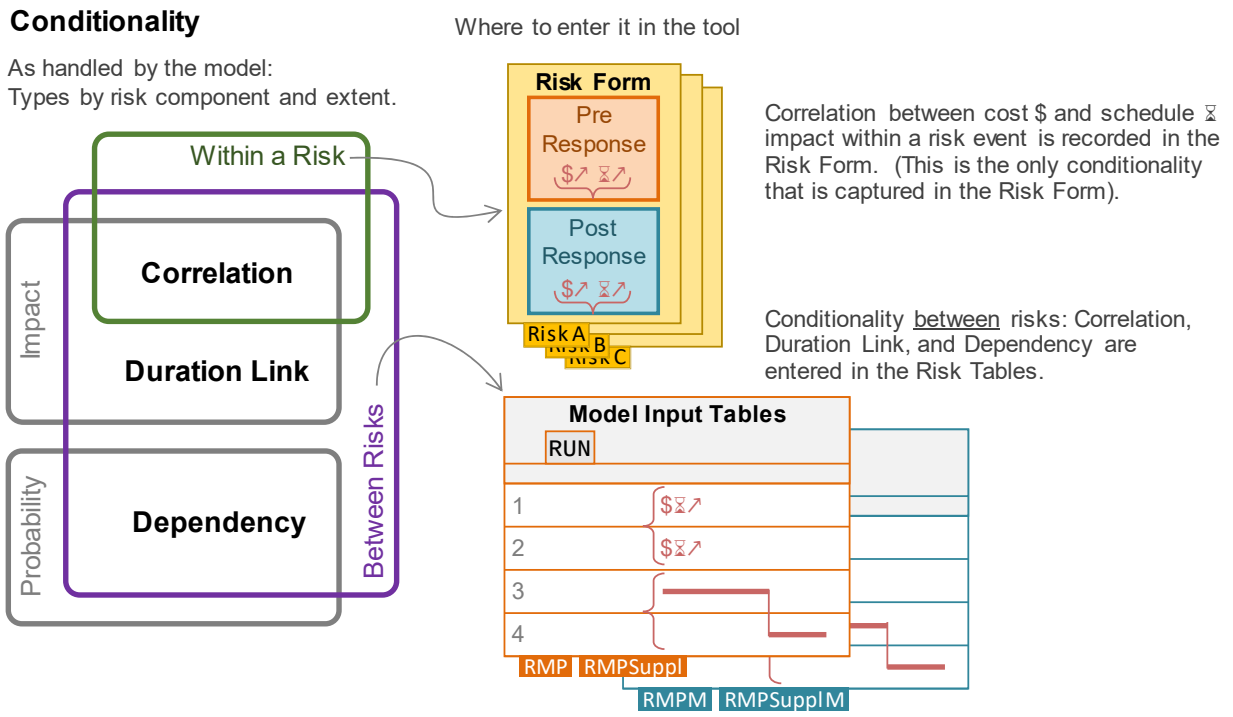
For more information regarding the RBS, see the Project Risk Management Guide, Chapter 7 for additional details.

RISK BREAKDOWN STRUCTURE

Level 1	Major Project Risks										
Level 2	**Environmental & Hydraulics** ENV	**Structures & Geotechnical** STG	**Design / PS&E** DES	**Right-of-Way** (Acquisition & Access) ROW	**Utilities** UTL	**Railroad** RR	**Partnerships & Stakeholders** PSP	**Management / Funding** MGT	**Contracting & Procurement** CTR	**Construction** CNS	**Enterprise Risk** ERO
Level 3	ENV 10 NEPA/SEPA Documentation Completion (Section 4f, etc.) NEPA/SEPA Challenges	STG 10 Changes to Structures Design (Bridge Superstructure, Retaining Walls)	DES 10 Changes to roadway design (vertical and/or horizontal alignment, earthwork, pavement, etc.)	ROW 10 Issues Associated with Development of ROW Plan	UTL 10 Utility Design Coordination and Agreements	RR 10 Railroad Design Coordination and Agreements	PSP 10 Tribal Issues	MGT 10 Change in Project Managers and/or other key Leadership	CTR 10 Change in Project Delivery Method	CNS 10 Traffic Control and Staging Issues (MOT/WZTC)	ERO 10 Safety
	ENV 20 ESA Issues (Consultation, Biologic Assessments / Biological Opinions, Fish Passage)	STG 20 Changes to Geotechnical Design Foundations, Liquefaction, Mitigation, etc. Challenging Geotech Conditions	DES 20 Approval of Design Deviations Changes to roadway design criteria (shoulder width, sight distance, etc.)	ROW 20 Uncertainty in Future ROW Escalation Rate (Project-Specific, including change in land use, urbanization, etc.)	UTL 20 Utility relocations and conflicts	RR 20 Railroad Coordination during construction (flagging, work restrictions, work windows, etc.)	PSP 20 Public Involvement Issues Other Interagency Agreements (Sound Transit, USFS, cities, counties, etc.)	MGT 20 Delayed Decision Making	CTR 20 Issues Related to Contract Language (Contract Packaging, Warranties, Liquidated Damages, DBE, Insurance/Bonding, etc.)	CNS 20 Construction Permitting Issues (work restrictions, etc.)	ERO 20 Trust
	ENV 30 Environmental Permitting (Appeals, etc.)	STG 30 Changes to Structural Design Criteria (seismic, etc.)	DES 30 Changes to Architectural, CSS, Landscape Design	ROW 30 Limited Access (Interchange Justification Report - IJR, Access Hearing, etc.)		RR 30 Contractor Right of Entry Requirements	PSP 30 Additional Scope in Response to Third Party Concerns (artwork, shared-use pathways, intersection improvements, etc.)	MGT 30 Availability of Funding / Cash Flow Restrictions	CTR 30 Delays in Ad-Bid-Award Process (Addenda, Protests, etc.)	CNS 30 Work Windows (Weather, Fish, etc.)	ERO 30 Credibility
	ENV 40 Archaeological/Cultural Discoveries, historic property impacts & mitigation (Section 106)		DES 40 Projects by other agencies affected by or affecting this project (design coordination)	ROW 40 Managed Access (Appeal Hearing, etc.)				MGT 40 Political/Policy Changes	CTR 40 Market Conditions (non-competitive bidding environment) Lack of Qualified Bidders	CNS 40 Construction Schedule Uncertainty (general, including timing of award)	ERO 40 Reputation
	ENV 50 Hazardous Materials Groundwater and Soil Contamination (PE, RW, CN)		DES 50 Changes to Design of Permanent Traffic Items (ITS, Illumination, Intersection, etc.)	ROW 50 ROW Acquisition Issues (condemnation, relocations, demolitions, etc.)				MGT 50 State Workforce Limitations	CTR 50 Delays in Procurement of Specialty Materials or Equipment and associated cost premiums	CNS 50 Marine/Over-Water Construction Issues	
	ENV 60 Wetlands / Stream / Habitat Mitigation		DES 60 Design / PS&E Reviews Additional Scope Driven by Internal Considerations (Maintenance, Traffic Projections, Tolling, extend project terminii, change to purpose and need, etc.)	ROW 60 Additional ROW is required (including full vs partial takes): Temporary and Permanent Access Breaks - FHWA approval Construction/Subterranean Easements					CTR 60 Contractor Non-Performance		
	ENV 70 Stormwater, Changes to Flow Control or Runoff Treatment / Hydraulic Requirements								CTR 70 Availability of Specialty Labor, Labor and/or Productivity Disruptions	CNS 70 Earthwork Issues (re-use, haul, disposal, etc.)	
	ENV 80 Environmental Impacts during Construction (water quality, TESC etc.)									CNS 80 Coordination with Adjacent Projects During Construction	
	ENV 90 Permanent Noise Mitigation									CNS 90 Contractor Access/Staging Coordination and Constructability Issues	
										CNS 100 Construction Accidents	
	ENV 900 Other ENV Issues	STG 900 Other STG Issues	DES 900 Other DES Issues	ROW 900 Other ROW Issues	UTL 900 Other UTL Issues	RR 900 Other RR Issues	PSP 900 Other PSP Issues	MGT 900 Other MGT Issues	CTR 900 Other CTR Issues	CNS 900 Other CNS Issues (unanticipated change orders, claims, etc.)	ERO 900 Other ERO Issues

Appendix: Conditionality

Refining the base estimate and identifying significant risks are most essential to project risk analysis, but a thorough assessment gives some attention to interactions between risks. To a degree, this model can accommodate some common risk relationships. The "Conditionality" risk relationships described here are limited to the model's capability. Further study of this subject equips one for more comprehensive risk assessment. Awareness of conditionality informs and forewarns the project team, allowing more pro-active, response options. The types of conditionality covered here are Correlation, Dependency, and Duration Link.



Where to enter inter-risk conditionality:

Correlation

Describes an expected parity or disparity of impact severity. Positive Correlation marks the expectation that if a certain risk occurs and its impact is high (↗), then the impact of a certain other risk, if it occurs, will tend toward the high end of its input range (↗); similarly if it strikes low (↘), the other will tend low (↘). Negative Correlation marks the expectation that if a certain risk occurs and its impact is high (↗), then the impact of a certain other risk, if it occurs, will tend toward the low end of its input range (↘); if it hits low (↘), the other will tend high (↗).

Shorthand:

***Positive Correlation:* ↗↗ or ↘↘**

***Negative Correlation:* ↗↘ or ↘↗**

Examples

1) Zebra herds crossing a river in Africa. High water means crocodiles are less visible and more mobile. The expectation is that when crossing, if the water is high, death by predation is high — positive correlation. This expectation is reasonable even if there happen to be no

crocodiles at the crossing that year, or they are already full — no actual crocodile strikes. If the crossing meets shallow water, the expectation is fewer zebras lost.

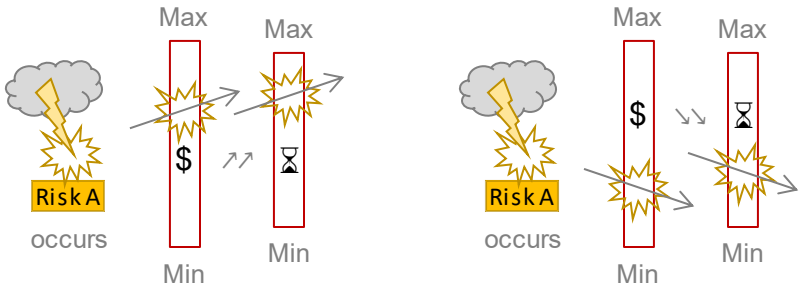
2) The higher the Nile floods, the more arable land is available for cultivation — positive correlation.

3) As prices go up, consumption goes down — negative correlation.

4) More excavation may be required at this end of the project, but if the material is suitable, it means less importation for the fill at the other end — negative correlation.

Correlation between Cost and Schedule Impacts (within a single risk)

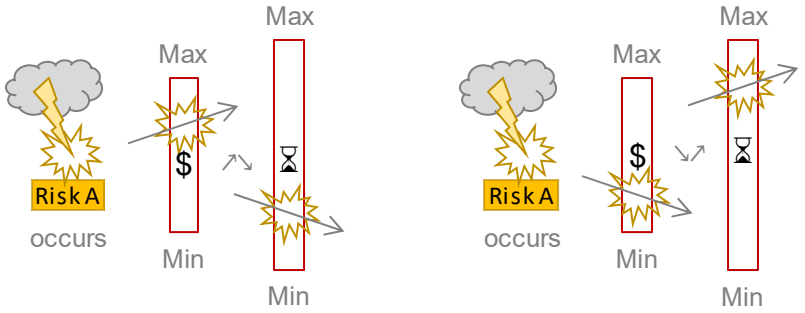
Risk A with Positive Cost and Schedule Impact Correlation: $↗⧖↗ or $↘⧖↘



When Cost $ Impact is high, Schedule ⧖ Impact is high

When Cost $ Impact is low, Schedule ⧖ Impact is low

Risks A with Negative Cost and Schedule Impact Correlation: $↗⧖↘ or $↘⧖↗



When Cost $ Impact is high, Schedule ⧖ Impact is low

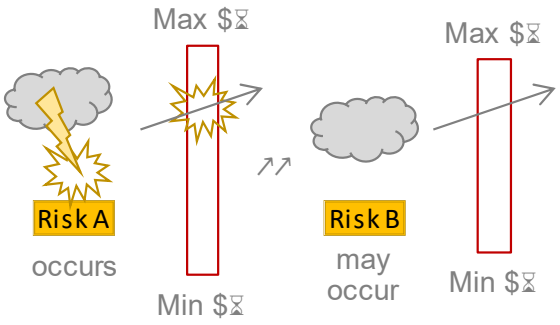
When Cost $ Impact is low, Schedule ⧖ Impact is high

Correlation within a single risk, between cost impact ($) and schedule impact (⧖) — Positive: $↗⧖↗ or $↘⧖↘, or Negative: $↗⧖↘ or $↘ ⧖↗ — is noted on the individual risk sheet.

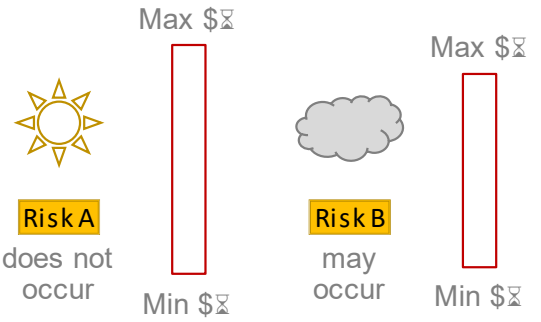
The default value is <blank> (no, unknown, or uncertain correlation). The dropdown selections affirm correlation while telling which type.

Correlation between Risk Impacts (between risks)

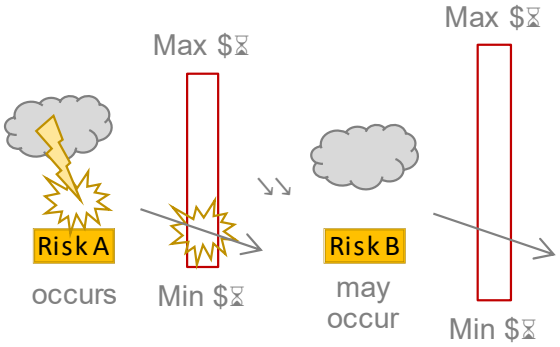
Risks A and B with Positive Impact Correlation: $⧖↗$⧖↗ or $⧖↘$⧖↘



If Risk B occurs, the impact will be high

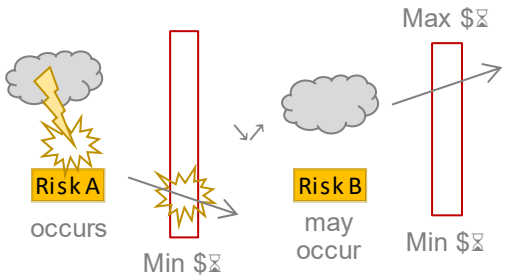


If Risk B occurs, the impact is free-range

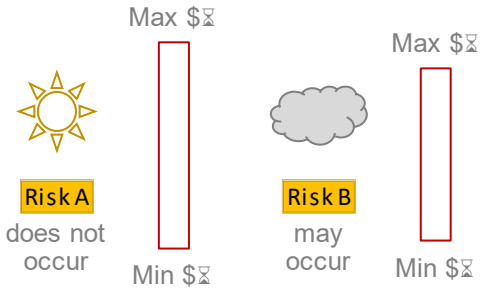


If Risk B occurs, the impact will be low

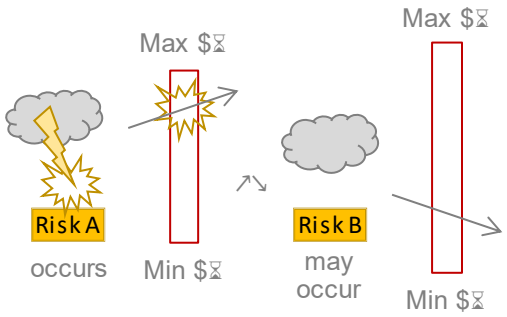
Risks A and B with Negative Impact Correlation: $⧖↗$⧖↘ or $⧖↘$⧖↗



If Risk B occurs, the impact will be high



If Risk B occurs, the impact is free-range



If Risk B occurs, the impact will be low

Impact correlations between risks are set in the Model Input Tables:

Note: The program assumes the **correlation between risks is driven by the preceding risk of a sequence on the list**: #1 governs #2, #17 governs #18, etc. **— risks must be ordered accordingly**. Note: the first batch of 12 risks cannot be connected to the second batch, 13 – 24, so #12 cannot govern #13.

The user may reorder risk sheets by dragging their respective sheet tabs, but conditionality indicators will not automatically update to suit a new order. Any that were set before a reordering should be checked afterwards to ensure risks are still connected as intended.

The initial risk randomly selects an impact severity within its input range — if it randomly occurs. If the initial risk does not occur, then the following risk is free to impact randomly over the full range of its input bounds — if it strikes.

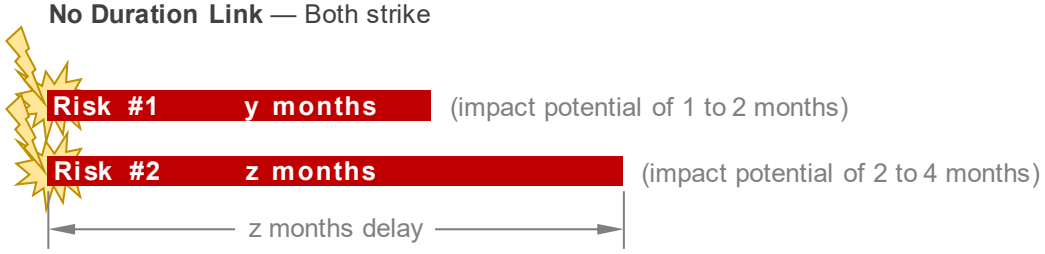
Duration Link

This simply means that if both risks occur the program adds both their duration impacts against the schedule base estimate (in "series"). This again is about impact or consequence, not about probability of occurrence.

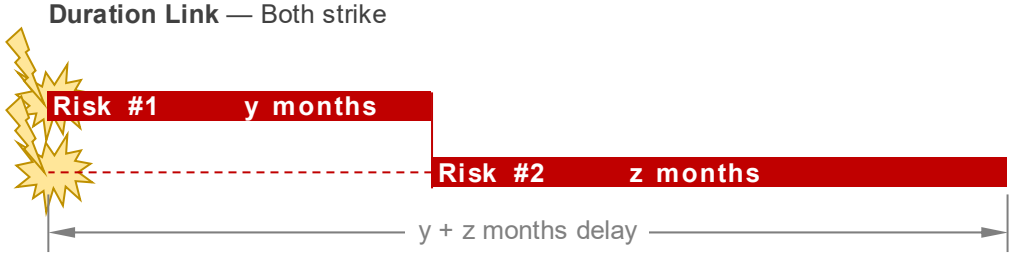
Illustration

y and z depict randomly generated durations, selected within entered (quantified) impact bounds (minimum, maximum, and most-likely).

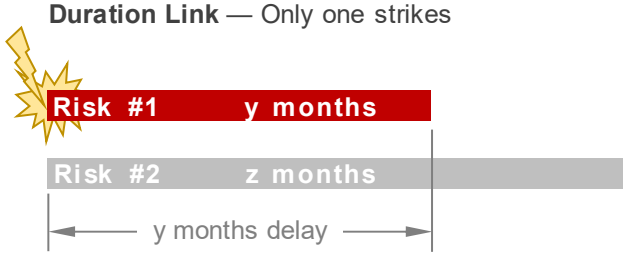
No Duration Link — Both strike



Duration Link — Both strike



Duration Link — Only one strikes



Duration Link is set in the Model Input Tables:

The default value is “0” (no, or unknown Duration Link). The dropdown selection of “1” affirms a link with the risk just below on the list. Indicator fields confirm the link.

The model is limited to pairs of sequential risks, as listed in the Model Input Tables. One signifies duration link from a “Master Duration Risk” on the list to the next down on the list. Link #1 and #2 from #1, #17 and #18 from #17, etc. **— risks must be ordered accordingly**. Caution: the first batch of 12 risks cannot be connected to the second batch, 13 – 24, so #12 cannot link #13.

The user may reorder risk sheets by dragging their respective sheet tabs, but conditionality indicators will not automatically update to suit a new order. Any that were set before a reordering should be checked afterwards to ensure risks are still connected as intended.

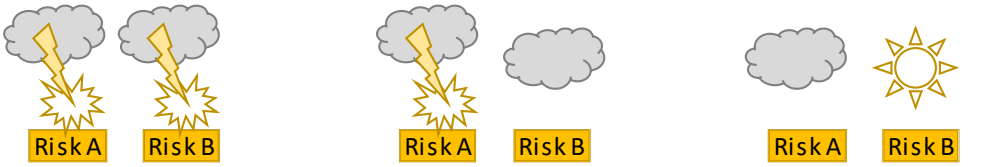
Dependency

Unlike the previous two conditionality types dealing with risk impacts, this one is a probability relationship. The model's default, also known as "mutually inclusive", allows all risks to occur or not, as random numbers dictate; however, the simulation may be sensitized for two other scenarios. One where a risk can only happen if some other does, and a lopsided "mutually exclusive", where a risk cannot happen if some other does.

The model default value, <blank>, is that each risk probability is independent. The dropdown selections affirm dependency while telling which type:

DEP-INCL = (Dependent-Inclusive) Yes, this risk is dependent on the preceding risk and may only occur if the preceding risk does occur.

Risk B can strike only if Risk A strikes.



Risk B might not strike. Risk B will not strike.

Example

Best route of excavation is near abandoned, buried vessels; contents vary from benign to toxic. Puncturing a vessel full of potable water is its own unfavorable impact, let alone having to deal with toxic waste; but if no tanks or lines are discovered, the hazmat suits can be stowed.

DEP-EXCL = (Dependent-Exclusive) Yes, this risk is dependent on the preceding risk and may only occur if the preceding risk does not occur.

Risk B can strike only if Risk A does not strike.

Risk B might not strike. Risk B will not strike.

Example

We will need increased capacity for de-watering if it rains heavy, but we will need water tanks and sprayers for dust control if it does not rain at all.

Example

An almost empty canteen while on expedition may mean perishing of dehydration, but one could resort to local sources. The more one drinks from these however, the greater the chance of contracting some other malady. Welcome to the jungle!

Dependency is set in the Model Input Tables:

Note: the program assumes that **dependency between risks is driven by the preceding risk of a sequence on the list**: #1 governs #2, #17 governs #18, etc. — **risks must be ordered accordingly**, with the selection made from the lower risk. Caution: the first batch of 12 risks cannot be connected to the second batch, 13 – 24, so #12 cannot govern #13.

The user may reorder risk sheets by dragging their respective sheet tabs, but conditionality indicators will not automatically update to suit a new order. Any that were set before a reordering should be checked afterwards to ensure risks are still connected as intended.