

# Estimating Project Risk Reserves

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## ABSTRACT

*All projects have risks. To provide resources needed to avert or mitigate these risks, planners must estimate a risk reserve. Setting a "reasonable" reserve is important. A large reserve may cause the project's bid price to be noncompetitive. A small reserve may be inadequate to handle the problems that will inevitably occur.*

*This paper describes a method to estimate an "optimal" reserve for a list of identified risks. For each risk, the estimator provides the probability and consequences (cost) of occurrence before mitigation, the cost of actions that could be performed to mitigate the risk, and the probability and consequences that would remain after performing these actions. The Risk Reduction Leverage, RRL, is the difference in the expected losses before and after mitigation, divided by the cost of mitigation. (RRL is similar to a Return On Investment except it uses expected costs instead of total estimated costs.) The method ranks the risks based on their Risk Reduction Leverage, and applies criteria to decide which risks should be mitigated and which should be accepted. The method also gives criteria for deciding which risks should be mitigated immediately ("preventative") and which can be deferred ("contingent"). The paper suggests ways to handle overlapped risks and mitigation actions, coupled risks, and compounded consequences.*

*This paper describes a spreadsheet that implements the method, and provides an example showing how the reserve is calculated. (This is a hard reserve because it is based on documented calculations that are tied to specific risks.) It explains how to use the data for planning, and for tracking the identified risks during a project.*

*This paper is based on Chapter 17, Estimating the Impacts of Risks, in "Software and System Estimation: Project, Products, and Process" by R. D. Stutzke, to appear in 2003.*

## 1.0 Introduction

Risks are inevitable for any complicated project due to imperfect knowledge about the product's requirements and operating conditions, the technology and tools being used, and staff capabilities, experience, and continuity. Ignorance of various factors compounds the problem. In addition, systems are developed in an environment that constantly changes, making these factors difficult to predict.

A risk is an uncertain condition or event that, if it occurs, could have a negative effect on the project's cost and schedule, or on the products it produces. Risks have a probability of occurrence and an associated cost of occurrence. (Uncertain events that occur and provide benefits to the project are called opportunities.) The product of the probability of occurrence and the cost of occurrence is called the *impact*. (Some authors call this quantity the *risk exposure*.)

Project planners, assisted by engineers, managers, and other experts, identify risks that could jeopardize project success. These individuals also identify possible mitigation actions that can be performed to reduce the impact of each identified risk. A typical mitigation action for hardware is over engineering the item to provide a large safety factor. (This is calculated based on the known strength of materials and the configuration of the component parts. The engineers design a structure that will support some multiple of the maximum expected load. The multiple is the safety factor.) Safety factors are commonly used in constructing bridges and buildings. Hardware engineers can also mitigate the risk of system failure by designing secondary backup systems that can contain or limit the damage, or can perform essential functions if the primary system fails. For example, elevators have brakes that prevent the elevator from falling if the cable breaks.

For software systems there is no analogy to the strength of materials, nor are there easy ways to provide backup systems. One approach that has been discussed in the literature is multi-version programming [Leveson, 1995]. Unfortunately, adding backup functions and the logic needed to invoke them (switchover logic) actually increases the amount of software and its associated complexity. Increasing software size and complexity is known to increase the total number of latent defects in the software, and so increases the probability of system failure.

Another way of addressing many kinds of risk is to define Terms and Conditions in the contract or in the product's written warranty. The provider of the product or service states in the contract the provider is not liable for certain types of failures that may occur. ("It is not my fault.") In some cases, the producer may purchase insurance to cover the occurrence of losses.

To mitigate risks requires resources. The challenge faced by project planners and estimators is how large the reserve should be. Estimating a value that is too small means that the project will lack the necessary funds to perform the mitigation actions or to cover the costs associated with the damage due to failures. On the other hand, choosing an amount that is too large means that the bid price will be excessively high, resulting in loss

of the bid. Another concern in many organizations is that the reserve be quantitatively justified. This is called a *hard reserve*. In contrast, a *soft reserve* is simply in monetary amount that is asserted without any quantitative justification.

Planners must also decide how to expend the reserves that are provided. Some risks have a very low probability of occurrence and so it may make sense to wait to see if the situation develops before expending funds to perform mitigation actions. Other risks have a high probability of occurrence, and so it makes sense to take perform mitigation actions. The planners plan and schedule the mitigation actions with the other project tasks.

The next sections describe a method to estimate an “optimal” reserve for a list of identified risks and a spreadsheet that implements the method. The description includes an example showing how the reserve is calculated.

## 2.0 Basic Calculations

For each risk, there is a probability of occurrence and a cost of occurrence. These values are defined before and after mitigation. Another important variable is the cost of mitigation. The following notation represents the basic quantities:

$P_B$	= Probability of occurrence before mitigation
$C_B$	= Cost of occurrence before mitigation
$P_A$	= Probability of occurrence after mitigation
$C_A$	= Cost of occurrence after mitigation
$C_M$	= Cost of mitigation

Using these, we can define two important quantities. The first is called the impact, and represents the expected loss associated with a particular risk. Second, the risk reduction leverage, RRL, is the difference in expected losses before and after mitigation, divided by the cost of mitigation. (RRL is similar to a return on investment except that it uses expected losses instead of total estimated costs.) Equations for these two quantities are:

$$I_i = \text{Impact} = P_i * C_i \quad \text{where } i = A, B$$

$$\text{RRL} = \text{Risk Reduction Leverage} = \frac{I_B - I_A}{C_M}$$

Insurance is a special type of mitigation. The policy has a face value,  $C_F$ , which covers some or all of the cost of occurrence before mitigation,  $C_B$ . The cost of occurrence after mitigation is performed,  $C_A$ , equals the cost of occurrence before,  $C_B$ , minus the face value of the insurance,  $C_F$ , less any deductible amount,  $C_D$ . The equation is:

$$C_A = C_B - (C_F - C_D)$$

Purchasing insurance does not affect the probability of occurrence. Thus,  $P_A = P_B$ . The impacts and RRL are:

$$I_B = P_B * C_B$$

$$I_A = P_B * [C_B - (C_F - C_D)]$$

$$RRL = (I_B - I_A) / C_I = P_B * (C_F - C_D) / C_I$$

If the face value of the insurance,  $C_F$ , is less than  $C_B$ , then RRL is lower than for the case where  $C_F = C_B$ .

### 3.0 The Spreadsheet

J. D. Hwang and H. M. Kodani describe a method for risk analysis in [Hwang, 1973]. Basically, their method compares impacts before and after mitigation. The Army's "Total Risk Assessing Cost Estimate" (TRACE) method extends their method [Army, 1979]. John Edgar summarizes the TRACE method in [Edgar, 1982]. In particular, his Figure 4 shows a tabular layout that can be implemented in a spreadsheet.

You can tabulate information for each risk in a spreadsheet, and apply criteria to rank the risks based on their risk reduction leverage and other criteria. This provides a way for planners to determine the amount of reserve and to determine which mitigation tasks should be scheduled and performed immediately instead of being postponed.

### 3.1 The Spreadsheet Layout

Figure 1 shows the risk analysis spreadsheet that records the results of your initial analysis. The spreadsheet has 14 columns. The following paragraphs describe the contents of each column. All costs and impacts are measured in your choice of monetary units.

Project:													
Date Prepared:													
A	B	C	D	E	F	G	H	I	J	K	L	M	N
Description		Before Mitigation			Mitigation		After Mitigation			Analysis			
ID	Owner	Title	Prob.	Cost (\$K)	Impact (\$K)	Action	Cost (\$K)	Prob.	Cost (\$K)	Impact (\$K)	Impact Red. (\$K)	RRL	Notes
1		A	0.4	45.0	18.0	A-1	10.0	0.05	10.0	0.5	17.5	1.75	
2		B	0.5	75.0	37.5	B-1	75.0	0.00	0.0	0.0	37.5	0.50	
3		C	0.3	25.0	7.5	C-1	2.0	0.00	0.0	0.0	7.5	3.75	
4		D	0.2	100.0	15.0	D-1	15.0	0.00	0.0	0.0	15.0	1.00	
5		E	1.0	150.0	150.0	E-1	5.0	0.00	0.0	0.0	150.0	30.00	
6		F	0.3	375.0	112.5	F-1	100.0	0.15	200.0	30.0	82.5	0.83	
7		G	0.1	1000.0	100.0	G-1	150.0	0.01	900.0	9.0	91.0	0.61	
8		H	0.2	1125.0	225.0	H-1	90.0	0.05	100.0	5.0	220.0	2.44	
9		I2	0.4	500.0	200	I-1	30.0	0.10	500.0	50	150	5.00	
10		J	0.4	1500.0	600	J-1	100.0	0.15	500.0	75	525	5.25	

Figure 1: Risk Analysis Spreadsheet

The spreadsheet contains the project name and date prepared at the top. The remainder of the spreadsheet has six regions:

	<b>Purpose</b>	<b>Columns</b>
<b>1</b>	Description	A – C
<b>2</b>	Before Mitigation	D – F
<b>3</b>	Mitigation Action	G – H
<b>4</b>	After Mitigation	I –K
<b>5</b>	Analysis	L – M
<b>6</b>	Notes	N

Columns A through C describe the risk. (In addition, column N may reference numbered notes that provide additional description. The notes are text that is recorded in a separate document, allowing descriptions to be of arbitrary length.) Column A contains some unique identifier to aid in tracking the risk. (You can add extra columns if desired to indicate the *type* of risk to aid in tracking. Possible types might be software risks (SW), hardware risks (HW), etc.) Column B identifies the *owner* of the risk. Some person (or department) *must* have responsibility for the risk. This person has the knowledge and expertise to estimate the quantities, and supervises (or performs) the mitigation actions. Column C contains a short phrase describing the risk. (The column shown in the table is narrowed for publication purposes. The descriptions are represented here as single letters: A, B, C, etc.) If you need additional detail, provide notes in column N.

Columns D, E, and F describe the risk prior to performing any mitigation actions. Column D is the estimated probability of occurrence. Column E records the cost to correct the damage if the risk occurs, here measured in thousands of dollars. Column F shows the impact, computed as the product of the values in columns D and E. The impact is also measured in thousands of dollars. If needed, you can describe detailed calculations in a separate document and cite it in column N.

Column G identifies the action to be performed to mitigate the risk. As in Column C, Column G is narrowed and the actions are merely “described” as A-1, etc. For a real project, you may need to refer to a numbered note that provides additional details. (Essentially, you should provide a short work package that describes what action is to be done, when it will be completed, the resources needed, etc.) Column H shows the additional cost needed to perform the mitigation action, measured in thousands of dollars to maintain consistency with the other monetary quantities. (I assume that the person who performs the mitigation action is the owner identified in Column B. If not, add a column to hold this information.)

Columns I, J, and K estimate the expected impact that will be incurred assuming that the mitigation action has been performed and that the identified risk still occurs. (This is called the residual impact.) For example, the mitigation action may not completely eliminate the probability that the risk will occur. Also, it may not totally reduce the associated cost of occurrence to zero. If needed, describe the details of the calculations in a separate document and cite it in column N.

Columns L and M contain calculated values that help to analyze the cost savings and return on investment. Column L gives the reduction in the expected loss (the impact), and equals the difference of the values in Columns F and K. Column M gives the Risk Reduction Leverage, which is the reduction in impact divided by the mitigation cost in Column H. RRL uses the “expected loss”, i.e., the impact, instead of the estimated costs shown in columns E and J. (The “worst case” loss is obtained by subtracting columns E and J.)

This spreadsheet is similar to a method described in the Department of the Army “Total Risk Assessing Cost Estimate (TRACE) Guide” [Army, 1979]. TRACE increases Baseline Cost Estimates based on the assessed risk. You can use probabilistic risk analysis to calculate costs for primary events and secondary events. The secondary events are triggered by the primary event. For details see Figure 4 in [Army, 1979].

### 3.2 Populating the Spreadsheet

During initial project planning, you use this spreadsheet to record data about potential risks. Members of the project team identify risks using various checklists plus past experience. Another good way to identify risks is to compare assumptions and estimated values with historical data from similar projects. This will identify overly optimistic assumptions or inconsistencies.

Next, identify possible actions to mitigate each risk. (You will document mitigation actions in the project plan or possibly in a separate risk management plan.)

A common way to assign probabilities is to use a Likert rating scale, mapped to probability values. For example, see [USAF, 1988], [Charette, 1989], and [Garvey, 2000].

To estimate the costs of occurrence and mitigation, you can use the techniques described in [Boehm, 1981] and [Stutzke, 2003]. To estimate the cost associated with the occurrence of a particular risk, you may want to first estimate the impacts of technical problems or schedule slips, and then convert these into costs. (You can use parametric models to do this.) For each risk, estimate the cost before and the cost after any mitigation actions have been done.

The cost of occurrence consists of tangible costs that will be incurred if the particular risk event occurs. You can also include intangible costs (such as loss of market share or customer goodwill) in the cost of occurrence. Such costs are difficult to estimate, however, and so it may not be appropriate to include them in the estimated amount for a hard reserve. Barry Boehm discusses some of these costs in the form of tangible benefits and intangible benefits in Section 31.7 of [Boehm, 1981]. From the standpoint of risk analysis, the occurrence of an adverse event causes the loss of benefits, which are represented by a cost.

### 3.3 Handling Coupling And Overlaps

The analysis documented in the spreadsheet assumes that risks are independent. In some cases, risks may be linked. *Coupling* occurs when mitigating one risk increases the impact of another risk. For example, purchasing software components instead of building them from scratch reduces the new development risk, but increases the risk associated with COTS volatility. *Compounding* occurs when a single risk source causes multiple occurrences of a bad consequence. One example might be the dependence upon and ICASE tool that is unproven, lacks needed features, and has inadequate reliability. Failure of the ICASE tool could impact various other tasks on the project, as well as other risks associated with software development.

Boehm also gives several examples of compound risks in Section 2.5.2 in [Boehm, 1989]:

- Using two untried technologies in the same component or subsystem
- Using new, untried technology without knowledgeable staff
- Using untried technology with an ambitious schedule
- Having unstable interfaces and an untried subcontractor
- Meeting vague requirements on an ambitious schedule

The recurring theme is “unprecedentedness” I think. New, poorly understood or untried technology or stakeholders are all sources of risks. Poorly defined interfaces and requirements are also tied to lack of information. (Buying information is a possible strategy.)

Boehm and Charette agree: the best approach to deal with compound risks is to reduce them to non-compound risks if at all possible. Otherwise, place compound risks at the top of your priority list and give them extra attention. This approach assumes that you can identify compound risks of course, which is not an easy task.

For further discussion of coupling and compounding see Sections 5.2.1 and 5.5.1 in [Charette, 1989]. There are no easy ways to identify coupling and compounding, especially for unprecedented systems since the relations between the system's elements are not well understood or may not even be recognized.

In some cases, a particular mitigation action may affect multiple risks. For example, having a good process (in the sense of the SEI's Capability Maturity Models) eliminates many potential risks. The process areas address various risk factors. If a particular mitigation action influences multiple risks, this may affect calculations of the Risk Reduction Leverage. Possible alternatives are to allocate the mitigation cost equally to each of the risks or to allocate using some proportion. For example, you might allocate the cost of mitigation in proportion to the benefit provided, defined as the difference between  $I_B$  and  $I_A$ .

## 4.0 Calculating the Reserve

The risk reserve provides the resources needed pay for the total “expected cost” of all the identified risks that have *not* been “prevented”. (The “expected cost” of a risk is either the impact before mitigation, or the impact after mitigation *plus* the cost of mitigation.) The reserve must also cover the costs to perform the contingent mitigation actions. The project budget must include the costs to perform the preventative mitigation actions.

### 4.1 Choosing The Reserve Amount

Setting a “reasonable” reserve amount is important. Overly large reserves increase the project’s bid price. Overly low reserves will be inadequate to handle the problems that will inevitably occur.

The spreadsheet described in Section 2 identifies all known risks and the expected financial impact if each occurs, before and after mitigation. The most conservative risk reserve covers the total costs of mitigation and occurrence after mitigation. Not all risks should be mitigated however. Each mitigation task has a benefit, indicated by RRL. If  $RRL > 1$  then the mitigation task “buys” a greater reduction in the expected loss (impact) than it costs to perform. If  $RRL < 1$  then the task is not a bargain.

We want to select the set of mitigation tasks that gives the most benefit. A reasonable solution is to order the mitigation tasks by decreasing RRL. Choosing tasks from this ordered list, select the tasks with the highest payoff first. Then move down the list, computing the cumulative decrease in impact and cumulative increase in mitigation cost as successive tasks are selected. To determine the value of the risk reserve, sum the cost of mitigating the risks with  $RRL > 1$ , the impact of these risks after mitigation, and the impact of all other risks before mitigation. I call this the Predicted Total Cost:

$$PTC = \sum_{RRL>1} I_A + \sum_{RRL<1} I_B + \sum_{RRL>1} C_M$$

Stop selecting tasks when the Predicted Total Cost reaches a minimum. This is the amount of the risk reserve.

So, the strategy is to mitigate risks for which  $RRL > 1$ , and accept the risks for which  $RRL < 1$ . Figure 2 shows the risks in Figure 1 ordered by decreasing RRL. Risk # 4 (Title “D”) has  $RRL = 1$ . This risk is number 7 in the list. Figure 3 shows a plot of the Predicted Total Cost. The minimum Predicted Total Cost occurs at \$635.5K. (For this particular set of data, the total is identical for mitigating either the first six or the first seven risks because  $RRL = 1$  for the seventh risk, Risk #4.) The Predicted Total Cost increases after the seventh risk because  $RRL < 1$  thereafter. It is more cost effective to let the risk occur and pay the damages than it is to perform the mitigation task.

Project:																
Date Prepared:																
A	B	C	D	E	F	G	H	I	J	K	L	M	N			
Description	Owner	Title	Before Mitigation		Mitigation		After Mitigation				Analysis		Rank	Cumul	Impact	Predicted
ID			Prob.	Cost (\$K)	Impact (\$K)	Action	Cost (\$K)	Prob.	Cost (\$K)	Impact (\$K)	Impact Red. (\$K)	RRL	(RRL)	Mitig	Remaining	Total Cost
5		E	1.0	150.0	150.0	E-1	5.0	0.00	0.0	0.0	150.0	30.00	1	0.00	1465.50	1465.50
10		J	0.4	1500.0	600	J-1	100.0	0.15	500.0	75	525	5.25	2	105.00	790.5	895.50
9		I2	0.4	500.0	200	I-1	30.0	0.10	500.0	50	150	5.00	3	135.00	640.5	775.50
3		C	0.3	25.0	7.5	C-1	2.0	0.00	0.0	0.0	7.5	3.75	4	137.00	633.0	770.00
8		H	0.2	1125.0	225.0	H-1	90.0	0.05	100.0	5.0	220.0	2.44	5	227.00	413.0	640.00
1		A	0.4	45.0	18.0	A-1	10.0	0.05	10.0	0.5	17.5	1.75	6	237.00	395.5	632.50
4		D	0.2	100.0	15.0	D-1	15.0	0.00	0.0	0.0	15.0	1.00	7	252.00	380.5	632.50
6		F	0.3	375.0	112.5	F-1	100.0	0.15	200.0	30.0	82.5	0.83	8	352.00	298.0	650.00
7		G	0.1	1000.0	100.0	G-1	150.0	0.01	900.0	9.0	91.0	0.61	9	502.00	207.0	709.00
2		B	0.5	75.0	37.5	B-1	75.0	0.00	0.0	0.0	37.5	0.50	10	577.00	169.5	746.50

Figure 2: Risks Ordered by Decreasing RRL

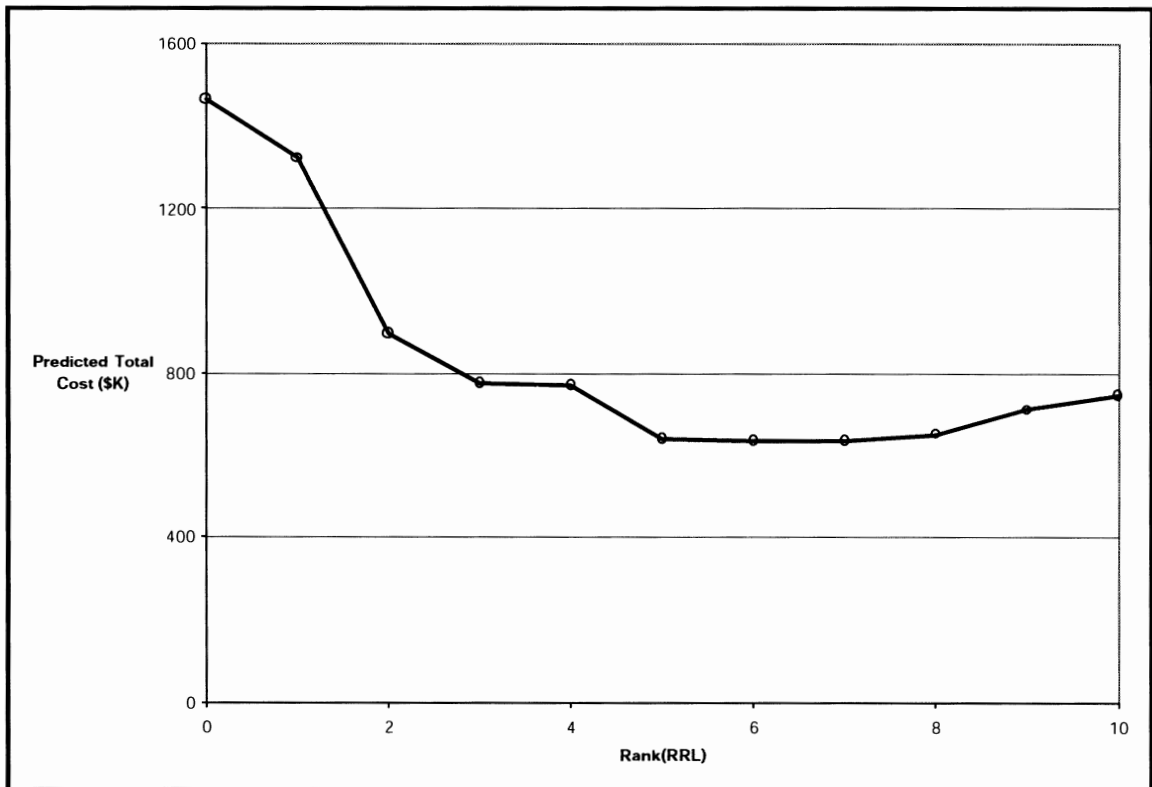


Figure 3: Predicted Total Cost vs Rank(RRL)

If the first seven risks are mitigated, the remaining impact is \$380.5K. (Of this amount, \$250K is the impact for the risks that are accepted, the last three in the ordered list). The estimated mitigation costs are \$252.0K. Based on this data, the expected costs to the project due to the identified risks will be \$632.5K. This is the risk reserve. (This is a large portion of the assumed \$3M project budget. The values chosen for the example are not realistic.)

## 4.2 Deciding Which Tasks to Defer

We can still potentially do better however. Some of the risks may never occur. If we delay performing some of the mitigation tasks, then the potential risk may “expire” and so will cost the project nothing. Here are two examples. First, if there is a freeze date on requirements, then there is no cost associated with requirements volatility risk after that date. Second, suppose there is a reserve for bad parts (scrap) produced during machining. Once all of the parts have been machined and passed inspection, the probability of having more bad parts becomes zero and the unused portion of the reserve can be released.

You need criteria to decide whether to execute or delay a mitigation task. (These tasks are called Preventative and Contingent, respectively.) This is a complex issue. The impact of some risks may increase the later you decide to mitigate them. As already noted, some risks may never occur. My recommended approach is twofold. First, select a set of risks to Prevent. Second, track the remaining Contingent risks and execute them “when appropriate”.

One possible approach is to use various ranking techniques to partition the set of risks (the nominal group technique, multivoting, and the analytic hierarchy process). Boehm mentions a betting analogy, adjective calibration (Likert ratings), and group consensus techniques such as the Delphi technique [Boehm, 1989, page 132].

To ensure consistency and reduce effort, however, I recommend using rules that can be automated in the risk analysis spreadsheet. This restricts the possible parameters to impact, mitigation cost, RRL, and probabilities. In my opinion, performing a Preventative mitigation task is beneficial if either of two conditions is true:

1. Impact (before)  $\geq$  5% of total project cost
2. RRL  $\geq$  2

Condition (1) says that the expected loss (the impact) is a significant fraction of the project’s total costs. The value of 5% is based on the assumption that the accuracy of the cost estimates is  $\pm 10\%$  or so. (Recall that parametric cost models have an accuracy of  $\pm 20\%$  or so.)

Condition (2) says that performing the mitigation action is definitely a winning bet. Strictly speaking, mitigation is cost effective as long as the amount of impact reduction exceeds the mitigation cost, i.e., RRL  $\geq$  1. I chose a conservative threshold of 2 since there are uncertainties in the estimates of costs and probabilities of occurrence.

There is another possible condition. If the cost of performing the mitigation task is smaller than the cost of continuing to track it, then we should perform the mitigation task to eliminate the risk. This assumes that the mitigation task completely eliminates the risk so that no further tracking is needed. In addition, the cost of tracking a risk is likely to be very small compared to the cost of a typical mitigation tasks. To keep the number of rules small, I discarded this criterion.

As an example, assume that the risks in Figure 1 apply to a project with a total cost of \$3M. The rules are to prevent the risk if:

$$\text{Impact}(\text{before}) \geq \$150\text{K}$$

or

$$\text{RRL} \geq 2$$

Figure 4 shows these rules applied to the risks in Figure 1. Specifically, I added Columns O-S to the spreadsheet. Columns O-P correspond to the two rules. If the condition is met, a "P" appears in Column O or P. Column Q sums the number of rules that have fired. For example, Risk ID 10 meets both conditions. (The parameters for the rules are in a separate worksheet named "Rules".) Column S records the mitigation cost for each "P" task, with the sum in row 3, Column S. This is the total budget for the Preventative tasks. Only two tasks are deferred, #1 and #4, amounting to \$25K in mitigation costs.

Project:																	Total	
Date Prepared:																	Budget	
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Description		Before Mitigation			Mitigation		After Mitigation			Analysis					Sum	Prevent		
ID	Owner	Title	Prob.	Cost (\$K)	Impact (\$K)	Action	Cost (\$K)	Prob.	Cost (\$K)	Impact (\$K)	Impact Red. (\$K)	RRL	Notes	1	2	CP	Disp.	Cost
5		E	1.0	150.0	150.0	E-1	5.0	0.00	0.0	0.0	150.0	30.00			P	1	P	5
10	J	0.4	1500.0	600	J-1	100.0	0.15	500.0	75	525	5.25		P	P	2	P	100	
9	I	0.4	500.0	200	I-1	30.0	0.10	500.0	50	150	5.00		P	P	1	P	30	
3	C	0.3	25.0	7.5	C-1	2.0	0.00	0.0	0.0	7.5	3.75			P	1	P	2	
8	H	0.2	1125.0	225.0	H-1	90.0	0.05	100.0	5.0	220.0	2.44			P	1	P	90	
1	A	0.4	45.0	18.0	A-1	10.0	0.05	10.0	0.5	17.5	1.75					0	C	0*
4	D	0.2	100.0	15.0	D-1	15.0	0.00	0.0	0.0	15.0	1.00					0	C	0*
6	F	0.3	375.0	112.5	F-1	100.0	0.15	200.0	30.0	82.5	0.83					0	A	0
7	G	0.1	1000.0	100.0	G-1	150.0	0.01	900.0	9.0	91.0	0.61					0	A	0
2	B	0.5	75.0	37.5	B-1	75.0	0.00	0.0	0.0	37.5	0.50					0	A	0

Figure 4: Categorization of Mitigation Actions

Although simple, these rules illustrate the basic approach. You can use other prioritization schemes to select which mitigation tasks to defer if desired.

### 4.3 Summary Of The Reserve Amount

Table 2 summarizes the components of the reserve computed in the preceding sections. Risks 6, 7, and 2 are accepted. Risks 5, 10, 9, 3, and 8 will be executed immediately (Preventative). The total cost to perform these tasks is \$227K. Risks 1 and 4 are deferred (Contingent). The mitigation cost for these totals \$25K. The remaining impact following mitigation (all Preventative and Contingent tasks) totals \$130.5K. This is the amount that will have to be paid to cover the expected losses even though the mitigation actions have all been performed.

**Table 1: Summary of Estimated Costs**

<b>Type</b>	<b>Amount</b>	<b>Category</b>	<b>Meaning</b>
R	\$250.0K	Accepted	Sum of IA for all non-mitigated tasks
P	\$227.0K	Preventative	Sum of mitigation tasks to be executed
R	\$ 25.0K	Contingent	Sum of mitigation costs for deferred tasks
R	\$130.5K	Remaining Impact	Sum of IB for all mitigated tasks

These components will be identified in the project's budget. The "Reserve for Risk" consists of items 1, 3, and 4, and totals \$405.5K. The remaining \$227.0K (item 2) is allocated to specific Preventative tasks in the project plan. The team executes these with the normal tasks in the project plan. (They are included in the budget and the schedule.) A portion of the plan describes the Contingent mitigation actions using "if, then" statements. For example, if a critical path slips more than one calendar month then you might request that additional engineers be assigned to the project. Thus, you defer executing these tasks until the impact (which is the expected loss) becomes larger than the mitigation cost, or other trigger events occur.

In some cases you may include a schedule reserve as well. Steve McConnell provides a good discussion in [McConnell, 1996]. If so, you will insert appropriate float amounts in the project schedule.

#### **4.4 Tracking and Updating**

Changes will inevitably occur during the course of the project. You must regularly track the status of all risks, and update the probability of occurrence, cost of occurrence as needed during the course of the project. In addition, you need to track any ongoing (active) mitigation tasks. You should track Preventive tasks as part of the project's normal management process.

#### **4.5 Other Approaches**

There are other approaches for estimating the potential impacts of a set of risks. This section mentions two.

##### ***The Risk Matrix Method***

The "Risk Matrix" method and supporting tool was developed by the MITRE Corporation. Paul Garvey and Zachary Lansdowne describe the method in [Garvey, 2000]. They describe a set of criteria for rating the severity of the risk ("impact category") and the probability of occurrence for a risk. They then provide mapping to combine the severity and the probability to give a risk rating. (This rating is equivalent to the impact discussed in this paper and in [Boehm, 1989].) Of particular interest, they

rank the risks using a technique from voting theory, called Borda voting [Borda, 1781]. The Borda method ranks the risks from the most to the least critical, on the basis of multiple evaluation criteria. They chose the Borda method because it produces fewer ties in the rankings, and it does not require additional subjective assessments (beyond the two original values, the original cost of occurrence and the probability of occurrence). They also discuss using this information for a sensitivity analysis. For details, see their paper.

### ***Cumulative Cost Risk***

John Gaffney and his colleagues describe a simple method to estimate the cost risk for a program in [Gaffney, 1995]. They compute project cost (actually, effort) as the product of the software size and the average unit cost of production. The size is in SLOC. The cost to produce a line of software is in person-months per SLOC. (This is just the inverse of the productivity). The estimators define a discrete probability distribution function for the size, and another for the unit cost of production. They convolve these two distributions to obtain the probability associated with a particular development "cost" (i.e., effort, which equals the size times the unit production cost). This produces pairs of values consisting of a probability of occurrence and an estimated project cost. Rank ordering these based on the cost of occurrence allows them to determine the cumulative probability as a function of project cost (effort). They define the risk as the difference between the cumulative probability and 1.0. For example, if a project cost of \$1 million is associated with the cumulative probability of 80%, the risk is 20%. For details see Section 8.10 in [Gaffney, 1995].

## 5.0 References

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