Risk Matrix: An Approach for Prioritizing Risks and Tracking Risk Mitigation Progress

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Introduction

Risk Matrix provides a structured way to identify, prioritize, and manage the impact of key risks on programs. A *risk* refers to the possibility that a program's requirement cannot be met by available technology or by suitable engineering procedures or processes. The original version of Risk Matrix was devised by the acquisition reengineering team at the Air Force's Electronic Systems Center (ESC) in 1995 (Franklin 1996).

To facilitate its use, The MITRE Corporation developed the Risk Matrix software application (Garvey and Lansdowne 1998). This application is built in Microsoft Excel; it includes all of the capabilities of the original Risk Matrix as well as new analytical features. These new features include: use of the Borda voting method to prioritize risks, use of reliability theory to track the progress of mitigation action plans, and automated sorting and charting capabilities. This article describes the Risk Matrix software tool and its analytical features.

Risk Matrix includes two worksheets: Risk Entries and Action Plan. Each worksheet has the standard Excel features as well as special pull-down menus to activate the various Risk Matrix functions, such as for ranking, sorting, and charting. A sample Risk Entries Worksheet is shown in Exhibit 1.

The initial phase of the Risk Matrix process is to identify a set of candidate risks. The approach focuses on the requirements-technology pair as the basis for identifying whether a risk exists to the program. The first four columns in Exhibit 1 are designed to support this phase. The first column is the risk number, which must be a unique positive integer. The second column lists the program requirements. The third column lists the available technologies that would help meet each requirement. The fourth column describes the risks that might prevent available technology from meeting each requirement.

The second phase of the Risk Matrix process is to assess the potential program impact of each risk and to assess the probability that each risk will occur. The fifth and sixth columns in Exhibit 1 are designed to support this phase. The fifth column lists the impact assessment (*I*) of each risk, according to the definitions given in Exhibit 2. The sixth column lists the assessed probability () that each risk will occur. Here, the user can pick any percentage from zero to 100 percent.

The third phase of the Risk Matrix process is to prioritize the risks based on the impact and probability assessments. The seventh and eighth columns in Exhibit 1 are designed to support this phase. The seventh column gives the Borda rank, as calculated with the Borda method from voting theory (Borda 1781). Given N candidates and multiple voters, the Borda method assigns points of N - 1, N - 2, . . . , and 0 to the first-ranked, second-ranked, . . . , and last-ranked candidate in each voter's preference order, and the winning candidate is the one with the greatest total number of points. When applied to Risk Matrix, the Borda method ranks risks from most-to-least critical on the basis of two evaluation criteria: the impact I, which is denoted by k = 1; and the probability assessment , which is denoted by k = 2. If is the rank of risk i under criterion k, the Borda Count for risk i is given by

The risks are then ordered (ranked) according to these counts. If ties are present in the criteria rankings, the are adjusted by evaluating the rank for a tied alternative as the arithmetic average of the associated rankings (Lansdowne 1996, Lansdowne and Woodward 1996). The Borda Rank for a given risk is the number of other risks that are more critical. In Exhibit 1, for example, risk 2 has a Borda Rank of 0, identifying it as the *most* critical area of the program. Risk 7 has a Borda Rank of 5, indicating that there are 5 other risks that are more critical.

The impact assessments are ordinal data, because they only designate places in an ordered sequence. For example, we can say that a Critical impact assessment is more severe than a Serious Assessment, but we cannot say how much more severe it is. Moreover, the interval between assessment values does not have a consistent meaning. For example, we cannot say that the difference in severity between Critical and Serious assessments is the same as the difference in severity between Serious and Moderate assessments. The Borda method is an ordinal ranking method, because it requires only that the rank order of the alternatives be known for each criterion. Thus, Risk Matrix uses the Borda method in a way that is consistent with the available input data (Lansdowne 1996, Pariseau and Oswalt 1994).

The eighth column in Exhibit 1 gives the risk rating (*R*), which is a second method for performing risk prioritization.

Exhibit 1. Sample Risk Entries Worksheet

Risk number	Requirement (Threshold)	Technology Available	RISK	I	Po(%)	Borda Rank	R	Manage/Mitigate
1	VHF Single Channel Comm	ARC-186	Poor design	C	10%	4	M	Demonstration as part of Source Selection
2	Talk SINCGARS	ARE-210, ARC-201, GRC-114	Algorithm misunderstood, ICD problems	C	60%	0	H	Demonstration as part of Source Selection
3	Talk 100 Miles	ARC-210	Antenna performance	S	90%	1	M	Make a key parameter of Test Program
4	Go on A-10, F-16, JSTARS and ABCCC	Technology currently not available	Wrong power supply ratings, wrong connectors, cosite problems	Mi	10%	6	L	Aircraft Surveys during Ground Team Meeting
5	Contol Radio with Control Head	N?A	Hard to get pilot consensus	Mi	100%	2	H	Control Head Demonstrations early in program
6	Joint Program Office	N?A	Different Users	S	60%	2	M	Information and Decision Making system
7	Schedule : 24 mons. Delivery	N?A	Integrated circuit lead time	S	40%	5	M	Incentivize on-time delivery

The risk rating is Low (L), Medium (M), or High (H), and it is determined by mapping each (*I*,) pair into the default matrix shown in Exhibit 3. For example, risk 1 in Exhibit 1 has a Critical impact assessment and a 10 percent probability of occurrence. According to Exhibit 3, this combination yields a Medium risk rating, which is the rating that appears in Exhibit 1.

The risk rating was part of the original Risk Matrix devised by ESC, whereas the Borda method was added by MITRE to the software tool. Both methods require the same inputs. The main limitation of the risk rating is that it yields too many ties, because all risks are placed in only three bins. With respect to risk rating, Exhibit 1 shows that two risks are tied for first place (High rating), and four risks are tied for second place (Medium rating). On the other hand, the Borda method generally yields a risk ranking with fewer ties, because there could be as many values for the Borda Rank as there are risks. With respect to the Borda Rank, Exhibit 1 has only two risks tied for third place (Borda Rank of 2). Moreover, the Borda method does not require additional subjective assessments beyond the original *I* and inputs, whereas the rating assignments in Exhibit 3 are based on subjective judgments.

The final phase in the Risk Matrix process is to manage or mitigate each risk. The ninth column in Exhibit 1 provides a brief description of the risk mitigation action plan. The Action Plan Worksheet, discussed in the next section, provides a more detailed description of each action plan. Both the ninth column in Exhibit 1 and the Action Plan Worksheet are designed to support the final phase in the process.

Exhibit 2. Risk Matrix Impact Assessments

Impact Category	Definition
Critical (C)	An event that, if it occurred, would cause program failure (inability to achieve minimum acceptable requirements).
Serious (S)	An event that, if it occurred, would cause major cost/schedule increases. Secondary requirements may not be achieved.
Moderate (Mo)	An event that, if it occurred, would cause moderate cost/schedule increases, but important requirements would still be met.
Minor (Mi)	An event that, if it occurred, would cause only a small cost/schedule increase. Requirements would still be achieved.
Negligible (N)	An event that, if it occurred, would have no effect on program.

Exhibit 3. Possible Risk Ranking Scale (R)

	Negligible	Minor	Moderate	Serious	Critical
0-10%	Low	Low	Low	Medium	Medium
11-40%	Low	Low	Medium	Medium	High
41-60%	Low	Medium	Medium	Medium	High
61-90%	Medium	Medium	Medium	Medium	High
91-100%	Medium	High	High	High	High

The columns in the Risk Entries Worksheet fall into three categories: mandatory user-defined inputs, which are shaded in green; optional user-defined inputs, which are white; and tool-generated outputs, which are yellow. In Exhibit 1, the mandatory user-defined columns are: Risk Number, Risk, I, and . The optional user-defined columns are: Requirements, Technology Available, and Manage/Mitigate. The tool-generated outputs are: Borda Rank and R.

The user can employ several other optional columns that are not shown in Exhibit 1: Related Risk Numbers, Timeframe Start, Timeframe End, Integrated Product Team, and Event Type. The user can also display additional tool-generated columns that show the details of the Borda calculations.

The rows in the Risk Entries Worksheet can be sorted in a variety of ways, such as by Risk Number (as illustrated in Exhibit 1) or by Borda Rank. In the latter case, the worksheet would display the risks in order of criticality. Risk Matrix provides several pre-defined charts as well as the standard Excel charting capabilities.

Risk Matrix also includes an optional method for handling risk dependencies. An "aggravated risk" is some other risk whose probability of occurrence or impact would increase significantly if the given risk occurs. The number of aggravated risks associated with the given risk is a measure of the adverse impact that this risk has on other risks. If dependency is considered, the Borda method ranks the risks based on three criteria: impact, probability of occurrence, and number of aggravated risks.

Exhibit 4. Sample Action Plan Worksheet

Risk No.	Task	OPR	Exit Criteria	Assessment	Discussion
2	1	OPR1	Exit for task 1 of risk2	Yellow	Task discussion
2	2	OPR2	Exit for task 2 of risk2	Red	Task discussion
2	3	OPR1	Exit for task 3 of risk2	Green	Task discussion
3	1	OPR1	Exit for task 1 of risk3	Green	Task discussion
4	1	OPR3	Exit for task 1 of risk4	Green	Task discussion
4	2	OPR2	Exit for task 2 of risk4	Red	Task discussion
5	1	OPR2	Exit for task 1 of risk5	Blue	Task discussion
5	2	OPR1	Exit for task 2 of risk5	Green	Task discussion

Action Plan Worksheet

MITRE also added an optional method for tracking the progress of risk mitigation actions. The first step is to specify the various tasks in the mitigation action plan for at least one risk. Action plans need not be specified for all risks, and the number of tasks in an action plan may vary from risk to risk. Exhibit 4 is a sample Action Plan Worksheet. Each row corresponds to a distinct task; the first column specifies the risk number to which the task applies, and the second column identifies the task number within the action plan for that risk. For example, the first row corresponds to the first task in the action plan for risk 2.

At any point in time, each task in an action plan has a particular status, such as completed or on-track. The second step is to assign one of four colors to represent the status of each task: Blue, Green, Yellow, and Red. The interpretations for these colors are given in Exhibit 5. These color assessments appear in the fifth column of Exhibit 4. For example, the first task in the action plan for risk 2 has yellow as its assessment, which means that the task may not be completed on schedule.

The third step is to translate each color into the probability that the implementation of the associated task will fail. The default translations are given in Exhibit 5, but they can be changed within the program. Based upon the color assessment made for each task in an action plan, the fourth step is to evaluate the probability of action plan failure ():

where is the status color assessed for *j*th task within the action plan, and is the probability that the implementation of this task will fail. For example, if is yellow, then may be set equal to 0.5. This formula gives the true probability of action plan failure if the tasks are arranged in series and are statistically independent. For a series system, the implementation of the action plan is successful if and only if the implementation of each task within the plan is successful.

It is possible, however, that other circumstances might be present. For example, a set of tasks would form a parallel system when the success of the action plan requires only one of these tasks to be successful. Parallel tasks might be desirable for high-risk exploratory investigations. A given action plan might have a combination of series and parallel tasks. In addition, some tasks might be statistically dependent. Reliability theory has established bounds for these situations. First, if an action plan is coherent (which means that there are no irrelevant tasks), its failure probability cannot exceed the failure probability for all tasks arranged in series. Second, if the tasks are associated (which means that they have non-negative covariances), an upper bound on the failure probability of a series system is obtained by treating the tasks as though they were independent. These two results, taken together, imply that the above formula provides a rigorous upper bound on the true probability of action plan failure for any set of coherent, associated tasks (Barlow and Proschan 1975).

The evaluated probability serves as the measure of risk mitigation progress. The fifth and final step is to rank the risks with the Borda method, but using as one of the criteria instead of the probability of occurrence for each risk having a specified action plan. If an action plan has not been specified for a particular risk, then the program will continue to use as a criterion for that risk.

When applying the foregoing method, the user is responsible for only the first and second steps. After the tasks have been defined and status colors have been assessed, the program automatically carries out the remaining steps.

The columns in the Action Plan Worksheet fall into two categories: mandatory user-defined inputs, which are shaded in green; and optional user-defined inputs, which

Exhibit 5. Assessment Colors for an Action Plan Task

Color	Interpretation	Default Failure Probability
Blue	the task has been completed	0.0
Green	the task is on schedule	0.1
Yellow	the task may not be completed on schedule	0.5
Red	the task is considered nonexecutable	1.0

are white. In Exhibit 4, the mandatory user-defined columns are: Risk Number, Task, and Assessment. The optional user-defined columns are: OPR (office of primary responsibility), Exit Criteria, and Discussion. Risk Matrix allows the rows in this worksheet to be sorted in a variety of ways.

This optional tracking method provides several advantages. First, it enables the data and assessments collected for Risk Matrix to be used throughout the risk management process. The risk management process has four basic phases: risk identification, risk assessment, risk prioritization, and risk mitigation. The tracking method supports the fourth phase by measuring risk-mitigation progress. Second, the risks whose action plans need the closest attention are identified with the Borda method. These critical risks are the ones whose and impact assessment (*I*) are both relatively high. Third, if the status colors are assessed periodically (perhaps monthly) for all action plan tasks, both the Borda rank and for each risk can be plotted over time. These high-level graphical displays show the changes in the status of each risk during the risk-mitigation phase of the process.

Conclusions

Risk Matrix is a simple, easy to use, structured process that identifies the risks that are most critical to the program and, therefore, most in need of resources. It facilitates discussions about requirements, technologies, and risks, and it is flexible and can be adapted to any project. The software application is implemented in Microsoft Excel, and so it is compatible on both Macintosh and PC platforms. It incorporates the Borda method, a voting algorithm for ranking most-to-least critical risks on the basis of multiple evaluation criteria, and the intuitive graphical interface displays risks by criticality. The software application includes a method for assessing and tracking the progress of risk mitigation action plans. Risk Matrix is put to use widely at ESC and throughout the Defense community, and the software application is part of the Defense Acquisition Deskbook.

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