

# MITRE

Bedford, Massachusetts

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# Risk Matrix User's Guide

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Version 2.2

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*Approved for public release; distribution unlimited*

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# Acknowledgements

The upgrade of Risk Matrix from version 2.02 to 2.1 was a collaborative effort between the Economic and Decision Analysis Center (EDAC) and the Systems Engineering Process Office (SEPO) at MITRE. Both organizations are grateful to all of the team members that made the update to this tool and users' guide possible. Version 2.2 includes additional enhancements.

As the lead author, Pam Engert conducted research, decided the content, and coordinated the teams efforts.

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Jennifer Anderson made significant contributions to the users' guide in researching and documenting system and year 2000 requirements as well as capturing graphics.

Zachary Lansdowne updated the text for Appendices A and B from the information that was originally published in the Risk Matrix 2.02 documentation.

The careful editorial review provided by Diana Arimento greatly improved the readability and overall flow of this users' guide.



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# Introduction

## What Is Risk?

Risks are events or occurrences that prevent a program from achieving its cost, schedule, or performance objectives.

## What Is Risk Matrix?

Risk Matrix is a software application that can be used to capture identified risks, estimate their probability of occurrence and impact, and rank the risks based on this information. Risk Matrix also provides a capability for documenting how these risks will be handled (action plans) and tracking the effect of this action on associated risks.

Risk Matrix was developed by the MITRE Corporation in Microsoft Excel using Visual Basic code. It supports a risk assessment process created by the Electronic Systems Center (ESC) a few years ago.<sup>1</sup> This structured process was created to help programs identify, prioritize, and manage key risks associated with meeting program objectives. Since then, MITRE has helped ESC expand and improve the original process, creating what's known as the *Baseline Risk Assessment Process*.<sup>2</sup>

The primary difference between Risk Matrix version 2.2 and version 2.1 lies in the probability used for ranking risks in the Advanced Mode. This probability is now taken to be the Probability of Occurrence times the Probability of Action Plan Failure, whereas previously it was one or the other of these two probabilities. In Basic mode, there is no change. In addition, the new version allows the user to enter more than 256 characters in a cell of text and corrects a rare bug that affected the scale of one of the charts (when no risks were ranked as Critical).

Chapter 2 contains a summary of the *Baseline Risk Assessment Process*. The remainder of this guide describes how to use Risk Matrix, version 2.2. Although the process and application were developed for use at ESC, the basic principles can be applied to any project that needs to manage risks.

## About This Guide

The information in this guide replaces all previous versions. Menu names are in **Bold**. Commands are in "*Italics*" surrounded by quotation marks.

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<sup>1</sup> Garvey, P. R., and Z. F. Lansdowne, 1998, "Risk Matrix: An Approach for Identifying, Assessing, and Ranking Program Risks," *Air Force Journal of Logistics*, Vol. 22, No. 1.

<sup>2</sup> Willhite, Anne Marie, November 1998, *Establishing A Program Risk Baseline*, an annotated briefing, The MITRE Corporation, Bedford, MA.



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## Baseline Risk Assessment Process

A good risk assessment and management process is essential to the success of any program. The process summarized here consists of

- Planning for Risk Assessment
- Identifying Program Objectives or Requirements
- Defining Program Risks
- Ranking Program Risks
- Managing Program Risks
- Managing Action Plans
- Continuously Assessing Program Risks.

More details about the process are described in the annotated briefing, *Establishing A Program Risk Baseline*.<sup>3</sup>

### Planning for Risk Assessment

The first stage of a risk assessment is to plan the activity. A program manager may begin this process by selecting the risk assessment team, setting forth ground rules, and determining the supporting risk management tools, such as the Risk Matrix application described in this users' guide. The risk assessment team should include representatives from all areas of the program, not just technical experts. In addition, a facilitator and recorder should be selected to assist the team.

The Risk Matrix application can be used at any time. We recommend you begin using it as soon as you begin defining risks during the baseline risk assessment.

### Identifying Program Objectives or Requirements

Once the Program Manager identifies the risk assessment team and tools, the team identifies the key program objectives or requirements. The program objectives and requirements should assist the team in identifying risks.

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<sup>3</sup> Willhite, Anne Marie, November 1998, *Establishing A Program Risk Baseline*, an annotated briefing, The MITRE Corporation, Bedford, MA.

## Defining Program Risks

A team facilitator leads the team through a structured brainstorming process to identify the program risks.<sup>4</sup> For example, each team member individually writes down risk ideas. Next, the facilitator asks each person to present one idea in sequence or pass in a rotation until all candidate risks are offered. Once all ideas are heard, an affinity diagram is created to group, merge, and eliminate duplicate risks, and to identify dependent risks. An affinity diagram is "...a technique for organizing verbal information into a visual pattern."<sup>5</sup> The facilitator has the team silently arrange candidate risks into related groups of one or more risks. Through this process, risks may be merged if similar or dependent, and eliminated if the same.

Next, the team agrees on category titles for each group. Collaboratively the team identifies complete risk statements for each risk on the affinity diagram. A suggested format for a complete risk statement may be in the form of "If a *risk condition*, then *the consequences*." The recorder documents each complete risk. These can be entered in the Risk Entries worksheet of Risk Matrix.

Following the identification of the risks, the team assigns various attributes to each risk. At a minimum, relevant time frame, impact, and probability of occurrence are assigned. Time frame is the beginning and end dates of when a risk may occur. Then the team sets impact definitions. The Risk Matrix impact definitions are:

- **C (Critical):** If the risk event occurs, the program will fail. Minimum acceptable requirements will not be met.
- **S (Serious):** If the risk event occurs, the program will encounter major cost/schedule increases. Minimum acceptable requirements will be met. Secondary requirements may not be met.
- **Mo (Moderate):** If the risk event occurs, the program will encounter moderate cost/schedule increases. Minimum acceptable requirements will be met. Some secondary requirements may not be met.
- **Mi (Minor):** If the risk event occurs, the program will encounter small cost/schedule increases. Minimum acceptable requirements will be met. Most secondary requirements will be met.
- **N (Negligible):** If the risk event occurs, it will have no effect on the program. All requirements will be met.

Probability of occurrence is the team's assessment of the likelihood of a risk happening. Estimating the probability of occurrence may be difficult in practice. Fortunately, all that matters when using Risk Matrix is the relative order of the probability estimates (which risks are more likely to occur). For this purpose, it is sufficient to estimate probabilities using a relative scale:

- **0-10%:** very unlikely the risk will occur
- **11-40%:** unlikely the risk will occur

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<sup>4</sup> AFMC, 1991, "The ESC Process Improvement Guide," Electronic Systems Center, Hanscom AFB, MA, page 6.

<sup>5</sup> AFMC, 1991, "The ESC Process Improvement Guide," Electronic Systems Center, Hanscom AFB, MA, p. 30.

- **41-60%:** even likelihood the risk will occur
- **61-90%:** likely the risk will occur
- **91-100%:** very likely the risk will occur.

This approach may be used to translate subjective probability estimates into numbers in the absence of hard data. However, if hard data is available for some risks, the other probability estimates must be chosen to be consistent with the hard data.

## Ranking Program Risks

At this point, the team has all the information needed to rank the risks. If using the Risk Matrix tool, this process is simple and automated. Risk rankings are calculated using the Borda voting method.<sup>6</sup> The Borda method *ranks* risks from most-to-least critical on the basis of multiple evaluation criteria. Appendix A provides more details about the Borda method.

If the team chooses not to use an automated tool, an alternative is to use a multi-voting technique.<sup>7</sup> With this method, each team member receives votes equal to approximately half the number of risks. Team members vote individually for items with perceived highest priority. The votes are tallied and the top risks are selected and ranked accordingly.

## Managing Program Risks

All risks need some form of management, whether it involves a plan for handling risks (action plan) or merely keeping watch.

After the risks are ranked, the team should identify the risks that are high priority, need to be managed, and require resources (identify the top *N* risks). The team should meet with the program manager to discuss the results and achieve agreement on the top *N* risks to be tracked and actively worked.

Decisions for handling the top *N* risks will vary. Some risks will be eliminated because the requirements changed; others will be transferred to other organizations (like a contractor) for action because the program team does not have the proper resources to handle the risks or because it's more appropriate for the other organization to handle them; and others will require mitigation strategies. The remaining risks (the ones not in the top *N*) should be watched.

NOTE: For the baseline assessment, teams are not required to create action plans for the top *N* risks, though they are strongly encouraged to do so. A brief summary of the action plans for each risk can be entered in the Manage/Mitigate column in the Basic Mode of Risk Matrix. Details about the action plans can be entered in the Action Plan worksheet in the Advanced Mode of Risk Matrix.

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<sup>6</sup> Borda, J-C, "Mémoire sur les Élections au Scrutin," *Histoire de l'Académie Royale des Sciences*, Paris, 1781.

<sup>7</sup> Willhite, Anne Marie, November 1998, *Establishing A Program Risk Baseline*, an annotated briefing, The MITRE Corporation, Bedford, MA.

## Managing Action Plans

Whenever feasible (usually after an initial Baseline Assessment), the program team should develop detailed action plans and enter an initial status, assign the Office of Primary Responsibility (OPR), and determine exit criteria for the top  $N$  risks. The status of each action plan should be reviewed and assessed periodically (approximately each week or month if possible), and the risks rankings adjusted accordingly.

The Risk Matrix tool provides an Action Plan worksheet in the Advanced Mode for tracking risk action plans and adjusting the risk rankings based on the action plan status.

## Continuously Assessing Risks

Continuously assessing risks is essential to good program risk management. As a program progresses, risks should be reassessed periodically (perhaps monthly or quarterly) to determine whether their level of importance has changed or whether new risks have developed that should be identified, assessed, ranked, and managed.

The Advanced Mode of Risk Matrix supports the continuous assessment process.

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## Getting Started

Risk Matrix 2.2 is available from The MITRE Corporation. To register for a copy, fill out the form on the MITRE web site at:

[http://www.mitre.org/resources/centers/sepo/risk/registration\\_form.html](http://www.mitre.org/resources/centers/sepo/risk/registration_form.html)

Or, you can send e-mail with your full name, your company name, telephone number, and e-mail address to [riskmatrix@mitre.org](mailto:riskmatrix@mitre.org).

## Customer Support

The information you provide when you register will allow us to notify you of updates and improvements in the tool.

If you need assistance with the basic operation of the Risk Matrix tool or the voting or computational theory behind it, send e-mail to [riskmatrix@mitre.org](mailto:riskmatrix@mitre.org). Or, you can fill out the Problem and Enhancement Form at:

[http://www.mitre.org/resources/centers/sepo/risk/problem\\_form.html](http://www.mitre.org/resources/centers/sepo/risk/problem_form.html).

For assistance with Microsoft Excel, contact Microsoft or visit their web site at <http://www.microsoft.com/>.

## System Requirements

Risk Matrix 2.2 was developed in Microsoft Excel 97 using Visual Basic code. It is compatible with Windows PC platforms and has the same system requirements as Microsoft Excel.

- IBM-compatible machine with an 80486 processor or higher
- 3.5-inch floppy disk drive
- 20 MB of available hard disk space
- Graphics display compatible with Microsoft Windows 95 or later, such as VGA
- 8 MB of memory (16 MB recommended)
- Mouse or compatible pointing device (recommended)
- Microsoft Excel 97

## Year 2000 Compliance

In Risk Matrix 2.2 the risk assessment calculations do not depend on dates or times. Nor are timers used in the program. As an option, you can enter dates corresponding to the start and end of the period when each risk will be an issue. These dates do not affect the risk assessment calculations. Four digit years are used for these entries. Therefore Risk Matrix 2.2 is Year 2000 compliant to the extent that Microsoft Excel is compliant. Microsoft Excel compliance information can be found on Microsoft's Year 2000 web site, located at <http://www.microsoft.com/technet/year2k/>.

NOTE: A product indicated as "Compliant" fully meets Microsoft's standard of compliance. Compliant products may have a prerequisite patch or service pack for full compliance. A product indicated as "Compliant with minor issues" meets Microsoft's standard of compliance with some disclosed exceptions that constitute minor date issues.

As of this publication, the following Y2K compliance information has been verified for the Windows PC Platform:

Microsoft Excel 97 8.0 (English) 32-bit Win – Compliant

[http://www.microsoft.com/technet/year2k/product/User\\_View68320EN.htm](http://www.microsoft.com/technet/year2k/product/User_View68320EN.htm)

Microsoft Excel 95 7.0 (English) 32-bit Win – Compliant with minor issues

[http://www.microsoft.com/technet/year2k/product/User\\_View68271EN.htm](http://www.microsoft.com/technet/year2k/product/User_View68271EN.htm)

## How to Launch Risk Matrix

- 1) To launch risk matrix, double-click on a risk matrix file (**Risk Matrix filename.xls**) or launch Microsoft Excel:
  - From the **File** menu, select the "Open..." command.
  - In the **Open** Dialog Box, navigate to where **Risk Matrix filename.xls** is located.
  - Select **Risk Matrix filename.xls**, and click the **Open** button.
- 2) Most users will receive the following message:

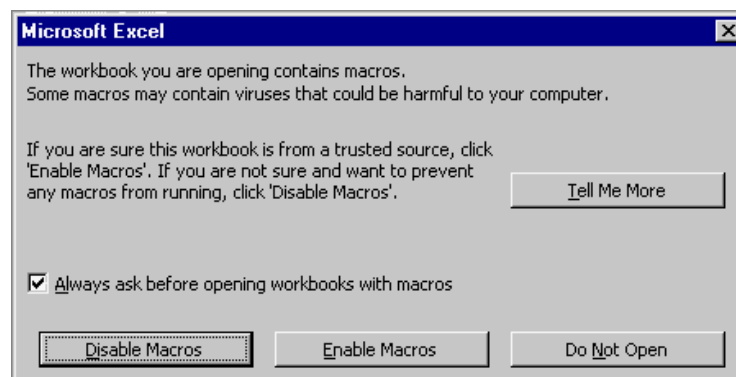


Figure 1. Excel Macros Warning



- 3) Risk Matrix requires Excel macros to operate correctly. Click the **Enable Macros** button.

**WARNING:**

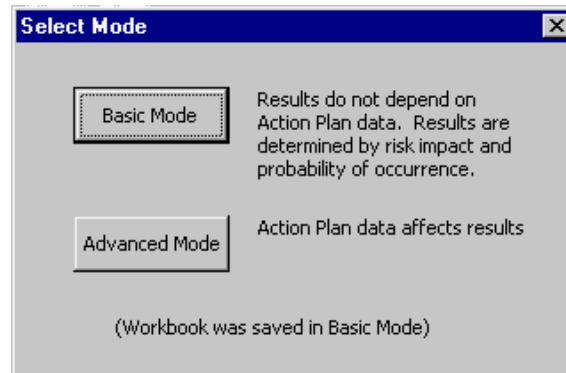
The Enable/Disable Macros dialog box will appear each time you open Risk Matrix. If you are only using Excel for Risk Matrix, you may decide to choose to unclick the box labeled "Always ask before opening workbooks with macros", which would not enforce protection each time Excel opens a document. However, be aware that this action could leave your computer vulnerable to Excel-based macro viruses if you routinely open Excel documents with macros from email or unprotected sources. It is recommended that if you choose this feature, you have an alternative and current form of virus protection installed on your computer.

- 4) The application will display the "Welcome to Risk Matrix" window:



**Figure 2. Welcome To Risk Matrix Window**

- 5) Click the **Dismiss** button to start using the tool. The application will display the "Select Mode" window.
- 6) Select the mode of operation: Basic or Advanced. For more information, see *Modes of Operation* later in this chapter.



**Figure 3. Mode Selection Window**

## How to Upgrade Your Files from Risk Matrix 2.02 or 2.1

If you are a previous user of Risk Matrix 2.02 who wants to use this release for your existing work, you will have to paste your data from the old workbook into a copy of the new one. Since the Risk Entries sheet has three new columns, the following procedure is recommended:

- 1) Make a copy of the Risk Matrix 2.2 (.xls) file. This will become the new workbook.
- 2) Open the old workbook and insert three new columns into the Risk Entries sheet of the old workbook. The reason you add columns is because the new version has additional columns. When you copy and paste columns in Excel, the selected areas have to match. To insert a column:
  - Highlight the IPT column and insert one column between "Risk No." and "IPT". The new column will become the "Related Risk" column. (Go to the **Insert** menu and select the "Columns" command.)
  - Highlight the Event Type column and insert two columns between "Risk" and "Event Type". These columns will become "Time Frame Start" and "Time Frame End". (Select "Columns" command twice).
- 3) Select all the data in the Risk Entries sheet of the old workbook. (Do not include the column headers.) From the **Edit** menu, select "Copy."
- 4) Open the workbook you created in Step 1. Select the Advanced Mode and "Show All" command from the **Optional Columns Menu**.
- 5) On the Risk Entries sheet, select a region that is the same size as the region just copied (starting in cell A2). From the **Edit** menu, select "Paste Special." On the dialog box that appears, select "Values" and "None". Click "Okay".
- 6) Use a similar approach to paste the Action Plan data into the new workbook. (No new columns are required):

- Select all the data in the Action Plan sheet of the old workbook. . (Do not include the column headers.) From the **Edit** menu, select "Copy."
  - Open the new workbook. On the Action Plan sheet, select a region that is the same size as the region just copied (starting in cell A2). From the **Edit** menu, select "Paste Special." On the dialog box that appears, select *Values* and *None*. Click Okay.
- 7) Save the new worksheet. To avoid macro confusion between the two versions of Risk Matrix, close all Excel applications and workbooks. Then, reopen the new Risk Matrix file to continue working.

Next, consider the case of upgrading from Risk Matrix 2.1. All columns in the Risk Entries sheet for Risk Matrix 2.1 already match those for Risk Matrix 2.2, and so it is not necessary to perform step 2 in the foregoing procedure, although it is necessary to perform the other steps.

## Worksheets

The Risk Matrix tool has two worksheets for entering and manipulating data: Risk Entries and Action Plan. The Risk Entries worksheet is the primary workspace for a risk assessment; risks are entered, assessed, and tracked in this workspace. The Action Plan worksheet is the secondary workspace of Risk Matrix. This is where action plans are defined, assessed, and linked to the risks identified in the Risk Entries worksheet. The requirements for entering data depend on the mode of operation you choose.

## Modes of Operation

The Risk Matrix tool offers a Basic and Advanced Mode of operation. Upon opening Risk Matrix, you can choose Basic or Advanced modes. Risk Matrix also offers an If-Then Mode option for Basic and Advanced modes for the construction of risk statements. It is accessible from the **Risk Entries** pull down menu.

### Basic Mode

The Basic Mode ranks risks based on data defined by the user and entered in the Risk Entries worksheet. Ranking results are a function of risk impact and probability of occurrence. Details about the Basic Mode of operation are in Chapter 4.

### Advanced Mode

The Advanced Mode of the Risk Matrix tool contains an Action Plan worksheet and a Risk Entries worksheet. In this mode you can record and track the status of multiple action plans for each risk. Risk Matrix factors this information into the Risk Entries worksheet and associates it with the appropriate risk entry. Details about the Advanced Mode of operation are in Chapter 5.

## Menus

All pull-down menus that Excel supports are available for data manipulation. You can use the Excel standard menus for basic edit functions. (This guide does not contain information on Microsoft Excel features; for those details, see your Excel User's Guide.)

Details about Risk Matrix pull down menus are provided in each chapter. The About Risk Matrix menu offers additional information and is accessible from the Risk Entries and Action Plan worksheets as shown in Figures 4 and 5.



**Figure 4. About-Risk-Matrix Menu in Basic Mode**



**Figure 5. About-Risk-Matrix Menu in Advanced Mode**

## Risk Matrix: Basic Mode

The Basic Mode ranks risks from data defined by the user and entered in the Risk Entries worksheet. The results are a function of risk impact and probability of occurrence and do not depend upon action plan data.

Risk rankings are calculated using the Borda voting method.<sup>8</sup> The Borda method *ranks* risks from most-to-least critical on the basis of multiple evaluation criteria. Appendix A provides more details about the Borda method.

This chapter describes how to use the Risk Matrix tool in Basic Mode and how to enter data in the Risk Entries worksheet.

### Selecting Basic Mode

To begin a session in Basic Mode, open Risk Matrix and select the Basic Mode of operation at the user prompt. (See Getting Started.) You can change from Basic Mode to Advanced Mode at any time by selecting the “Go to Advanced Mode” command under the **Risk Entries** menu as shown in Figure 6. If you change from Basic to Advanced Mode, you’ll see a warning that the Action Plan worksheet will be considered when calculating Borda Rank as shown in Figure 7.

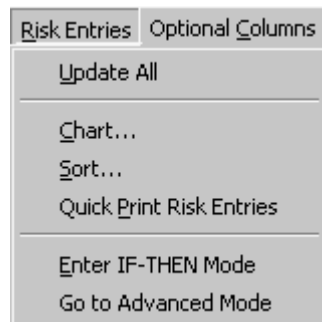


Figure 6. Risk Entries Pull-Down Menu

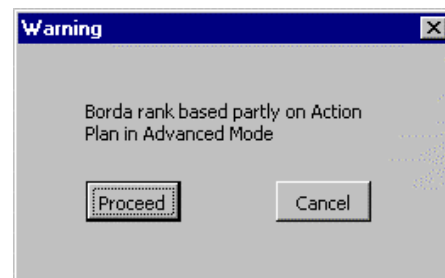


Figure 7. Go to Advanced Mode Warning Message

<sup>8</sup> Borda, J-C, “Mémoire sur les Élections au Scrutin,” *Histoire de l’Académie Royale des Sciences*, Paris, 1781.

# Risk Entries Worksheet

The Risk Entries worksheet is the primary workspace for entering, assessing, and tracking risks. Figure 8 shows an example of the default columns in Risk Entries worksheet in Basic Mode.

	A	B	F	G	H	J	K	O	P	U
	Risk No.	Related Risk	RISK	Timeframe Start	Timeframe End	I	Po (%)	Borda Rank	R	Manage/Mitigate
1	1	4	IF contract is not awarded before 30 Sep, THEN program loses \$8M in expiring funds.	30 Jan 1999	30 Sep 1999	C	60%	0	H	Use existing Task Order contract to assure award before 30 Sep.
2	2	N/A	IF unmodified commercial laptops are used, THEN operational availability cannot be met in intended environment.	28 Feb 1999	28 Feb 2000	S	100%	0	H	Limit buy for first release and plan technology insertion for improved environmental performance for second release.
3	3	4	IF DII COE V1.5 is more than 1 mo. late, THEN first release will slip day for day.	30 Jan 1999	30 Oct 1999	S	90%	3	M	Use DII COE V1.4 for first release and modify requirements.
4	4	1,3	IF first release is not demonstrated in EFX, THEN program will be assigned to Navy.	15 Feb 1999	15 Apr 2000	C	60%	0	H	Integrate only those capabilities available at contract award for first release.
5	5	1	IF all KPPs must be satisfied by second release, THEN program funding is insufficient.	30 Jan 1999	30 Jul 2001	S	40%	4	M	Use CAIV to prioritize release content subject to budget and plan for third and fourth release.
6										

**Figure 8. Risk Entries Worksheet in Basic Mode Showing Default Columns**

Each column heading has helpful hint comments associated with it. To view a comment, point the mouse to the red triangle in the upper right hand corner of the column-heading cell.

Each row in the Risk Entries worksheet represents a risk “entry”. Each “entry” consists of mandatory and optional cells for your inputs and tool-generated outputs. The mandatory input is required to generate valid output data. Optional input data can be used to further describe the risks that the program team wants to follow.

- Mandatory input cells are shaded in green: Risk Number (No.), Risk, Impact (I), and Probability of Occurrence (Po).
- Optional input cells shown by default in the worksheet are Related Risk Number, Timeframe Start, Timeframe End, and Manage/Mitigate.
- Tool-generated outputs are shaded in yellow. The outputs shown by default are Borda Rank and R.

To generate or update output results in Basic Mode, select the “Update All” command under the **Risk Entries** menu as shown in Figure 6.

Figure 9 shows an example of the Risk Entries worksheet in Basic Mode with all columns visible.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	U
1	Risk No.	Related Risk	IPT	Requirement (Threshold)	Technology Available	RISK	Timeframe Start	Timeframe End	Event Type	I	Po (%)	I Rank	Po Rank	Borda Count	Borda Rank	R	Manage/Mitigate
1	1	4	Contract Team	Award Contract before end of this fiscal year		IF contract is not awarded before 30 Sep, THEN program loses \$8M in expiring funds.	30 Jan 1999	30 Sep 1999	C	C	60%	1.50	3.50	5.00	0	H	Use existing Task Order contract to assure award before 30 Sep.
2	2	N/A	IT Eval Team	Use commercial laptop processors	Intel Pentium, II, III Processors. Dell, IBM, Compaq Laptops	IF unmodified commercial laptops are used, THEN operational availability cannot be met in intended environment.	28 Feb 1999	28 Feb 2000	S	S	100%	4.00	1.00	5.00	0	H	Limit buy for first release and plan technology insertion for improved environmental performance for second release.
3	3	4		Use COP in DII COE Release 1.5	Common Operational Picture (SW App)	IF DII COE V1.5 is more than 1 mo. late, THEN first release will slip day for day.	30 Jan 1999	30 Oct 1999	P, S	S	90%	4.00	2.00	4.00	3	M	Use DII COE V1.4 for first release and modify requirements.
4	4	1,3		Include first release in next year's EFX baseline		IF first release is not demonstrated in EFX, THEN program will be assigned to Navy.	15 Feb 1999	15 Apr 2000	S	C	60%	1.50	3.50	5.00	0	H	Integrate only those capabilities available at contract award for first release.
5	5	1		Deliver all KPPs in first or second version and keep within 6 year		IF all KPPs must be satisfied by second release, THEN program funding is insufficient.	30 Jan 1999	30 Jul 2001	C	S	40%	4.00	5.00	1.00	4	M	Use CAIV to prioritize release content subject to budget and plan for third and fourth release.

**Figure 9. Risk Entries Worksheet in Basic Mode Showing All Columns**

- Additional optional input cells hidden by default in the worksheet are Integrated Product team (IPT), Requirement, Technology Available, and Event Type.
- Tool-generated outputs hidden by default are I Rank, Po Rank, and Borda Count.

To view all hidden columns, select the "Show All" command on the **Optional Columns** menu. Similarly, the "Hide All" command hides all of the optional columns. To view or hide a particular column, toggle the "Show/Hide" commands under the **Optional Columns** menu. To return to the columns shown by default, select the "Show Defaults" command under the **Optional Columns** menu.

Chapter 7 contains a list of limitations and warnings about data entry and deletions. Appendix C contains a Risk Entries reference sheet that identifies worksheet columns, definitions, formats, and types.

## Risk Entries Column Definitions

This section describes what should appear in each column of the Risk Entries worksheet.

### Mandatory Input Columns

The following columns contain mandatory input cells. To generate valid ranking results, these cells must be populated.

- **Risk No:** A unique positive integer used to identify a risk. This number is used to cross reference entries between worksheets. The format is a positive integer (1-N).
- **Risk:** A text description of a risk that may prevent a program from achieving its cost, schedule, or performance objectives. The format is text.

The "If-Then" mode is recommended for entering risk statements. Selecting this mode of operation forces you to enter all risk statements in an "If-Then" format in the Risk column. To use the If-Then Mode, select the "If-Then Mode" command in the **Risk Entries** pull-down menu. (See Figure 6.)

- **I:** An assessment of the impact a risk consequence may have on an overall program. The format is text and is limited to C, S, Mo, Mi, or N. The definitions of these categories can be specific to each program. Default definitions are:
  - **C (Critical):** If the risk event occurs, the program will fail. Minimum acceptable requirements will not be met.
  - **S (Serious):** If the risk event occurs, the program will encounter major cost/schedule increases. Minimum acceptable requirements will be met. Most secondary requirements may not be met.
  - **Mo (Moderate):** If the risk event occurs, the program will encounter moderate cost/schedule increases. Minimum acceptable requirements will be met. Some secondary requirements may not be met.
  - **Mi (Minor):** If the risk event occurs, the program will encounter small cost/schedule increases. Minimum acceptable requirements will be met. Most secondary requirements will be met.
  - **N (Negligible):** If the risk event occurs, it will have no effect on the program. All requirements will be met.
  
- **Po (%):** Probability of occurrence is the team's assessment of the likelihood that a risk may happen. Estimating the probability of occurrence may be difficult in practice. Fortunately, all that matters when using Risk Matrix is the relative order of the probability estimates (which risks are more likely to occur). For this purpose, it is sufficient to estimate probabilities using a relative scale:
  - **0-10%:** very unlikely the risk will occur
  - **11-40%:** unlikely the risk will occur
  - **41-60%:** even likelihood the risk will occur
  - **61-90%:** likely the risk will occur
  - **91-100%:** very likely the risk will occur

This approach may be used to translate subjective probability estimates into numbers in the absence of hard data. However, if hard data is available for some risks, the other probability estimates must be chosen to be consistent with the hard data.

### Optional Input Columns

The following columns contain optional input cells. You are not required to populate these cells, however, this information can further describe the risks that should be followed. Related Risk Number, Timeframe Start, Timeframe End, and Manage/Mitigate columns appear on the default Risk Entries worksheet. IPT, Requirement, Technology Available, and Event Type columns can be viewed by using a command from the **Optional Column** menu.

- **Related Risk Number:** Risk numbers whose occurrence affects or is affected by the risk entry. The format is a list of integers separated by commas.



- **Timeframe Start:** The earliest date or estimated date when the risk is likely to occur. The format is day-month-year (for example, 12 Jun 2006).
- **Timeframe End:** The latest date or estimated date when the risk is likely to occur. The format is day-month-year (for example, 20 Dec 2008).
- **Manage/Mitigate:** A strategy to manage or mitigate the risk entry. The format is text.
- **IPT:** An Integrated Product Team (IPT) is typically the name of the group associated with the risk entry. This cell could identify a point of contact as an alternative. The format is text.
- **Requirement (Threshold):** A list of cost, schedule, or performance requirements that are associated with the risk entry. The format is text.
- **Technology Available:** A list of available technologies that help meet each requirement. The format is text.
- **Event Type:** A user-defined attribute to classify an entry. For example, event type may be "C" for cost, "S" for schedule, or "P" for performance. They could also be user-defined categories (for example, from an affinity grouping). The format is text.

#### Output Columns Shown By Default

The following columns contain the output cells that the Risk Matrix tool generates and shows by default. These cells are populated after all the mandatory cells in the Risk Entries worksheet are populated and "Update All" command is selected from the **Risk Entries** pull-down menu. (See Figure 6.)

- **Borda Rank:** Represents the number of other risks in the risk matrix that are more critical. For example, a Borda rank of 0 represents the most critical risk and a Borda rank of 1 indicates that one other risk is more critical. The format is integer (0-N). See Appendix A for details about the Borda method.
- **R:** Represents a rating of high, medium, or low risk as mapped to the I and Po pair in Table 1. The format is "H" for high, "M" for medium, or "L" for low risk. The Risk Rating Scale is based on a table developed at ESC and the results may be inconsistent with the results from the Borda ranking method. The Borda ranking method is more precise and should serve as the primary value for ranking.

**Table 1. Risk Rating Scale<sup>9</sup>**

<b>Po</b>	<b>Impact Category</b>				
	<i>Negligible</i>	<i>Minor</i>	<i>Moderate</i>	<i>Serious</i>	<i>Critical</i>
<i>0-10%</i>	Low	Low	Low	Medium	Medium
<i>11-40%</i>	Low	Low	Medium	Medium	High
<i>41-60%</i>	Low	Medium	Medium	Medium	High
<i>61-90%</i>	Medium	Medium	Medium	Medium	High
<i>91-100%</i>	Medium	High	High	High	High

Output Columns Hidden by Default

In addition to the shown output columns, you can view the Borda Calculation Details by toggling the “*Show/Hide Borda Calculation Details*” command from the **Optional Columns** menu. Borda Calculation Details are helpful if you want to understand how the Borda method is applied to a problem.

The following columns are the Borda Calculation Details. These cells are calculated after all the mandatory input cells in the Risk Entries worksheet are populated, and the “*Update All*” command is selected from the **Risk Entries** pull-down menu. (See Figure 6.)

- **I Rank:** Calculated rank position for impact. If there are no ties, then the risk with the most critical impact has an I Rank of 1. The risk with the second most critical impact has an I Rank of 2, and so forth. Appendix A discusses how these ranks are adjusted when there are ties. The format is a real number.
- **Po Rank:** Calculated rank position for probability of occurrence. If there are no ties, then the risk with the highest probability occurrence has a Po Rank of 1. The risk with the second highest probability occurrence has a Po Rank of 2, and so forth. The format is a real number.
- **Borda Count:** Calculated total points based on Borda voting method. The Borda Count for a risk is found by adding I rank and Po rank, then subtracting the result from twice the total number of tasks. (Appendix A contains the explicit formula.) The risk with the highest Borda Count is the most critical risk with respect to impact and probability criteria. Similarly, the risk with the second highest Borda Count is the second most critical risk. The format is a real number.

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<sup>9</sup> Franklin, C. E., Lt. Gen (USAF) Commander ESC, January 1996, Memorandum for ESC Program Managers, ESC/CC, Risk Management, Department of the Air Force, Headquarters ESC (AFMC) Hanscom Air Force Base, MA.

## Risk Matrix: Advanced Mode

The Advanced Mode of the Risk Matrix tool contains a Risk Entries worksheet and an Action Plan worksheet. In this mode you can record and track the status of multiple action plans for each risk. Risk Matrix factors this information into the Risk Entries worksheet and associates it with the appropriate risk entry.

### Selecting Advanced Mode

You can begin a session in Advanced Mode or convert a file to Advanced Mode.

- To begin a session in Advanced Mode, open Risk Matrix and select the Advanced Mode of operation at the user prompt.
- To convert a file from Basic Mode to Advanced Mode, select the “Go to Advanced Mode” command under the **Risk Entries** menu. (See Figure 6.) When you switch from Basic to Advanced Mode, a warning will prompt: “Borda Rank partly based upon Action Plan in Advanced Mode”. Click “Proceed”.

To change from Advanced Mode to Basic Mode at any time, select the “Go to Basic Mode” command under the **Action** menu on the Action Plan worksheet as shown in Figure 10.

toggling to Basic Mode will not clear entries in the action plan worksheet; however, it will update the Borda results to **not** be dependent upon Action Plan data. When you switch to Basic Mode you’ll see a warning message as shown in Figure 11. Click “Proceed”.

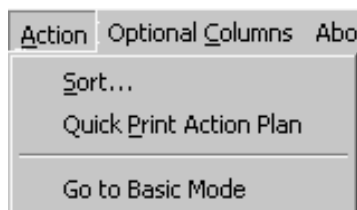


Figure 10. Action Plan Menu

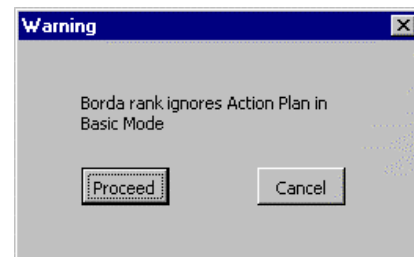


Figure 11. Go to Basic Mode Warning Message

## Worksheets

Advanced Mode contains Action Plan and Risk Entries worksheets. Chapter 7 contains a list of limitations and warnings about data entry and deletions. Appendix C contains Risk Entries and Action Plan reference sheets that identify worksheet columns, definitions, formats, and types.

## Action Plan Worksheet

The Action Plan worksheet is the secondary workspace of Risk Matrix. Figure 12 shows an Action Plan worksheet with sample data. On this worksheet, details about action plans are entered and linked to the risks depicted in the Risk Entries worksheet.

	A	B	C	D	E	F
1	Risk No.	Task	OPR	Exit Criteria	Assessment	Discussion
2	3	Obtain concurrence from user that 1.4 is OK for release if 1.5 is not ready	Smith, P.		Blue	To be completed before RFP release, 1 Sep
3	3	Monitor version 1.5	Todd, A.	1.5 release	Yellow	Determine if release slippage is likely
4	3	Obtain version 1.4 for contractor	Smith, P.		Yellow	
5	3	Identify requirements delta between 1.4 and 1.5	Todd, A.		Green	
6	3	Modify requirements for 1st delivery GFG	Michaels, R.		Green	
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						

**Figure 12. Action Plan Worksheet in Advanced Mode**

Each row in the Action Plan worksheet represents a separate entry. More than one entry can be associated with a risk as shown in Figure 12. Each entry consists of mandatory and optional input cells.

- Mandatory input cells are shaded in green: Risk Number, Task, and Assessment.
- Optional input cells are OPR, Exit Criteria, and Discussion.

## Risk Entries Worksheet in Advanced Mode

On the Risk Entries worksheet, mandatory and optional inputs are the same in Basic and Advanced modes. Chapter 4 provides details about entering data on the Risk Entries worksheet.

The Risk Entries outputs are shaded in yellow.

- Outputs shown by default are the same in Advanced Mode as in Basic Mode (i.e., Borda Rank and R). The difference is in the method of calculating the results. In Advanced Mode, action plan assessment data is used in the calculations; in Basic Mode, this data is not used.

- Similar to Basic Mode, the Risk Entries worksheet in Advanced Mode has output columns hidden by default: the Borda Calculation Details (I Rank, Ponm Rank, Borda Count, and Ponm %) and Action Plan Summary (Total Tasks, Worst Task Color, and Papf %). Figure 13 shows all the Risk Entries columns in Advanced Mode.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
Risk No.	Related Risk No.	IPT	Requirement (Threshold)	Technology Available	RISK	Timeframe Start	Timeframe End	Event Type	Po (%)	I Rank	Ponm Rank	Borda Count	Borda Rank	Total Tasks	Worst Task Color	Papf (%)	Ponm (%)	Manage	Mitigate	
1	4	Contract Team	Award Contract before end of this fiscal year		IF contract is not awarded before 30 Sep, THEN program loses \$5M in expiring funds.	30 Jan 1999	30 Sep 1999	C	60%	1.50	3.50	5.00	0	H				60%	Use existing Task Order contract to assure award before 30 Sep.	
2	N/A	IT Eval Team	Use commercial laptop processors	Intel Pentium, II, III Processors, Dell, IBM, Compaq Laptops	IF unmodified commercial laptops are used, THEN operational availability cannot be met in intended environment.	28 Feb 1999	28 Feb 2000	S	100%	4.00	1.00	5.00	0	H				100%	Limit buy for first release and plan technology insertion for improved environmental performance for second release.	
3	4		Use COP in DII COE Release 1.5	Common Operational Picture (SW App)	IF DII COE V1.5 is more than 1 mo. late, THEN first release will slip day for day.	30 Jan 1999	30 Oct 1999	P, S	90%	4.00	2.00	4.00	3	M	5	Yellow	80%	72%	Use DII COE V1.4 for first release and modify requirements.	
4	1,3		Include first release in next year's EFX baseline		IF first release is not demonstrated in EFX, THEN program will be assigned to Navy.	15 Feb 1999	15 Apr 2000	S	60%	1.50	3.50	5.00	0	H				60%	Integrate only those capabilities available at contract award for first release.	
5	1		Deliver all KPPs in first or second version and keep within 6 year budget profile		IF all KPPs must be satisfied by second release, THEN program funding is insufficient.	30 Jan 1999	30 Jul 2001	C	40%	4.00	5.00	1.00	4	M				40%	Use CAIV to prioritize release content subject to budget and plan for third and fourth release.	

Figure 13. Risk Entries Worksheet in Advanced Mode Showing All Columns

To generate or update output results in Advanced Mode, select the “Update All” command under the **Risk Entries** menu. (See Figure 6.)

To view all columns, select the “Show All” command on the **Optional Columns** menu. Similarly, the “Hide All” command hides all of the optional columns. To view or hide a particular column, toggle the “Show/Hide” commands under the **Optional Columns** menu. To return to the columns shown by default, select the “Show Defaults” command under the **Optional Columns** menu

## Action Plan Column Definitions

This section describes what should appear in each column of the Action Plan worksheet in Advanced Mode.

Each column heading has helpful hint comments associated with it. To view a comment, point the mouse to the red triangle in the upper right hand corner of the column-heading cell.

### Mandatory Input Columns

The following columns contain mandatory input cells. The Risk Matrix tool requires these cells to be populated to generate valid results in Advanced Mode.

NOTE: Not every risk entry needs to have an action plan entry associated with it for the tool to properly operate. If no action plans are entered, the tool will calculate results as if it were in Basic Mode.

- Risk No:** The referenced risk number in the Risk Entries worksheet that the risk-mitigation entry supports. The format is a positive integer (i.e., 1-N).
- Task:** A description of the action plan activity. The format is text.

- **Assessment:** Assessment status colors are predefined as:
  - **Blue:** Task has been completed.
  - **Green:** Task is on target for cost and schedule.
  - **Yellow:** Task is at risk for meeting cost or schedule.
  - **Red:** Task is non-executable.

The format is limited text: Blue, Green, Yellow, or Red. Appendix B provides a complete discussion of the reliability theory associated with the translation of the Assessment values into the probability that the implementation of associated action plan task will fail.

### Optional Input Columns

The following columns contain optional input cells. You are not required to populate these cells. However, this data can be useful in further describing the risks that should be followed.

- **OPR:** The Office of Primary Responsibility (OPR) is the organization or person responsible for executing/managing the task. The format is text.
- **Exit Criteria:** Exit criteria states the requirements for successful completion of the task. The format is text.
- **Discussion:** Discussion contains status notes, interim actions, point of contacts, etc. The format is text.

To hide all optional columns, select the *“Hide All”* command under the **Optional Columns** menu. To view all columns, select the *“Show All”* command in the **Optional Columns** menu. To view or hide a particular column, toggle the *“Show/Hide”* commands under the **Optional Columns** menu.

## Risk Entries Output Column Definitions

This section describes the Risk Entries output columns in Advanced Mode.

### Output Columns Shown by Default

The following columns contain the output cells that the Risk Matrix tool generates and shows by default in Advanced Mode. These cells are populated after all of the mandatory input cells in the Risk Entries and Action Plan worksheets are populated and the *“Update All”* command is selected from the **Risk Entries** pull-down menu. (See Figure 6.) NOTE: If no action plans have been entered, the tool will calculate results as if it were in Basic Mode.

- **Borda Rank:** The Borda rank represents the number of other risks in the risk matrix that are more critical. For example, a Borda rank of 0 represents the most critical risk and a Borda rank of 1 indicates that one other risk is more critical. The format is integer (0-N).

- **R:** Risk (R) represents a rating of high, medium, or low as mapped to I (Impact) and Probability of occurrence not mitigated (Ponm)--as shown in Table 2. (For more details about Ponm, see the next section.) The format is “H”, “M”, or “L” for high, medium, or low risk, respectively.

**Table 2. Risk Rating Scale<sup>10</sup>**

Ponm	Impact Category				
	<i>Negligible</i>	<i>Minor</i>	<i>Moderate</i>	<i>Serious</i>	<i>Critical</i>
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

Output Columns Hidden by Default

In addition to the shown output columns, you can view the Borda Calculation Details and Action Plan Summary by toggling the “*Show/Hide Borda Calculation Details*” and the “*Show/Hide Action Plan Summary*” commands under the **Optional Column** menu. These columns are helpful if you want to understand how the Borda method is applied. The cells are populated after all of the mandatory input cells in the Risk Entries and Action Plan worksheets are populated and the “*Update All*” command is selected from the **Risk Entries** pull-down menu. (See Figure 6.) More details about the Borda method are available in Appendix A.

- **I Rank:** Calculated rank position for impact assessment. If there are no ties, then the risk with the most critical impact assessment has an I Rank of 1, the risk with the second most critical impact assessment has an I Rank of 2, etc. Appendix A discusses how these ranks are adjusted when there are ties. Format is a real number.
- **Ponm Rank:** Calculated rank position for probability assessment. If there are no ties, then the risk with the highest probability assessment has a Ponm Rank of 1, the risk with the second highest probability assessment has a Ponm Rank of 2, etc. Format is a real number.
- **Borda Count:** Calculated total points based on Borda voting method. The Borda Count for a risk is found by adding I rank and Ponm Rank, then subtracting the result from twice the total number of tasks. For the explicit formula, see Appendix A. The risk with the highest Borda Count is the most critical risk with respect to impact and probability criteria. Similarly, the risk with the second highest Borda Count is the second most critical risk. Format is real number.

<sup>10</sup> Franklin, C. E., Lt. Gen (USAF) Commander ESC, January 1996, Memorandum for ESC Program Managers, ESC/CC, Risk Management, Department of the Air Force, Headquarters ESC (AFMC) Hanscom Air Force Base, MA.

- **Ponm (%):** Specifies  $P_o$  if no action plan corresponding to this risk is specified; otherwise,  $P_o$  times  $P_{apf}$  is specified. Formally,  $P_{onm}$  is the joint probability that the risk occurs and the action plan fails to mitigate it. The format is a percentage (Integer %).
- **Total Tasks:** The number of action plan entries corresponding to a risk. The format is integer (1-N). A blank cell means that no entries are associated with this risk.
- **Worst Task Color:** The worst color (Blue, Green, Yellow, or Red) of the Action Plan entries corresponding to this risk. The text format is "Blue", "Green", "Yellow", or "Red". A blank cell means that no entries are associated with this risk. NOTE: If the status of any one action plan assessment is Red, it will affect the status of the risk.
- **Papf (%):** Probability of Action Plan Failure and it is calculated as a function of action plan entries and their associated assessment status colors. The format is a percentage point (Integer %). A blank cell means that no entries are associated with this risk. Appendix B contains a complete discussion of the reliability theory associated with the translation of the "Assessment" values into the probability that the implementation of associated action plan task will fail.



## Charting, Sorting, and Printing

The Risk Matrix application provides charting, sorting and printing capabilities adapted for Basic and Advanced modes. This chapter describes how to use each capability.

### Charting

The Risk Matrix charting capability helps visualize specific information in a graphical format. To create a chart, select the “*Chart...*” command under the **Risk Entries** menu on the Risk Entries worksheet in Basic or Advanced modes.

In Basic Mode, you can chart “I by Borda Rank” or “Po by Borda Rank”. Excel row numbers of the first and last entries to plot are required. Figures 14 and 15 show the Chart Risk Matrix Results windows for each mode. Risk Matrix automatically checks for valid inputs and re-computes all outputs before displaying these windows. This computation ensures that charts are constructed with current output information. Therefore, you do not need to select “*Update All*” before charting.

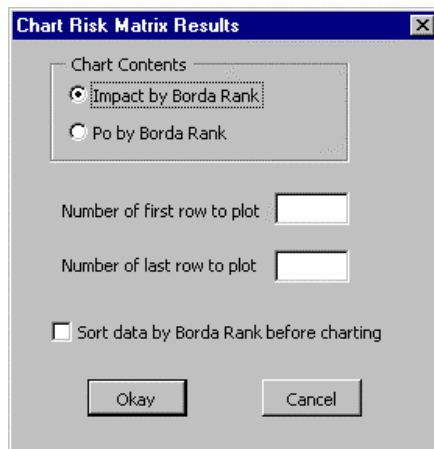


Figure 14. *Chart Risk Matrix Results* Window in Basic Mode

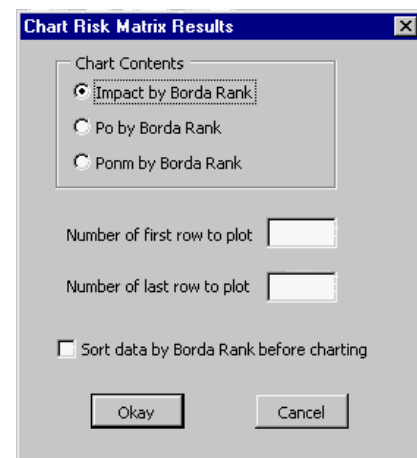


Figure 15. *Chart Risk Matrix Results* Window in Advanced Mode

This window also provides an option to sort data before charting. Figure 16 and 17 show example charts for Basic Mode. In Advanced mode, you have an option to chart "Ponm by Borda Rank". An example of this chart is shown in Figure 18.

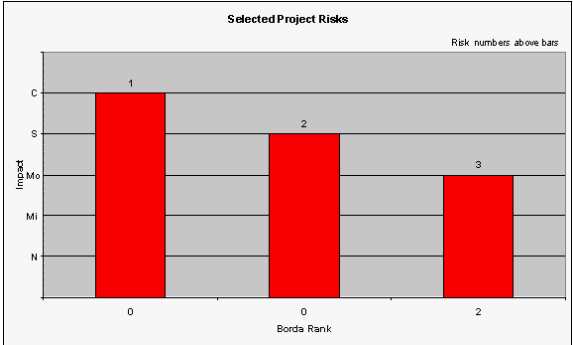


Figure 16. Impact by Borda Rank

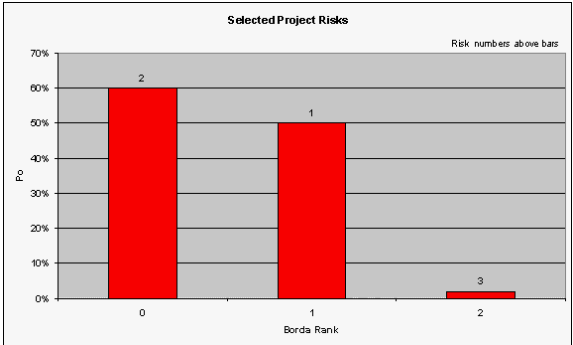


Figure 17. Probability of Occurrence

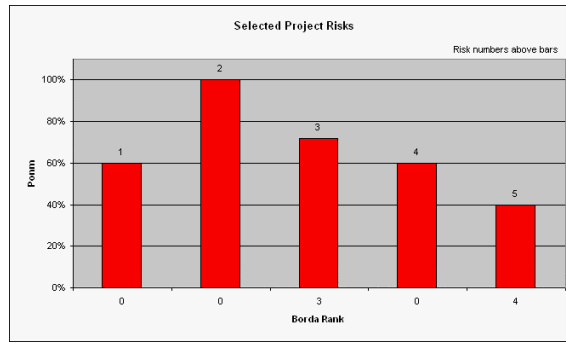


Figure 18. Ponm by Borda Rank

## Sorting

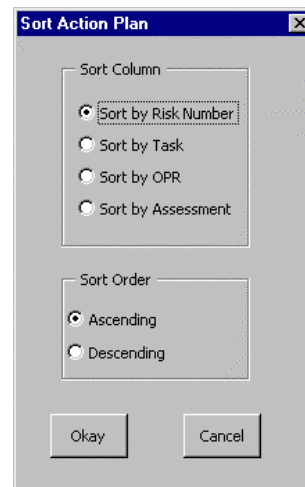
Risk Matrix provides specific row sorting capabilities in the Risk Entries and Action Plan worksheets.

### Risk Entries Sort

To sort the rows in the Risk Entries worksheet, select the “Sort...” command under the **Risk Entries** menu. (See Figure 6.) Figure 19 shows an example of the Sort Risk Entries window. You can sort by: “Risk No”, “IPT”, “Event Type”, “Borda Rank”, or Timeframe Start”. You also have the choice to sort the data in ascending or descending order.



### Action Plan Sort



To sort the rows in the Action Plan worksheet, select the “Sort...” command under the **Action** menu. Figure 20 shows an example of the Sort Action Plan window. You can sort by: “Risk No”, “Task”, “OPR”, or “Assessment” in ascending or descending order.

Risk Matrix automatically checks all inputs and re-computes all outputs before displaying these windows.

Compound Sorts

To do a compound sort on either the Risk Entries or Action Plan worksheet, use the Excel “Sort” command under the Excel **Data** menu. For details, see the Excel User’s Guide.

## Printing

To print the Risk Entries or Action Plan worksheet in color, use the “Print...” command under the Excel **File** menu. Risk Matrix also provides a black and white quick print capability for the Risk Entries and Action Plan worksheets. To print the Risk Entries or Action Plan worksheet in black and white, select the “Quick Print Risk Entries” command under the **Risk Entries** or **Action** menu.

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## Limitations and Warnings

### Insertions and Deletions

- Risk Matrix accepts a maximum of 300 risk entries for the Risk Entries worksheet. There is no preset limit on the number of action plan entries for the Action Plan worksheet.
- To delete cell entries, use the Excel “*Clear Contents*” command under the **Edit** menu. Another deletion alternative is to select a region and push the Delete key. Do **not** use the “*Clear All*” command; this command removes columns colors and formatting in addition to contents
- When you clear a row, select the ENTIRE row by clicking on the row number at the left of the row.
- Do **not** insert or delete columns in the Risk Matrix worksheets. The Borda algorithm works with absolute addressing and the insertion or deletion of columns will prevent the tool from working properly.
  - If you need to associate an additional attribute with entries, create the additional columns in Excel columns V and beyond for the Risk Entries worksheet and columns G and beyond for the Action Plan worksheet. Do **not** skip a column when the entering additional data. If you insert a blank column between the Manager/Mitigate column and additional data on the Risk Entries worksheet, then the Sort and Print commands will not process the additional data. Similarly, if you insert a blank column between the Discussion column and additional data on the Action Plan worksheet, the Sort and Print commands will not process the additional data.
  - Rather than delete columns, use the hide commands under the **Optional Columns** menu to remove them from the screen.
- Do **not** skip a row when entering data in a worksheet. If a row is skipped, Risk Matrix will not include entries after the blank row in an “*Update All*” command.

### Menus Unavailable During Data Entry

- Do not attempt to use pull-down menus while in the middle of entering data in a cell (something has been typed in a cell, but Enter has not been pushed). The selected pull-down menu operation will not work until cell entry is complete.

## Charts

- When you chart more than 50 risks, the bars on the chart set will appear so close together that the numbers written above them (i.e., the risk number) may overlap and be difficult to read.
- When you make a chart of Ponm, the chart will show Po if there is no action plan for the associated risk, or Po times Papf if there is an action plan.

## Limited Error Checks

- When you update results with the *"Update All"* command, Risk Matrix only checks for errors in the entries that impact the calculated results. The columns that are verified by the tool are: Risk No., I, and Po (%) on the Risk Entries worksheet and Risk No. and Assessment on the Action Plan worksheet.

## Borda Voting Method

The Borda method is used in the Risk Matrix software application to rank risks from most-to-least critical on the basis of multiple evaluation criteria. This appendix describes in detail how the Borda method is applied, using the sample Risk Entries Worksheet in Figure 8 of Chapter 4 as an illustration.

### Background

Borda<sup>11</sup> proposed the following voting method in 1770: Given  $N$  candidates, if points of  $N - 1$ ,  $N - 2$ , . . . , and 0 are assigned to the first-ranked, second-ranked, . . . , and last-ranked candidate in each voter's preference order, then the winning candidate is the one with the greatest total number of points. Instead of voters, suppose that there are multiple criteria. If  $r_{ik}$  is the rank of alternative  $i$  under criterion  $k$ , the Borda count for alternative  $i$  is

$$b_i = \sum_k (N - r_{ik})$$

The alternatives are then ordered according to these counts.

The Borda method is an example of a *positional voting method*, which assigns  $P_j$  points to a voter's  $j$ th-ranked candidate,  $j = 1, . . . , N$ , and then determines the ranking of the candidates by evaluating the total number of points assigned to each of them. Voting theorists<sup>12,13,14</sup> have shown that the Borda method is the optimal positional voting method with respect to several standards, such as minimizing the number and kinds of voting paradoxes. In addition, if ties are not present in the criteria rankings, Cook and Seiford<sup>15</sup> demonstrated that the Borda method is equivalent to determining the consensus rankings that minimize the sum of the squared deviations from the criteria rankings. The Borda

<sup>11</sup> Borda, J-C, 1781, "Mémoire sur les Élections au Scrutin," *Histoire de l'Académie Royale des Sciences*, Paris.

<sup>12</sup> Saari, D. G., 1994, *Geometry of Voting*, Springer-Verlag, New York.

<sup>13</sup> Fishburn, P. C., and W. V. Gehrlein, 1976, "Borda's Rule, Positional Voting, and Condorcet's Simple Majority Principle," *Public Choice*, Vol. 28, pp. 79-88.

<sup>14</sup> Van Newenhizen, J., 1992, "The Borda method is most likely to respect the Condorcet principle," *Economic Theory*, Vol. 2, pp. 69-83.

<sup>15</sup> Cook, W. D., and L. M. Seiford, 1982, "On the Borda-Kendall Consensus Method for Priority Ranking Problems," *Management Science*, Vol. 28, pp. 621-637.

method has been used to rank alternatives in a variety of applications, including a cost and operational effectiveness analysis (COEA)<sup>16</sup> and an aircraft maintenance study.<sup>17</sup>

In the Risk Matrix application, let  $N$  be the total number of risks, and the index  $i$  denote a particular risk. Let the impact assessment be denoted by  $k = 1$ , and the probability assessment be denoted by  $k = 2$ . The rest of this appendix describes how the Borda voting method is implemented in the software application.

## Evaluate Rank of Each Risk with Respect to Impact

Let  $J$  be the total number of possible impact assessments. As discussed in Chapter 4, a risk event can be assessed as either Critical, Serious, Moderate, Minor, or Negligible, and so there are  $J = 5$  possible assessments. Let  $Q_j$  be the  $j$ th possible impact assessment, which is assumed to be ordered in the following way:  $Q_j$  has a higher impact than  $Q_{j+1}$ . Thus,  $Q_1 = C$  (Critical),  $Q_2 = S$  (Serious), etc. Let  $M_j$  be the number of risks having  $Q_j$  as the impact rating. Table A-1 gives the values of  $M_j$  that correspond to the sample problem in Figure 8.

**Table A-1. Values of  $Q_j$ ,  $M_j$ , and  $T_j$  for Sample Matrix**

$j$	$Q_j$	$M_j$	$T_j$
1	C	2	1.5
2	S	3	4
3	Mo	0	N/A
4	Mi	0	N/A
5	N	0	N/A

Let  $T_j$  be the rank position for all risks that are given the  $j$ th possible impact assessment.

How can we evaluate this rank position? The basic approach is to evaluate the rank of a tied alternative as the average of the associated rankings.<sup>18,19,20</sup> The following is a key result: if  $a$  is the first term in an arithmetic progression,  $t$  is the final term, and  $n$  is the

<sup>16</sup> Lansdowne, Z. F., 1996, "Ordinal Ranking Methods for Multicriterion Decision Making," *Naval Research Logistics*, Vol. 43, pp. 613-627.

<sup>17</sup> Lansdowne, Z. F., and B. S. Woodward, 1996, "Applying the Borda Ranking Method," *Air Force Journal of Logistics*, Vol. 20, No. 2, pp. 27-29.

<sup>18</sup> Cook, W. D., and L. M. Seiford, 1982, "On the Borda-Kendall Consensus Method for Priority Ranking Problems," *Management Science*, Vol. 28, pp. 621-637.

<sup>19</sup> Lansdowne, Z. F., 1996, "Ordinal Ranking Methods for Multicriterion Decision Making," *Naval Research Logistics*, Vol. 43, pp. 613-627.

<sup>20</sup> Lansdowne, Z. F., and B. S. Woodward, 1996, "Applying the Borda Ranking Method," *Air Force Journal of Logistics*, Vol. 20, No. 2, pp. 27-29.



number of terms, then  $(n/2)(a + t)$  is the sum of the  $n$  terms. Because there are  $M_1$  risks that are tied for positions 1 through  $M_1$ , the sum of these rank positions is  $(M_1/2)(1 + M_1)$ . Thus, the average of this sum is  $T_1 = (1/2)(1 + M_1)$ . Similarly, there are  $M_2$  risks that are tied for positions  $M_1 + 1$  through  $M_1 + M_2$ , so that the average of this sum is  $T_2 = (1/2)(2M_1 + 1 + M_2)$ . More generally, if  $M_j > 0$ ,

$$T_j = \frac{1}{2} (2C_j + 1 + M_j)$$

where

$$C_j = \sum_{r=1}^{j-1} M_r$$

for  $j > 1$  and  $C_1 = 0$ . The values of  $T_j$  are given in Table A-1 for the sample Risk Matrix in Figure 8.

Let  $r_{il}$  be the rank of the  $l$ th risk with respect to the impact assessment. If the  $l$ th risk has the  $j$ th possible impact assessment, then set  $r_{il} = T_j$ . The values of  $r_{il}$  are given in Table A-2 for the sample Risk Matrix.

**Table A-2. Borda Points and Count**

Risk No.	$l$	$P_o$	$r_{i1}$	$r_{i2}$	Borda Count	Borda Rank
1	C	60%	1.5	3.5	5	0
2	S	100	4	1	5	0
3	S	90	4	2	4	3
4	C	60	1.5	3.5	5	0
5	S	40	4	5	1	4

## Evaluate Rank of Each Risk Based on Probability of Occurrence

Let  $H$  be the total number of possible probability assessments. As discussed in Chapter 4, there are five default probability ranges and so  $H = 5$ . Let  $P_h$  be the highest probability associated with the  $h$ th possible assessment, and let these probabilities be ordered such that  $P_h > P_{h+1}$ . Let  $N_h$  be the number of risks that are assigned the  $h$ th possible

probability assessment. Table A-3 shows the values of  $P_h$  and  $N_h$  that are used for our numerical example, where the values of  $N_h$  are derived from Figure 8.

**Table A-3. Values of  $P_h$ ,  $N_h$ , and  $S_h$  for Sample Matrix**

$h$	$P_h$	$N_h$	$S_h$
1	100%	1	1
2	90	1	2
3	60	2	3.5
4	40	1	5
5	10	0	N.A.

Let  $S_h$  be the rank position for all risks that are given the  $h$ th possible probability assessment. As before, if  $N_h > 0$ ,

$$S_h = \frac{1}{2} (2B_h + 1 + N_h)$$

where

$$B_h = \sum_{r=1}^{h-1} N_r$$

for  $h > 1$  and  $B_1 = 0$ . The values of  $S_h$  are given in Table A-3 for the sample Risk Matrix in Figure 8.

Let  $r_{12}$  be the rank of the  $l$ th risk respect to the probability of occurrence. If the  $l$ th risk has the  $h$ th possible assessment, then set  $r_{12} = S_h$ . The values of  $r_{12}$  are given in Table A-2 for the sample Risk Matrix.

## Determine Borda Ranking

Let  $N$  be the total number of risks, which satisfies

$$N = \sum_{h=1}^H N_h$$

The Borda Count for risk  $i$  is computed with

$$b_i = (N - r_{i1}) + (N - r_{i2})$$

The final step is to rank the risks with respect to their Borda Count. In particular, the risk with the highest Borda Count is the most critical, the risk with the second highest count is the next most critical, and so forth. The Borda Rank for a given risk is the number of other risks that are more critical. Table A-2 provides both the Borda Count and Borda Rank for the sample problem. Risks 1, 2, and 4 are tied with the highest Borda Count, and so their Borda Rank is 0. Risk 3 has a Borda Rank of 3, because there are three other risks that are more critical. Risk 5 has a Borda Rank of 4, because there are four other risks that are more critical.

The foregoing algorithm has been implemented as part of the software application. Figure 9 of Chapter 4 shows the Risk Entries Worksheet for the sample problem with all hidden columns displayed, including the columns that give the details of the Borda calculations. Note that all columns in Table A-2 also appear in Figure 9:  $r_{i1}$  and  $r_{i2}$  appear in Figure 9 under the headings "I Rank" and "Po Rank," respectively; the Borda Count and Borda Rank given in Table A-2 for each risk also appear under those headings in Figure 9.



## Risk Mitigation Tracking

The Advanced Mode provides an optional method for tracking the progress of risk mitigation actions, and it was presented in Chapter 5. This appendix describes in detail the calculations used for risk mitigation tracking.

When using the Advanced Mode, 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. For example, Figure 12 of Chapter 5 is a sample Action Plan Worksheet, and it shows the tasks in the action plan for risk entry number 3.

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 Table B-1. 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 Table B-1.

**Table B-1. 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

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 ( $P_{apf}$ ):

$$P_{apf} = 1 - \prod_j [1 - v(y_j)]$$

where  $y_j$  is the status color assessed for  $j$ th task within the action plan, and  $v(y_j)$  is the probability that the implementation of this task will fail. For example, if  $y_j$  is yellow, then  $v(y_j)$  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.<sup>21</sup>

For example, Risk 3 has five tasks in the sample Action Plan Worksheet shown in Figure 12: one task has blue as its assessment, two tasks have green, and two tasks have yellow. According to the above formula,

$$P_{apf} = 1 - (0.9)(0.9)(0.5)(0.5) = 0.80$$

for this action plan, which is the value given in Figure 13. Adding an additional task to an action plan would tend to increase  $P_{apf}$ , because all of the tasks must succeed in order for the risk to be mitigated.

The evaluated probability  $P_{apf}$  serves as the measure of risk mitigation progress. The fifth and final step is to rank the risks with the Borda method, but using the probability of occurrence not mitigated,  $P_{omm} = P_{apf} \times P_o$ , as one of the criteria instead of the probability of occurrence  $P_o$  for each risk having a specified action plan. Thus, creating an action plan for a risk makes the risk less critical, because there is a chance it will be

mitigated. If an action plan has not been specified for a particular risk, then the program will continue to use  $P_o$  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.

This tracking method provides several advantages. First, it enables the data and assessments collected for Risk Matrix to be used throughout the risk management process. According to the Defense Systems Management College (DSMC), the risk management process has four basic stages: risk planning, risk assessment, risk analysis, and risk handling.<sup>22</sup> The Basic Mode of Risk Matrix supports the first three stages; the Advanced Mode with the optional tracking method supports the fourth stage (i.e., measuring risk handling progress).

Second, the risks whose action plans need the closest attention are identified with the Borda method. These critical risks are the ones whose  $P_{onm}$  and impact assessment ( $I$ ) are both relatively high.

Third, if the status colors are assessed periodically (perhaps weekly or monthly) for all action plan tasks, both the Borda rank and  $P_{onm}$  for each risk can be plotted over time. These high-level graphical displays show the changes in the mitigation status of each risk during the risk-handling stage of the process.

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<sup>21</sup> Barlow, R. E., and F. Proschan, 1975, *Statistical Theory of Reliability and Life Testing: Probability Models*, Holt, Reinhart and Winston, New York.

<sup>22</sup> Defense Systems Management College, 1989, *Risk Management: Concepts and Guidance*, Fort Belvoir, Virginia.





## Quick Reference Sheets

### Risk Entries Reference Sheet

Worksheet Column	Definition	Format	Type
A. Risk No.	A risk number is a unique numeric identifier assigned to an entry by the user.	Integer (1-N)	Mandatory Input
B. Related Risk No.	Risk numbers whose occurrence affects or is affected by the risk entry.	Integers (I,J,K)	Optional Input
C. IPT	An Integrated Product Team (IPT) is the name of the group associated with an entry.	Text	Optional Input
D. Requirement (Threshold)	A list of cost, schedule, or performance requirements that are associated with the risk entry.	Text	Optional Input
E. Technology Available	A list of available technologies that help meet each requirement.	Text	Optional Input
F. Risk (to meeting the requirement)	A description of a risk that may prevent a program from achieving its cost, schedule, or performance objectives.	Text	Mandatory Input
G. Timeframe Start	The earliest date or estimated date when a risk entry could occur.	dd mmm yyyy	Optional Input
H. Timeframe End	The latest date or estimated date when a risk entry could occur.	dd mmm yyyy	Optional Input
I. Event Type	An event type is a user-defined attribute to further classify an entry. For example, event type may be "C", "S", or "P" representing the risk event primarily affecting cost, schedule, or performance, respectively.	Text	Optional Input
J. I	A subjective assessment of the impact a risk may have on the overall program. Valid options are: C = Critical, S = Serious, Mo = Moderate, Mi = Minor, N = Negligible.	Text: C, S, Mo, Mi, or N	Mandatory Input
K. Po (%)	Probability of Occurrence (Po) is a subjective assessment of the probability that the risk will occur.	Percentage (Integer %)	Mandatory Input
L. I Rank	Calculated rank position for impact.	Real Number (X.XX)	Output
M. Ponm Rank	Calculated rank position for probability assessment.	Real Number (X.XX)	Output
N. Borda Count	Calculated total points based on Borda voting method.	Real Number (X.XX)	Output
O. Borda Rank	A Borda rank for an entry represents the number of other risks that are more critical (e.g., Borda rank of 0 represents the most critical entry).	Integer (0-N)	Output
P. R	Risk Rating (R) for an entry represents a risk rating of high, medium, or low as a function of the I and Ponm pair.	Text: H, M, or L	Output
Q. Total Tasks	If Action Plan worksheet is populated, then the number of tasks associated with the entry is represented in Total Tasks.	Integer (1-N)	Output
R. Worst Task Color	If Action Plan worksheet is populated, then the Worst Assessment Color associated with the entry is represented in Worst Task Color. Valid colors are Blue, Green, Yellow, and Red.	Text: (Blue, Green, Yellow, Red)	Output
S. Papf (%)	If Action Plan worksheet is populated, then the Probability of Action Plan Failure is calculated as a function of action plan tasks and their associated assessment status colors.	Percentage (Integer %)	Output
T. Ponm	Specifies Po if no corresponding action plans are specified; else Papf times Po.	Percentage (Integer %)	Output
U. Manage/Mitigate	Strategy to manage or mitigate the risk.	Text	Optional Input

### Action Plan Reference Sheet

Worksheet Column	Definition	Format	Type
A. Risk No.	For each risk mitigation entry, the risk number is cross-referenced to the risk number in the Risk Entries.	Integer (1-N)	Mandatory Input
B. Task	A description of the action plan activity for a particular risk, which is cross-referenced to the risk with the risk number.	Text	Mandatory Input
C. OPR	The Office of Primary Responsibility (OPR) is the organization or person responsible for executing/managing a task.	Text	Optional Input
D. Exit Criteria	The requirements for successful completion of the task.	Text	Optional Input
E. Assessment	A color depicting the status of each task, where Blue, Green, Yellow, and Red represent task completed, task on track, task at risk, and task non-executable, respectively.	Text: Blue, Green, Yellow, or Red	Mandatory Input
F. Discussion	Status notes, interim actions, point of contacts, etc.	Text	Optional Input

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