
Chapter 2: An Overview to Risk Analysis

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Introduction

@RISK brings advanced modeling and Risk Analysis to Microsoft Excel. You might wonder if what you do qualifies as modeling and/or would be suitable for Risk Analysis. If you use data to solve problems, make forecasts, develop strategies, or make decisions, then you definitely should consider doing Risk Analysis.

Modeling is a catch-all phrase that usually means any type of activity where you are trying to create a representation of a real life situation so you can analyze it. Your representation, or model, can be used to examine the situation, and hopefully help you understand what the future might bring. If you've ever played "what-if" games with your project by changing the values of various entries, you are well on your way to understanding the importance of uncertainty in a modeling situation.

Okay, so you do analyses and make models – what is involved in making these analyses and models explicitly incorporate risk? The following discussion will try to answer this question. But don't worry, you don't have to be an expert in statistics or decision theory to analyze situations under risk, and you certainly don't have to be an expert to use @RISK. We can't teach you everything in a few pages, but we'll get you started. Once you begin using @RISK you'll automatically begin picking up the type of expertise that can't be learned from a book.

Another purpose of this chapter is to give you an overview of how @RISK works with your spreadsheet to perform analyses. You don't have to know how @RISK works to use it successfully, but you might find some explanations useful and interesting. This chapter discusses:

- *What risk is and how it can be quantitatively assessed.*
- *The nature of Risk Analysis and the techniques used in @RISK.*
- *Running a simulation.*
- *Interpreting @RISK results.*
- *What Risk Analysis can and cannot do.*

What Is Risk?

Everyone knows that "risk" affects the gambler about to roll the dice, the wildcatter about to drill an oil well, or the tightrope walker taking that first big step. But these simple illustrations aside, the concept of risk comes about due to our recognition of future uncertainty — our inability to know what the future will bring in response to a given action today. Risk implies that a given action has more than one possible outcome.

In this simple sense, every action is "risky", from crossing the street to building a dam. The term is usually reserved, however, for situations where the range of possible outcomes to a given action is in some way significant. Common actions like crossing the street usually aren't risky while building a dam can involve significant risk. Somewhere in between, actions pass from being nonrisky to risky. This distinction, although vague, is important — if you judge that a situation is risky, risk becomes one criterion for deciding what course of action you should pursue. At that point, some form of Risk Analysis becomes viable.

Characteristics of Risk

Risk derives from our inability to see into the future, and indicates a degree of uncertainty that is significant enough to make us notice it. This somewhat vague definition takes more shape by mentioning several important characteristics of risk.

First, risk can be either objective or subjective. Flipping a coin is an objective risk because the odds are well known. Even though the outcome is uncertain, an objective risk can be described precisely based on theory, experiment, or common sense. Everyone agrees with the description of an objective risk. Describing the odds for rain next Thursday is not so clear cut, and represents a subjective risk. Given the same information, theory, computers, etc., weatherman A may think the odds of rain are 30% while weatherman B may think the odds are 65%. Neither is wrong. Describing a subjective risk is open-ended in the sense that you could always refine your assessment with new information, further study, or by giving weight to the opinion of others. Most risks are subjective, and this has important implications for anyone analyzing risk or making decisions based on a Risk Analysis.

Second, deciding that something is risky requires personal judgment, even for objective risks. For example, imagine flipping a coin where you win \$1 for a heads and lose \$1 for a tails. The range between \$1 and -\$1 would not be overly significant to most people. If the stakes were \$100,000 and -\$100,000 respectively, most people would find the situation to be quite risky. There would be a wealthy few, however, who would not find this range of outcomes to be significant.

Third, risky actions and therefore risk are things that we often can choose or avoid. Individuals differ in the amount of risk they willingly accept. For example, two individuals of equal net worth may react quite differently to the \$100,000 coin flip bet described above – one may accept it while the other refuses it. Their personal preference for risk differs.

The Need for Risk Analysis

The first step in Risk Analysis and modeling is recognizing a need for it. Is there significant risk involved in the situation you are interested in? Here are a few examples that might help you evaluate your own situations for the presence of significant risk:

- **Risks for New Product Development and Marketing** – *Will the R&D department solve the technical problems involved? Will a competitor get to market first, or with a better product? Will government regulations and approvals delay product introduction? How much impact will the proposed advertising campaign have on sales levels? Will production costs be as forecast? Will the proposed sales price have to be changed to reflect unanticipated demand levels for the product?*
- **Risks for Securities Analysis and Asset Management** – *How will a tentative purchase affect portfolio value? Will a new management team affect market price? Will an acquired firm add earnings as forecast? How will a market correction impact a given industry sector?*
- **Risks for Operations Management and Planning** – *Will a given inventory level suffice for unpredictable demand levels? Will labor costs rise significantly with upcoming union contract negotiations? How will pending environmental legislation impact production costs? How will political and market events affect overseas suppliers in terms of exchange rates, trade barriers, and delivery schedules?*
- **Risks for Design and Construction of a Structure (building, bridge, dam,...)** – *Will the cost of construction materials and labor be as forecast? Will a labor strike affect the construction schedule? Will the levels of stress placed on the structure by peak load crowds and nature be as forecast? Will the structure ever be stressed to the point of failure?*

- **Risks for Investment in Exploration for Oil and Minerals** – *Will anything be found? If a deposit is found, will it be uneconomical, or a bonanza? Will the costs of developing the deposit be as forecast? Will some political event like an embargo, tax reform, or new environmental regulations drastically alter the economic viability of the project?*
- **Risks for Policy Planning** – *If the policy is subject to legislative approval, will it be approved? Will the level of compliance with any policy directives be complete or partial? Will the costs of implementation be as forecast? Will the level of benefits be what you projected?*

Assessing and Quantifying Risk

The first step in Risk Analysis and modeling is recognizing a need for it. Is there significant risk involved in the situation you are interested in? Here are a few examples that might help you evaluate your own situations for the presence of significant risk.

Realizing that you have a risky situation is only the first step. How do you quantify the risk you have identified for a given uncertain situation? "Quantifying risk" means determining all the possible values a risky variable could take and determining the relative likelihood of each value. Suppose your uncertain situation is the outcome from the flip of a coin. You could repeat the flip a large number of times until you had established the fact that half of the times it comes up tails and half of the times heads. Alternatively, you could mathematically calculate this result from a basic understanding of probability and statistics.

In most real life situations, you can't perform an "experiment" to calculate your risk the way you can for the flip of a coin. How could you calculate the probable learning curve associated with introducing new equipment? You may be able to reflect on past experiences, but once you have introduced the equipment, the uncertainty is gone. There is no mathematical formula that you can solve to get the risk associated with the possible outcomes. You have to estimate the risk using the best information you have available.

If you can calculate the risks of your situation the way you would for a coin flip, the risk is objective. This means that everyone would agree that you quantified the risk correctly. Most risk quantification, however, involves your best judgment.

There may not be complete information available about the situation, the situation may not be repeatable like a coin flip, or it just may be too complex to come up with an unequivocal answer. Such risk quantification is subjective, which means that someone might disagree with your evaluation.

Your subjective assessments of risk are likely to change when you get more information on the situation. If you have subjectively derived a risk assessment, you must always ask yourself whether additional information is available that would help you make a better assessment. If it is available, how hard and how expensive would it be to obtain? How much would it cause you to change the assessment you already have made? How much would these changes affect the final results of any model you are analyzing?

Describing Risk with a Probability Distribution

If you have quantified risk — determined outcomes and probabilities of occurrence — you can summarize this risk using a probability distribution. A probability distribution is a device for presenting the quantified risk for a variable. @RISK uses probability distributions to describe uncertain values in your Excel worksheets and to present results. There are many forms and types of probability distributions, each of which describes a range of possible values and their likelihood of occurrence. Most people have heard of a normal distribution — the traditional "bell curve". But there is a wide variety of distribution types ranging from uniform and triangular distributions to more complex forms such as gamma and weibull.

All distribution types use a set of arguments to specify a range of actual values and distribution of probabilities. The normal distribution, for example, uses a mean and standard deviation as its arguments. The mean defines the value around which the bell curve will be centered and the standard deviation defines the range of values around the mean. Over thirty types of distributions are available to you in @RISK for describing distributions for uncertain values in your Excel worksheets.

The @RISK Define Distribution window allows you to graphically preview distributions and assign them to uncertain values. Using its graphs, you can quickly see the range of possible values your distribution describes.

What Is Risk Analysis?

In a broad sense, Risk Analysis is any method — qualitative and/or quantitative — for assessing the impacts of risk on decision situations. Myriad techniques are used that blend both qualitative and quantitative techniques. The goal of any of these methods is to help the decision-maker choose a course of action, given a better understanding of the possible outcomes that could occur.

Risk Analysis in @RISK is a quantitative method that seeks to determine the outcomes of a decision situation as a probability distribution. In general, the techniques in an @RISK Risk Analysis encompass four steps:

- **Developing a Model** — *by defining your problem or situation in Excel worksheet format*
- **Identifying Uncertainty** — *in variables in your Excel worksheet and specifying their possible values with probability distributions, and identifying the uncertain worksheet results you want analyzed*
- **Analyzing the Model with Simulation** — *to determine the range and probabilities of all possible outcomes for the results of your worksheet*
- **Making a Decision** — *based on the results provided and personal preferences*

@RISK helps with the first three steps, by providing a powerful and flexible tool that works with Excel to facilitate model building and Risk Analysis. The results that @RISK generates can then be used by the decision-maker to help choose a course of action.

Fortunately, the techniques @RISK employs in a Risk Analysis are very intuitive. As a result, you won't have to accept our methodology on faith. And you won't have to shrug your shoulders and resort to calling @RISK a "black box" when your colleagues and superiors query you as to the nature of your Risk Analysis. The discussion to follow will give you a firm understanding of just what @RISK needs from you in the way of a model, and how an @RISK Risk Analysis proceeds.

Developing an @RISK Model

You are the "expert" at understanding the problems and situations that you would like to analyze. If you have a problem that is subject to risk, then @RISK and Excel can help you construct a complete and logical model.

A major strength of @RISK is that it allows you to work in a familiar and standard model building environment – Microsoft Excel. @RISK works with your Excel model, allowing you to conduct a Risk Analysis, but still preserves the familiar spreadsheet capabilities. You presumably know how to build spreadsheet models in Excel – @RISK now gives you the ability to easily modify these models for Risk Analysis.

Variables

Variables are the basic elements in your Excel worksheets that you have identified as being important ingredients to your analysis. If you are modeling a financial situation, your variables might be things like Sales, Costs, Revenues or Profits whereas if you are modeling a geologic situation, your variables might be things like Depth to Deposit, Thickness of Coal Seam or Porosity. Each situation has its own variables, identified by you. In a typical worksheet, a variable labels a worksheet row or column, for example:

Certain or Uncertain

You may know the values your variables will take in the time frame of your model – they are certain, or what statisticians call "deterministic". Conversely, you may not know the values they will take – they are uncertain, or "stochastic". If your variables are uncertain you will need to describe the nature of their uncertainty. This is done with probability distributions, which give both the range of values that the variable could take (minimum to maximum), and the likelihood of occurrence of each value within the range. In @RISK, uncertain variables and cell values are entered as probability distribution functions, for example:

RiskNormal(100,10)

RiskUniform(20,30)

RiskExpon(A1+A2)

RiskTriang(A3/2.01,A4,A5)

These "distribution" functions can be placed in your worksheet cells and formulas just like any other Excel function.

Independent or Dependent

In addition to being certain or uncertain, variables in a Risk Analysis model can be either "independent" or "dependent". An independent variable is totally unaffected by any other variable within your model. For example, if you had a financial model evaluating the profitability of an agricultural crop, you might include an uncertain variable called Amount of Rainfall. It is reasonable to assume that other variables in your model such as Crop Price and Fertilizer Cost would have no effect on the amount of rain – Amount of Rainfall is an independent variable.

A dependent variable, in contrast, is determined in full or in part by one or more other variables in your model. For example, a variable called Crop Yield in the above model should be expected to depend on the independent variable Amount of Rainfall. If there's too little or too much rain, then the crop yield is low. If there's an amount of rain that is about normal, then the crop yield would be anywhere from below average to well above average. Maybe there are other variables that affect Crop Yield such as Temperature, Loss to Insects, etc.

When identifying the uncertain values in your Excel worksheet, you have to decide whether your variables are correlated. These variables would all be “correlated” with each other. The Corrmat function in @RISK is used to identify correlated variables. It is extremely important to correctly recognize correlations between variables or your model might generate nonsensical results. For example, if you ignored the relationship between Amount of Rainfall and Crop Yield, @RISK might choose a low value for the rainfall at the same time it picked a high value for the crop yield – clearly something nature wouldn't allow.

Output Variables

Any model needs both input values and output results, and a Risk Analysis model is no different. An @RISK Risk Analysis generates results on cells in your Excel worksheet. Results are probability distributions of the possible values which could occur. These results are usually the same worksheet cells that give you the results of a regular Excel analysis – Profit, the "bottom line" or other such worksheet entries.

Analyzing a Model with Simulation

Once you have placed uncertain values in your worksheet cells and have identified the outputs of your analysis, you have an Excel worksheet that @RISK can analyze.

Simulation

@RISK uses simulation, sometimes called Monte Carlo simulation, to do a Risk Analysis. Simulation in this sense refers to a method whereby the distribution of possible outcomes is generated by letting a computer recalculate your worksheet over and over again, each time using different randomly selected sets of values for the probability distributions in your cell values and formulas. In effect, the computer is trying all valid combinations of the values of input variables to simulate all possible outcomes. This is just as if you ran hundreds or thousands of "what-if" analyses on your worksheet, all in one sitting.

What is meant by saying that simulation "tries all valid combinations of the values of input variables"? Suppose you have a model with only two input variables. If there is no uncertainty in these variables, you can identify a single possible value for each variable. These two single values can be combined by your worksheet formulas to calculate the results of interest — also a certain or deterministic value. For example, if the certain input variables are:

Revenues = 100
Costs = 90

then the result

Profits = 10

would be calculated by Excel from

Profits = 100 - 90

There is only one combination of the input variable values, because there is only one value possible for each variable.

Now consider a situation where there is uncertainty in both input variables. For example,

Revenues = 100 or 120
Costs = 90 or 80

gives two values for each input variable. In a simulation, @RISK would consider all possible combinations of these variable values to calculate possible values for the result, Profits.

There are four combinations:

Profits = Revenues - Costs

10 = 100 - 90

20 = 100 - 80

30 = 120 - 90

40 = 120 - 80

Profits also is an uncertain variable because it is calculated from uncertain variables.

How Simulation Works

In @RISK, simulation uses two distinct operations:

- *Selecting sets of values for the probability distribution functions contained in the cells and formulas of your worksheet*
- *Recalculating the Excel worksheet using the new values*

The selection of values from probability distributions is called sampling and each calculation of the worksheet is called an iteration.

The following diagrams show how each iteration uses a set of single values sampled from distribution functions to calculate single-valued results. @RISK generates output distributions by consolidating single-valued results from all the iterations.

The Alternative to Simulation

There are two basic approaches to quantitative Risk Analysis. Both have the same goal – to derive a probability distribution that describes the possible outcomes of an uncertain situation – and both generate valid results. The first approach is the one just described for @RISK, namely, simulation. This approach relies on the ability of the computer to do a great deal of work very quickly – solving your worksheet repeatedly using a large number of possible combinations of input variable values.

The second approach to Risk Analysis is an analytical approach. Analytical methods require that the distributions for all uncertain variables in a model be described mathematically. Then the equations for these distributions are combined mathematically to derive another equation, which describes the distribution of possible outcomes. This approach is not practical for most uses and users. It is not a simple task to describe distributions as equations, and it is even more difficult to combine distributions analytically given even moderate complexity in your model. Furthermore, the mathematical skills necessary to implement the analytical techniques are significant.

Making a Decision: Interpreting the Results

@RISK analysis results are presented in the form of probability distributions. The decision-maker must interpret these probability distributions, and make a decision based on the interpretation. How do you interpret a probability distribution?

Interpreting a Traditional Analysis

Let's start by looking at how a decision-maker would interpret a single-valued result from a traditional analysis — an "expected" value. Most decision-makers compare the expected result to some standard or minimum acceptable value. If it's at least as good as the standard, they find the result acceptable. But, most decision-makers recognize that the expected result doesn't show the impacts of uncertainty. They have to somehow manipulate the expected result to make some allowance for risk. They might arbitrarily raise the minimum acceptable result, or they might non rigorously weigh the chances that the actual result could exceed or fall short of the expected result. At best, the analysis might be extended to include several other results — such as "worst case" and "best case" — in addition to the expected value. The decision-maker then decides if the expected and "best case" values are good enough to outweigh the "worst case" value.

Interpreting an @RISK Analysis

In an @RISK Risk Analysis, the output probability distributions give the decision-maker a complete picture of all the possible outcomes. This is a tremendous elaboration on the "worst-expected-best" case approach mentioned above. But the probability distribution does a lot more than just fill in the gaps between these three values:

- **Determines a "Correct" Range** — *Because you have more rigorously defined the uncertainty associated with every input variable, the possible range of outcomes may be quite different from a "worst case-best case" range — different, and more correct.*
- **Shows Probability of Occurrence** — *A probability distribution shows the relative likelihood of occurrence for each possible outcome.*

As a result, you no longer just compare desirable outcomes with undesirable outcomes. Instead, you can recognize that some outcomes are more likely to occur than others, and should be given more weight in your evaluation. This process also is a lot easier to understand than the traditional analysis because a probability distribution is a graph — you can see the probabilities and get a feel for the risks involved.

Individual Preference

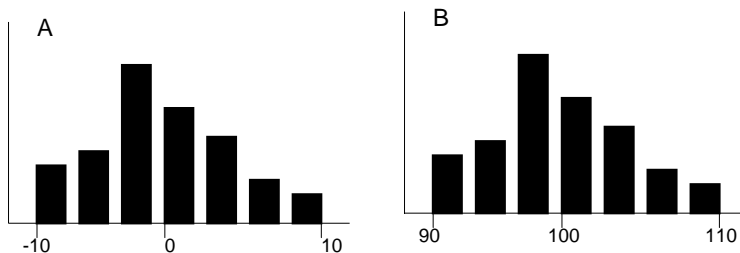
The results provided by an @RISK analysis must be interpreted by you as an individual. The same results given to different individuals may be interpreted differently, and lead to different courses of action. This is not a weakness in the technique, but a direct result of the fact that different individuals have different preferences with regard to possible choices, time, and risk. You might feel that the shape of the output distribution shows that the chances of an undesirable outcome far outweigh the chances of a desirable outcome. A colleague who is less risk averse might come to the opposite conclusion.

The Distribution "Spread"

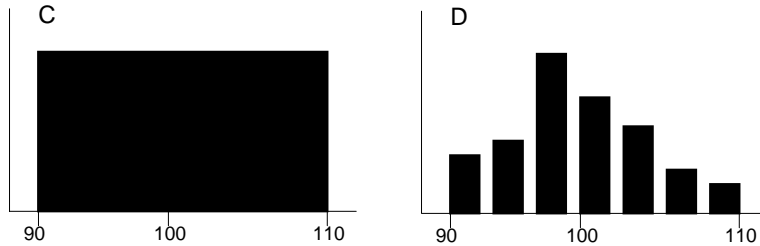
Range and likelihood of occurrence are directly related to the level of risk associated with a particular event. By looking at the spread and likelihood of possible results, you can make an informed decision based on the level of risk you are willing to take. Risk averse decision-makers prefer a small spread in possible results, with most of the probability associated with desirable results. But if you are a risk-taker, then you will accept a greater spread or possible variation in your outcome distribution. Furthermore, a risk-taker will be influenced by "bonanza" outcomes even if their likelihood of occurrence is small.

Regardless of your personal risk preferences, there are some general conclusions about riskiness that apply to all decision-makers. The following probability distributions illustrate these conclusions:

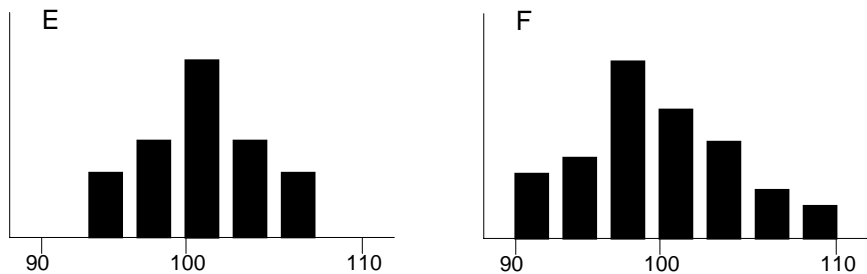
Probability distribution A represents greater risk than B despite identical shapes because the range of A includes less desirable results – the spread relative to the mean is greater in A than B.



Probability distribution C represents greater risk than D because the probability of occurrence is uniform across the range for C whereas it is concentrated around 98 for D.



Probability distribution F represents greater risk than E because the range is larger and the probability of occurrence is more spread out than for E.



Skewness

A simulation output distribution also can show skewness – how much the distribution of possible results deviates from being symmetrical. Suppose your distribution had a large positive 'tail'. If you saw only a single number for the expected result, you might not realize the possibility of a highly positive outcome that could occur in the tail. Skewness such as this can be very important to decision makers. By presenting all the information, @RISK "opens up" a decision by showing you all possible outcomes.

What Risk Analysis Can (Cannot) Do

Quantitative analysis techniques have gained a great deal of popularity with decision-makers and analysts in recent years. Unfortunately, many people have mistakenly assumed that these techniques are magic "black boxes" that unequivocally arrive at the correct answer or decision. No technique, including those used by @RISK, can make that claim. These techniques are tools that can be used to help make decisions and arrive at solutions. Like any tools, they can be used to good advantage by skilled practitioners, or they can be used to create havoc in the hands of the unskilled. In the context of Risk Analysis, quantitative tools should never be used as a replacement for personal judgment.

Finally, you should recognize that Risk Analysis cannot guarantee that the action you choose to follow – even if skillfully chosen to suit your personal preferences – is the best action viewed from the perspective of hindsight. Hindsight implies perfect information, which you never have at the time the decision is made. You can be guaranteed, however, that you have chosen the best personal strategy given the information that is available to you. That's not a bad guarantee!