Risk...

Most of us hate the idea of risk. While we collectively spend a great deal of time and money to reduce it, we can never hope to eliminate it. The reason is that some amount of uncertainty is "built in" to all aspects of the world around us. In fact, at the smallest level of physical reality, quantum physicists must deal only in probabilities, as they cannot predict with certainty which events will occur, or where or when they might occur.

The very word "risk" tends to make us nervous, as it portends the probability that something bad may happen to us. The word "happen" is also a clue to our deep concerns about risk, because it indicates events that are out of our control.

It is this feeling of helplessness that is at the heart of why we are concerned about some risks and not others, and why we tend to react emotionally when confronted with risk-related issues. According to Dr. Robert Scheuplien, former head of the U.S. Food and Drug Administration's Office of Toxicology:

"When risks are perceived to be dread[ful], unfamiliar, uncontrollable by the individual, unfair, involuntary, and potentially catastrophic, they are typically of great public concern, or high outrage. When risks are perceived as voluntary, controllable by the individual, familiar, equitable, easily reducible, decreasing, and non-catastrophic, they tend to be minimized by the public, or low outrage."

Our natural tendency to think in the manner described by Dr. Scheuplien leads us to be overly concerned about risks for which we feel little control and to feel little concern for risks where we can exercise significant control. Thus, we are far more afraid of the potential effects of chemicals we unknowingly ingest than of the food, drink and other substances we willingly ingest but shouldn't: Studies indicate that poor diet, smoking and excessive alcohol consumption together account for about two-thirds of cancers (68%); while food additives account for less than one percent (The Causes of Cancer, Doll and Peto, 1981).

This doesn't mean that risks associated with chemicals, electromagnetic fields and the like should be ignored. On the contrary! For example, the potential for a nuclear accident may be relatively small, but the amount of harm that would be caused by one is so large that the possibility of such a mishap must be taken very seriously. Thus, risk entails not just the probability of something happening, but also the magnitude of the problem if it were to happen.

Frankly, we humans are not particularly good at assessing risks in the absolute, or when comparing one risk against another. We hope to provide you with some reasons as to why this is so, and to highlight some of the ways that scientists, engineers and other professionals are working to improve our ability to assess, manage and communicate about risk.

How We Perceive Risk...

When trying to evaluate risk, we are typically forced to deal with a number of quantitative and qualitative tradeoffs. These include:

- Time -- Is the potential negative outcome related to the risk going to occur now, or sometime in the future?
- Physical Distance -- Is the risk nearby or far away?
- Personal Distance -- Will the risk affect me or my family?
- Cost vs. Benefit -- Which is greater, the benefit derived from taking the risk, or the costs associated with either reducing it or remediating its effects?
- Probability -- Is the risk in question a rare event, or something that is likely to occur?
- Magnitude -- Is the resulting affect of taking the risk likely to be large or small?

In general, risks that 1.) appear closest to us in terms of time, space and kinship; 2.) would seem to cost more than their benefits, and 3.) have a higher likelihood of occurring or causing serious damage, are logically of greater importance to us. The problem is that many times we are unable to properly apply these ideas to the risk at hand.

Sometimes, our inability to judge risk is based on factors outside of our control. For example, it is virtually impossible to tell if:

- the information we receive from the media or other sources is reliable and well-balanced.
- a particular expert is in fact well versed in the subject at hand or held in high esteem by his or her peers.
- the information provided is up-to-date and in agreement with the currently accepted body of knowledge for that field.

Just as important are the ways in which we can fool ourselves about risk. There are many mental devices we use every day to help with decision-making tasks. Known as heuristics, many of these rules-of-thumb can actually reduce our chances of making good decisions.

The reason why our mental faculties often fail us today probably has to do with the fact that we are still "programmed" or "wired" to deal with life-threatening situations that occurred eons ago, when reflexive reactions were critical to survival. Reaction time was at a premium then, so unconscious or subconscious decision-making was the fastest way to literally remove oneself from harm's way.

Today, survival is not generally an everyday concern in the industrialized world, as the number of immediate negative consequences are dwindling. Thanks to improvements in sanitation, medicine, nutrition and working conditions, we unconsciously assume survival, rather than consciously expect to fight for it.

Further, issues are far more complex and cerebral today, meaning that responses to them need to be more measured and thoughtful. Thus, the heuristics and biases that ensured success in the past can lead to failure in the present.

Recognizing which heuristics interfere with our ability to make accurate judgements about risk and uncertainty is the first step in overcoming them. They generally fall into four categories known as availability, overconfidence, anchoring and adjustment and representativeness.

Availability

People using the availability heuristic will judge an event as either frequent or likely to occur if it is easy to imagine or recall, i.e., if it is readily available to one's memory. If an event is truly frequent, availability can be a very appropriate cue. However, availability can be affected by many factors other than frequency of occurrence.

Example: The film Independence Day could convince many people that the risk of alien invasion is either probable or imminent, when in fact the risk is at best nonexistent, or at worst no different than before the film was released.

Another effect of the availability heuristic is the mistake of viewing the future only in terms of the immediate past. The way in which we deal with natural disasters is particularly prone to this problem:

- After a flood, hurricane or earthquake, planners are so conditioned by the immediate past that they have a hard time taking into account that an even bigger one may occur next time. (This is why engineers have developed the "100 Years" concept for designing buildings, dams and bridges.)

- After a natural disaster, catastrophic insurance sales increase dramatically and then fall off over time. Thus, people tend to forget about the past, while the odds of an event recurring haven't really changed at all.

Finally, the availability heuristic slants our perceptions regarding the frequency of, and thus our concern for, low probability events which have been highly sensationalized. Since we read more about airplane crashes, factory explosions and volcanoes than we do about asthma or old age, we tend to overestimate the probability of the former and underestimate the probability of the latter. In reality, the number of people dying from asthma and old age is far greater than the number succumbing to the more sensational, but far less frequent, occurrences.

Overconfidence

There are many ways in which people tend to be overconfident about their judgements regarding risk. Importantly, it isn't just laypersons who are at the mercy of these heuristics. Experts can be just as overconfident in their assessments as well. Thus, an understanding of heuristics which lead to overconfidence is critical, since we can't always rely on the experts to overcome their own biases.

Knowing with Certainty

People tend to place great faith in their own judgements. For example, studies indicate that subjects are extremely confident in their assessment of risks caused by pesticides, dam failures, nuclear accidents, etc., when in fact they overestimate the true risks by factors as high as 25 to 1. (This effect may be caused in large part by the availability of news relating to these factors, as discussed above under "Availability.")

People also tend to be sure that bad things "won't happen to them." Even though exposure to smoking, radon, etc. is the same for one person as another, each of us tends to see ourselves as being at a lower risk level than our neighbors. This effect helps explain the shock we feel when something happens to us, but the lack of shock felt when it happens to "the next guy." (This is the same type of situation that leads 85 percent of Americans to rate themselves as "better than average" drivers!)

Desire for Certainty

Similar to our belief that we are somehow different (and better) than others is the fact that we tend to crave certainty and abhor uncertainty. This heuristic leads us to see issues as black and white, rather than gray. The result can be to overreact in either direction.

Example: After a hurricane, residents might convince themselves that such a storm can never happen again. The result is that proper safety precautions aren't taken when rebuilding.

Conversely, accidental discharges at a paper mill caused by a malfunctioning piece of equipment may cause people to try and close down the mill in order to eliminate any more potential hazards. The result may be a total loss of a productive facility when what was required was the replacement of one particular system with another of better design.

Overconfident Experts

When forced to rely on judgement, rather than on data, experts are prone to making the same types of mistakes that the rest of us make. These include overconfidence in current scientific knowledge, ignoring the role of human errors when designing technological systems, and not taking into account ways in which humans may interact with technology.

This is not really surprising. Experts, like the rest of us, are biased towards believing in the value of what they do, and therefore tend to play up the positives.

Example: In 1976, the Teton Dam collapsed. The Committee on Government Operations attributed the disaster to overconfidence on the part of the construction engineers, who were certain that they had solved the many serious problems that occurred while building the dam.

Thus, it is important when assessing risk to include outside investigators whose expertise is in the subject of risk, and not in the specific technical field that is under consideration (e.g., power plant construction, pharmaceutical development, etc.).

Anchoring and Adjustment

It is not uncommon for us to make estimates by starting with a value we know (the anchor) and adjusting from that point. The initial value colors our perception of future events because we judge the probability of the future by looking at what has occurred in the past.

Two of the more common ways in which we adjust our thinking by referring to a given starting point occur when we try to predict the future by examining the present. In one scenario, we will predict the success of an entire project by looking at the probability of success for each of the steps used to construct it. This is known as a conjunctive event, because it is based upon constructing a plan, process or product.

The other common scenario occurs when we start with a completed project, and try to make predictions about the parts by examining the completed structure. These is known as a disjunctive event, because it is based upon disassembly.

Conjunctive Events

Conjunctive events are based on chains of occurrences that are supposed to produce an expected result. Examples include all types of planning processes in which there is a linear progression of steps. Because each step is an independent event, the probability of the step occurring is higher than the probability that the entire project will be successfully completed. This leads people to overestimate the probability that the outcome will succeed.

Example: Let's say you're planning a rally. You map out all of the steps required, from forming a committee, to creating subcommittees, to finding a site, securing a permit, generating publicity, to holding the rally. You estimate the probability of success for each of the 30 steps to be 97 percent. Thus, you feel confident that the rally will occur.

The problem is that because each of the steps is independent, the probabilities must be multiplied together, not averaged. Multiplying 97 percent by itself 30 times produces a true probability of success closer to 40 percent! Thus, rather than looking as if the rally is virtually certain to succeed, it now appears that the odds of success are only 40/60.

Disjunctive Events

Disjunctive events work the opposite way. Because the entire system is functioning properly, we tend to believe that each of the pieces will continue to function properly as well. Thus, we underestimate the chances for a system failure. Even if the probability of failure for each system component is slight, the chance for an overall failure can be high if it contains many parts or components.

Example: Computers, cars, the human body and nuclear reactors are all examples of complex systems that usually function smoothly because the components all have low breakdown rates. But because there are so many parts, it's very possible (even probable) that one will eventually fail. Thus, a portion of the system, or even the entire system may fail, depending upon the parts involved.

You'll note that there is a strong similarity between these two types of heuristics and two fallacies of logic known as **errors of composition and division**. Errors of composition apply standards from a small group to a larger one (if a few ladybugs help control pests, lots of them will work even better). This is similar to the Conjunctive heuristic in which our confidence in one step in an event leads to overconfidence that the entire event will occur as planned.

Errors of division apply standards of the whole system to the components of that system (if the Rolling Stones are a great band, each of the members will have great success as a solo act). This is very much like the Disjunctive heuristic, in which we are overconfident that each of the components will continue to function properly.

It is thus very possible that our tendency to unconsciously utilize heuristic devices explains many of the fallacies found in the study of logic. From this perspective, it becomes clear that errors in logic go way beyond our merely "making a mistake" -- we may actually be programmed to make these errors! Unless we become conscious of our decision-making processes, our reliance on heuristics will inevitably lead to mistakes in logic and ultimately to our making poor decisions.

Representativeness

The representativeness heuristic is based on the fact that we tend to judge events by how much they resemble other events with which we are familiar. In so doing, we ignore relevant facts that should be included in our decision-making process, but are not.

Insensitivity to Sample Size

People have a tendency to apply what they know about a large population to a small sample, or vice versa. The effects of these types of judgements can reduce the opportunity to make good decisions, since they bias our ability to put information in context.

Example: Using small sample sizes in toxicology studies can lead us to believe that a particular risk is lower than it really is. The reason is that small samples increase the probability that researchers won't find a particular relationship when in fact one exists. Thus, by projecting the results of a small sample to the whole population, we underestimate the size of the risk to which the larger population is being exposed.

Conversely, using small samples can also lead us to believe that a particular risk is higher than it really is. Positive correlations found in small samples are subject to high error factors which, when projected to whole populations, overestimate the size of risks to which the larger population is being exposed.

Regression Toward the Mean

Simply put, things have a way of moving toward the middle, which means they "regress toward the mean." This is why the football team that won by a landslide this week will not do quite as well next week, and why the team they beat will go on to have a better game next Sunday. This phenomenon has been studied for over 100 years. (Galton)

The effect of ignoring the statistical tendency for things to change over time is that we attribute results to specific occurrences when in fact the results would have happened anyway. Thus, when an industry complains that regulations are hurting productivity, it is very possible that productivity would have fallen by itself. Conversely, when government claims that pollution controls are working, it is possible that pollution would have declined as a result of normal fluctuations or because levels had been abnormally high during the recent past.

Risk Analysis…

Risk analysis has become the umbrella term for the process of identifying, controlling and discussing risk-related issues. A brief description of these three components can be found below, while more detailed discussions will be included in our module on economics, as well as future modules on public policy, and quantitative decision making.

Risk Assessment

As defined by the National Research Council, risk assessment is the estimation of the probability, and extent of harm posed by, a human health risk. It includes four major components:

1. Hazard Identification -- What is the source of the risk?

2. Dose-Response (Toxicity) Assessment -- What is the increased risk per unit of increased exposure to the hazard?

3. Exposure Assessment -- What is the amount and type of exposure that people have with the hazard? How many people are exposed and for what duration?

4. Risk Characterization -- What is the risk level for people at varying levels of exposure to the hazard?

Risk Management

Risk management is a step up from risk assessment, in that it attempts to develop, evaluate and implement strategies that can reduce risks.

Example: State governments may try to manage the risk of auto injuries by educating the public about the effects of drunk driving or passing mandatory seat belt laws. We may also develop personal strategies to reduce risks -- not driving on Friday nights, appointing a designated driver, driving no faster than the speed limit, etc.

Risk Communication

Because of differing values, perceptions, ideologies and assumptions, clearly and accurately communicating information about risk is extremely difficult.

This difficulty is compounded when risk-related issues are brought into the political and public arenas, where more emotional reactions and involvement tend to occur. To help risk communicators with their efforts to work effectively with the public, legislators and the media, the EPA has established what it calls:

The Seven Cardinal Rules of Risk Communication

1. Accept and involve the public as a legitimate partner.
2. Plan carefully and evaluate your performance.
3. Listen to the public's feelings.
4. Be honest, open and frank.
5. Coordinate and collaborate with other credible sources.
6. Meet the needs of the media.
7. Speak clearly and with compassion.

A Final Thought

While risk analysis is a quantitative process, the people conducting the analyses are subject to all of the cognitive and heuristic biases mentioned in this module. Thus, even the best studies, conducted by the most careful and well-meaning researchers, are subject to the errors which make all of us human and help put at least a little bit of risk into everything we do.

Summary…

Risk is a fact of life, thanks to a combination of this being an uncertain world and our less-than-perfect judgements regarding how best to deal with that uncertainty. The starting point is to recognize why and how we make poor decisions, and to continually apply this knowledge to our ever-evolving quantitative decision making tools and processes.

Here are some ways to think about risk before making a decision:

Risk Analysis Crib Sheet

1. Are there clear benefits involved with the risk in question?
2. Are the risks being borne by the same people to whom the benefits accrue? Or do some people bear risks without having a proportional share of the benefits, or receive benefits without bearing a proportional share of the risk?
3. Has the risk in question been put through an assessment procedure?
4. If research is being quoted, was the sample size large enough to allow for accurate projections?
5. Is the source of the risk-related information a credible professional or government organization?
6. What types of cognitive or heuristic biases could be introduced?

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