What is Risk?

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Risks and Disasters

- Risks and disasters are related notions.
  - Risk of a disaster occurring
    - Global
    - Regional
    - Individual
  - Risks to individuals during a disaster
- Any vocabulary or ontology of disasters should include risks
  - There are many notions of risk
  - Miscommunication can occur if different interpretations of risk are conflated
  - The lexical context of the word “risk” does not always disambiguate the intended interpretation

Topics to be covered

- Many definitions of risk
- Some examples of risk scenarios
- Develop a rudimentary ontology of risk
- Validate the rudimentary ontology
  - Adequate for the definitions of risk
  - Adequate for the disaster lifecycle
- Mathematical theory of risk

The Common Definitions of Risk

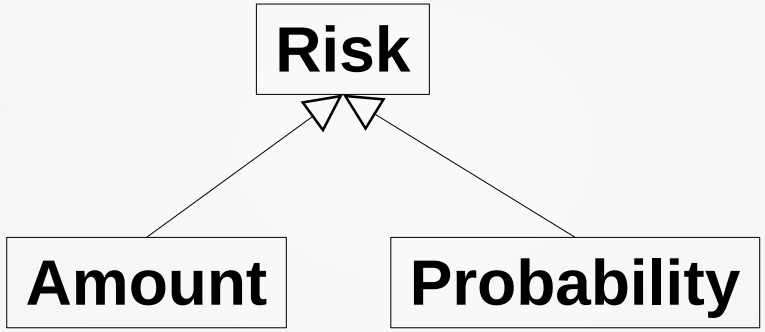
- International Standard
  - “Effect of uncertainty on objectives”
  - Includes both positive and negative effects
- Dictionary (OED)
  - “(Exposure to) the possibility of loss, injury, or other adverse or unwelcome circumstance; a chance or situation involving such a possibility”
  - Only includes negative effects

Simple example

- Consider the phrase “risk $1000 on a venture”
  - What is the risk?
    - The amount $1000 that is at risk
    - The probability that the venture will not achieve the expected return
  - Suppose that the amount was $2000
    - First interpretation: $2000 is twice as risky.
    - Second interpretation: The risk is the same.
  - The common definition is the second interpretation, but the first interpretation seems to be more “intuitive”.

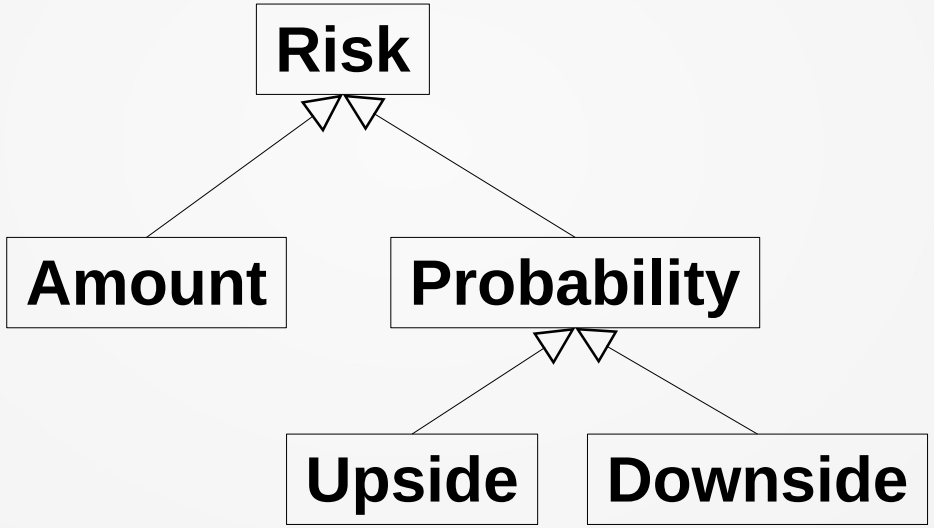
Initial Taxonomy of Risk

- The example suggests the following taxonomy:



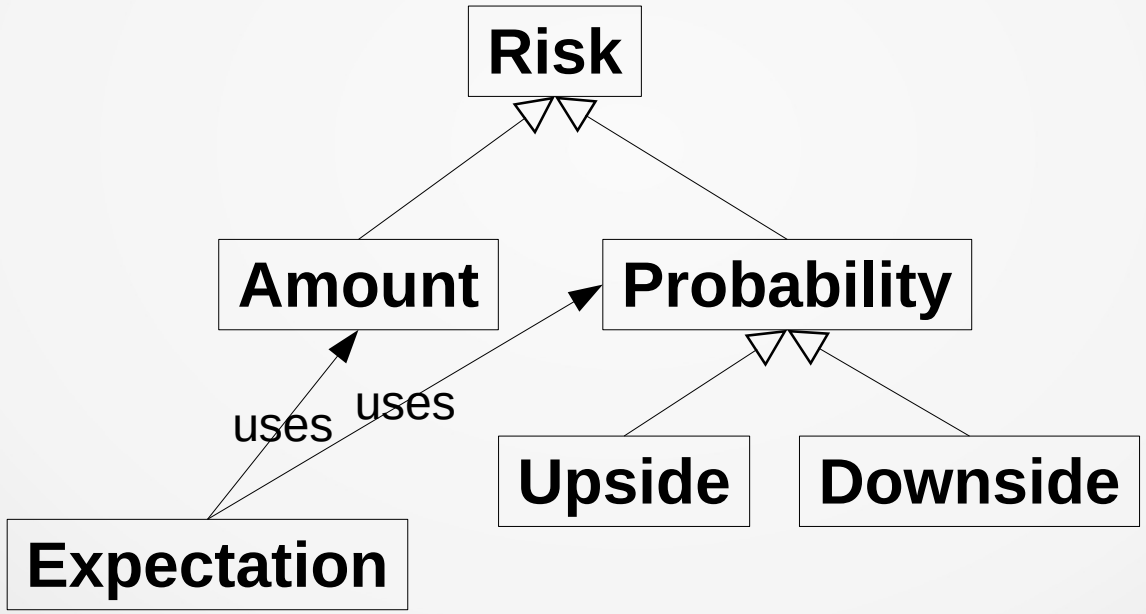
Taxonomy of Risk Continued

- However, a risk can have either a positive or a negative effect
  - A positive effect is an *upside* risk
  - A negative effect is a *downside* risk



Taxonomy of Risk Continued

- Multiplying the amount by the probability produces the expected result
  - Expectation is a term from probability theory

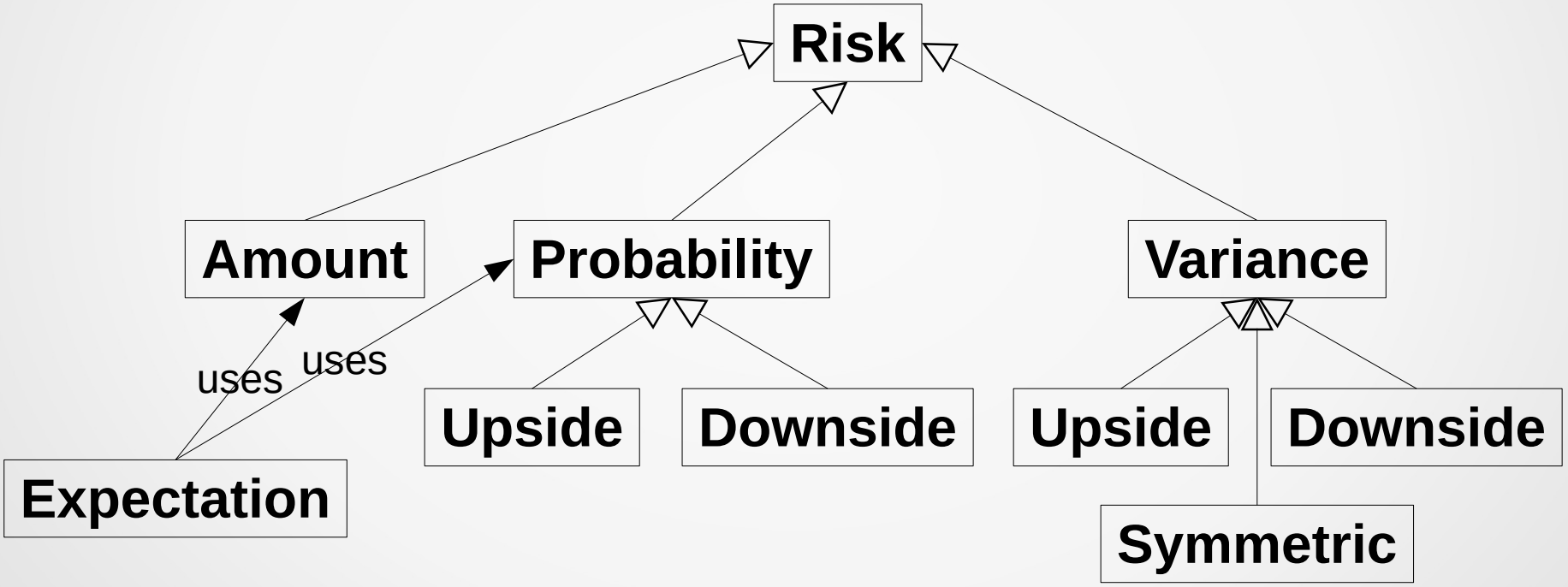


Financial Risk

- None of interpretations of risk just given are the definition of risk in finance.
- In finance, risk is the *variance*
  - Harry Markowitz won a Nobel prize for this observation (Markowitz, 1952).
  - His work is the foundation for the field of **modern portfolio theory**.
- There are three interpretations of risk as variance
  - Symmetric or two-sided
  - Downside risk
  - Upside risk
- Although developed for finance, the same techniques could be applied to other risks

Taxonomy of Risk

- Add risk as variance to the taxonomy



Simple example again

- Consider the phrase “risk $1000 on a venture” again
  - A “safe” venture is one with a low variance
  - A “high-risk” venture is one with a high variance
- Two ventures can represent different risks (using the interpretation of risk as a variance) even if they have the same amount at risk and have the same probability of achieving objectives.

Insurance

- Insurance is a “shared risk”
- For example: automobile accident insurance
  - With no insurance, a rare event could result in an unaffordable cost to the driver
    - The variance is very high
  - With insurance, drivers pay for the average cost of accidents plus administrative costs for the insurance
    - The variance is low
- In general, reducing variance has a cost

Domain Definitions of Risk

- The taxonomy of risk shown above is adequate for many domains. (See the Wikipedia page for risk).
- **Business risk**.
  - Nearly the same as economic/financial risk.
  - However, it is a broader category of risks, some of which use a Probability definition, such as occupational and safety risks.
- **Environmental risk**.
  - The Downside Probability definition
  - Minimizing environmental risk is the same as minimizing the chance of harmful environmental effects.

Domain Definitions of Risk

- **Health risk**.
  - The Downside Probability definition
  - Minimizing health risk is the same as minimizing the chance of harmful health effects such as disease.
  - On the other hand, health insurance is a form of insurance, and risk for insurance has a different meaning.
  - In addition, healthcare is starting to recognize the need for improving quality of life (i.e., upside risk) as well as minimizing diseases (i.e., downside risk).

Domain Definitions of Risk

- **Information technology risk**.
  - The Probability definition
- **Occupational risk.**
  - The Downside Probability definition
  - Special case of safety risk.
- **Project risk**.
  - Both Downside and Upside Probability definitions
  - The probability of positive effects should be maximized, and the probability of negative effects should be minimized.

Domain Definitions of Risk

- **Safety risk**.
  - The Downside Probability definition
  - Minimizing safety risk is the same as minimizing accidents.
  - Note that safety, health and environment risks are related to each other.
  - On the other hand, accident insurance has a different definition of risk, as noted above.
- **Security risk.**
  - The Downside Probability definition

Risks in the Disaster Lifecycle

- **Identifying**
  - *Determining potential disasters*
    - Disasters have a range of outcomes and severities associated with the outcomes. For example, automobile accidents can range from minor “fender benders” to major accidents involving loss of life. Note that disasters can have both positive and negative effects. For example, naturally occurring wildfires may have beneficial effects on native vegetation, animals, and ecosystems that have evolved with fire (Hutto, 2008).
  - *Planning to deal with disasters*
  - *Estimating probabilities and costs*
    - The probability of a potential disaster is one factor in determining the risk of an identified disaster. The other factor is the cost (which can be negative for a positive effect). The product of the probability and the cost is the expectation (in the probabilistic sense of this word) of the cost of the potential disaster. Since disasters have a range of outcomes, there will generally be a probability distribution rather than a single probability associated with the potential disaster.

Risks in the Disaster Lifecycle

- **Mitigating**
  - *Reducing risks*
    - Risk reduction is the process of actively reducing the expectation (see above for what this means) of the cost of the potential disaster.
  - *Analyzing costs and benefits*
    - Risk reduction has a cost. So engaging in risk reduction should be justified by a cost/benefit analysis. If the cost of mitigating the risk exceeds the reduction in the expectation of the cost of the potential disaster, then it would appear that a rational course of action is to "take the risk" without attempting to mitigate the potential disaster. However, such a course of action is only realistic if the affected entities can afford the costs of the most severe outcomes. This is where risk as a variance rather than a probability becomes relevant.

Risks in the Disaster Lifecycle

- **Monitoring**
  - *Tracking a disaster as it is occurring*
  - *Managing knowledge*
    - Ontologies could be useful for managing knowledge
- **Managing**
  - *Dealing with the disaster*
  - *Communicating among disaster relief entities*
    - Avoiding miscommunication is important

Portfolio Theory

- Portfolio management requires two inputs
  - The investment vehicles (stocks, bonds, funds, etc.)
  - The level of risk tolerance
- The first step is to select the potential investment vehicles
  - For example, “Only invest in eco-friendly companies”
  - Requires some effort to investigate
  - In practice, an investment vehicle is either acceptable to or not.
    - No partly acceptable vehicles

Portfolio Theory

- The second step is to maximize the return of the portfolio subject to the risk tolerance
- R is the risk (or return) vector
  - Consists of a random variable for the return of each investment vehicle
- W is the weight vector
  - Stochastic vector whose entries determine the proportions of the total portfolio for each investment vehicle
- $P = W^T R$ is the return of the portfolio as a whole
  - T is the matrix transpose operation
- $E(P) = W^T E(R)$ is the expected (average) return of P

Portfolio Theory

- Var(P) = $W^T Cov(R) W$ is risk associated with the portfolio W
  - Cov(R) is the covariance matrix of the random variables in R.
  - Use a one-sided covariance matrix for downside and upside risk.
- L is the maximum level of risk that can be tolerated.
- The objective is to maximize E(P) subject to Var(P) ≤ L.
  - This is a quadratic programming (optimization) problem.
- There are many methods for solving quadratic programming problems (Nocedal & Wright, 2006)
  - Software is freely available from many sources (See Wikipedia)
  - Software is freely available that will determine the best portfolio for a specified level of risk tolerance and selection of investment vehicles

Portfolio Theory

- Other techniques have been developed for portfolio management. However,
  - Every alternative technique improves one issue at the expense of other issues
  - The risk tolerance is only seldom exactly known
- So the basic portfolio management technique is good enough.

Conclusion

- There are many kinds of risk.
- It is important to be precise about what one means by risk to avoid miscommunication.
- We surveyed different kinds of risk in various domains and different phases of the disaster lifecycle
- A taxonomy was developed that is adequate for the domains surveyed and for the disaster lifecycle
- Financial risk was developed in more detail.
- Financial risk techniques might also be applicable to risks of other kinds, including disasters such as pandemics or environmental disasters.

Acknowledgement and References

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