Basic Training 4: Risk Analysis

Student Workbook

A Program of The Actuarial Foundation
Modeling the Future Challenge

The Modeling The Future Challenge

As part of the Scenario Phase of the MTFC, teams will be demonstrating and applying their mathematical analysis skills to a scenario response paper as well as identifying a potential project and writing a proposal. The Actuarial Process Guide to be an invaluable resource.

- The Actuarial Process Guide

How to Use this MTFC Risk Analysis Scaffolding Guide

When all of the potential topics in the world are at your fingertips, identifying a topic, identifying possible risks, finding sources, mathematically modeling, and studying risks can seem overwhelming to begin. This guide will help scaffold the process and guide participants through the process of risk analysis in the MTFC Project Proposal. Each task refers to a specific section of The Actuarial Process Guide for more in-depth information.

Content: The process is scaffolded into 1 explanatory lesson and 2 total tasks.

Suggested pacing: 1 task per week for 2-3 weeks. Completing the *Basic Training 3. Mathematical Modeling* resource first will provide context to the scenario and scaffolding procedure.

Common Core Standards for Mathematical Practice

The Common Core Standards for Mathematical Practice. The MTFC Project Proposal specifically addresses the following standards:

- ❏ CCSS.MATH.PRACTICE.MP1 **Make sense of problems and persevere in solving them.**
- ❏ CCSS.MATH.PRACTICE.MP2 **Reason abstractly and quantitatively.**
- ❏ CCSS.MATH.PRACTICE.MP3 **Construct viable arguments and critique the reasoning of others.**
- ❏ CCSS.MATH.PRACTICE.MP4 **Model with mathematics.**

4.1 Fundamentals of Characterizing & Quantifying Risk

Risk and Loss

The Oxford English Dictionary defines risk as "a situation involving exposure to danger." However, actuaries and other insurance professionals use the term in a narrower sense. A **risk** is the *uncertain* possibility of something harmful happening. This might involve the loss, theft, or damage of property, or it may involve a person being injured or dying.

A **loss** occurs when an event anticipated as a risk takes place. A risk is a potential for a loss. A loss is the realization of that negative potential. A risk is playing in traffic. A loss is getting hit by a car while doing that. Not all risks result in losses, and not all losses result from risks.

What makes a loss insurable?

1. It is a **pure risk** (or event risk), which refers to an uncertain situation where the opportunity for loss is present but the opportunity for financial gain is absent. Speculative risks refer to uncertain situations that might produce a profit or a loss, such as business ventures, market trading, or gambling transactions. Speculative risks are almost never insurable.

2. The loss must be **accidental**, meaning that it is the result of an unintended action and is unexpected in its exact timing and impact. A landlord burning down his or her own building is not insurable. Losses caused by a divorce are not insurable.

3. One must be able to demonstrate a **definite** proof of loss, and the amount of the loss must be a **measurable** amount. If the existence of a loss cannot be definitively established, or the extent of the loss cannot be calculated, then the loss is not insurable.

4. The loss must be **statistically predictable**, meaning it must be possible to use statistical and mathematical techniques to estimate how frequently a loss might occur and the severity of the loss. Lack of statistical predictability is one reason why earthquakes are generally considered non-insurable events.

5. The loss must be **non-catastrophic**. Nuclear war is not insurable.

6. The number of exposures to any specific event must be **sufficiently large** to allow the insurer to make a reasonable prediction about the loss related to that event. Furthermore, the number of exposures must be **independent** (often this can only be partially accomplished) and encompass a **statistically random** sample of the overall population.

7. The loss must result in **non-trivial economic hardship**. If it does not, then there is no reason to insure against the loss. You cannot insure against breaking your house key in the lock and needing the services of a locksmith.

8. The insurer and the insured must share a **common understanding** of the risk, which is why insurance contracts are so lengthy (which often ironically results in the insured NOT understanding the risk).

This material was adapted from resources created by Alberto L. Dominguez.

Quantifying Risk

In the MTFC, risks must be quantified in some meaningful way. Not all risk has an inherent or measurable value, but assigning a description to the way that risk is being identified and quantified will go hand-in-hand with the assumptions made in your Math Modeling section.

Some values that can be used to quantify an identified risk:

- expected value
- standard deviation & variance
- confidence intervals
- histograms
- projecting trends (possibly linear regression)
- distribution of results

Qualifying reports do not leave risk analysis in general, qualitative forms but instead measure and describe risk in quantitative ways. But how do you actually do this?

1. **Identify Risks:** the first step in your risk analysis section is to identify what risks there may be. It is fine to start off by simply writing these out. Once you have a good list of potential risks, you can then analyze the numbers and quantify the risks.

   For example, consider an example project in the fictional city of Farmland, USA. This city's population is primarily made up of pecan farmers. Imagine in our project we can identify two key things about water access in the coming decades: (1) Farmland, USA will have 20% less annual precipitation by 2050 than it does today, and (2) Farmland, USA will have a 20% increased chance of having a devastating severe summer storm than it does today – increasing from 1.2% chance to 1.44% chance.

   From these two facts, we might be able to identify these risks:
   - Farmland, USA pecan farmers may be at risk of not having enough water to irrigate their crops.
   - Farmland, USA pecan farmers may be at risk of losing crops due to increases in severe storms.

2. **Make and Validate Assumptions**: once you have identified a few potential risks, you may need to make some assumptions about how your data projections will impact the risks you have identified. For example, consider the following assumptions (remember that this is a VERY SIMPLIFIED example, and your real project may need to go into more depth with your assumptions):

   - We assume that the amount of precipitation directly correlates to the amount of water available for pecan farmers in Farmland, USA.
   - We assume that all severe storms calculated in our projections are equally severe an are above a threshold where they would result in a loss of 50% of farm production for the entire city of Farmland, USA.

   Make sure that you can validate your assumptions with some kind of background data or logical reasoning. It doesn't matter so much what assumptions you make, so long as you have sound data and reasoning behind them.

3. **Quantify Risks**: use other numbers to identify the severity and frequency of the risks you calculate. In our example, you may need to identify the price pecans sell for, or the change in output of pecan farms per acre, or other data about the economics of pecan farming. Let's assume the following:
    - Pecan prices are $10/bushel.
    - Farmland, USA includes 10,000 acres of pecan farms.
    - Each acre of pecan farms typically produces 250 bushels during a regular annual growing season.

    With these very basic assumptions and numbers we can make some simple quantifications of the risks:
    - With our assumption of a direct correlation between precipitation and water available for farming, by 2050, the projected trend means that there will be 20% less water available for farmers in Farmland, USA, and they may have to cut their production by 20%. This would result in a potential loss of $5,000,000 a year for the farmers of Farmland, USA.
    - The total annual value of Farmland, USA pecan crops is $25,000,000. With our assumption that the occurrence of a severe storm will result in a 50% loss of pecan crops, a 5% increase in these severe storms (from 1.2% chance to 1.26% chance) means that the expected value for pecan profits for Farmland, USA will go from $24,850,000 today, to $24,820,000 in 2050. Or a loss in expected value of $30,000.

Task 4.1: Identifying and Quantifying Risk

For this task, consider water quality in the USA as a whole (think broader than just the 5 suburbs in that initial scenario). The topic is considerably broad (and more reminiscent of what you will encounter when approaching your MTFC project) and leaves a lot of areas for identifying risk (potential for loss).

- Who or what is at risk when it comes to water quality in the USA?
- With each risk that is identified, how could it be measured, counted, or otherwise quantified?

Who/what is at risk?	How can that risk be quantified? What kind of data?

Task 4.2: Water Quality Scenario Risk Analysis

Continue referencing the water quality scenario and data introduced in Basic Training Resource 2.

Questions	Response
If the acceptable limit of average lead content in a child's blood is between 0 and 11 µg/dL, does the EPA need to take action in any of the suburbs? What are the risks of strictly adhering to these limits? Use data to justify your answer. Which suburbs have an average lead content above this level? What percentage of children in Montgomery are above the EPA's cutoff? Is there a risk in strictly using the 11 µg/dL marker to identify when the EPA should take action in a suburb? Use the data to explain and justify your answer.	
What are some risks of dividing the data up into suburbs? Are there any solutions to these risks?	
Is it dangerous to evaluate the situation based on the quantitative analysis of this data alone? What other data could make this analysis better?	

After collecting the data, the statisticians realized that the samples were not randomly selected. What kind of problems can this create in our models?	
It is discovered that the 20 highest blood concentration samples from the Mason suburb observations were all from the same street, and all the houses were constructed in 1950 with lead-based paint that was proven to increase the lead concentration in blood of a child by 15 μg/dL. If these effects are taken into account, how will our analysis change? Cite specific numbers. EFFECTS ARE INDEPENDENT	
How would an insurer and the EPA evaluate this situation differently? Be sure to mention acceptable levels of risk.	