A Program of The Actuarial Foundation

Modeling the Future Challenge

Actuarial Process Guide

The Actuarial Foundation

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Challenge Development Committee

The Modeling the Future Challenge is supported by a volunteer committee of actuaries who have dedicated time to reviewing challenge resources and materials. The current Challenge Development Committee (CDC) includes the following members:

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Roy Goldman, FSA, helped launch the MTFC as a founding sponsor and volunteer for the Challenge's first three years. In addition to the Current Challenge Development committee, Roy has worked tirelessly to help bring the vision of the Actuarial Process Guide (APG) to life. A special thanks to Steve Alpert, Bob Conger, and Paul Heffernan for the substantial updates to the the APG over the summer of 2024.

www.actuarialfoundation.org

About The Actuarial Foundation

TThe Actuarial Foundation is a 501(c)(3) organization committed to changing lives through math education. Established in 1994, our mission is to unleash the power of math education and transform futures by leveraging the talents and resources of the actuarial community. Our vision is a future where everyone experiences confidence and opportunities available through math proficiency. Built upon two years of pilot programs, the MTFC is becoming one of the premier academic competitions for high school students. In 2016, the Foundation engaged the Institute of Competition Sciences – a leading academic challenge design firm – to help make this vision a reality and ensure that the Modeling the Future Challenge has a lasting impact on students across the nation.

www.competitionsciences.org

About The Institute of Competition Sciences

The Institute of Competition Sciences (ICS) is a world leader in challenge-based learning and STEM competitions. ICS has led National Science Foundation awarded projects, worked with the White House Office of Science and Technology Policy, and developed and operated high-profile prizes with over $14,000,000 in awards with NASA, the Lemelson Foundation, the Methuselah Foundation, The Actuarial Foundation, and many others. ICS has been defining best-practices in Challenge-Based-Learning since 2012 and maintains a world-leading expertise in using competitions to revolutionize how we approach learning. We are turning STEM education into an exciting challenge for all students, and are bringing this expertise to the Modeling the Future Challenge.

Overview

The Actuarial Process as outlined in this Guide extends your mathematics and science knowledge into the world of data analysis and risk management. It helps you become successful at identifying, characterizing, modeling and managing risks in all aspects of your life.

If you had a crystal ball to tell you exactly what will happen in the future, there would be no need for the Actuarial Process; however, the future is uncertain, and the Actuarial Process provides an organized approach to understanding that uncertainty and making sound decisions based upon your analysis. Success isn't about being risk-averse, it's about understanding probabilities and quantifying potential outcomes to take the right risks.

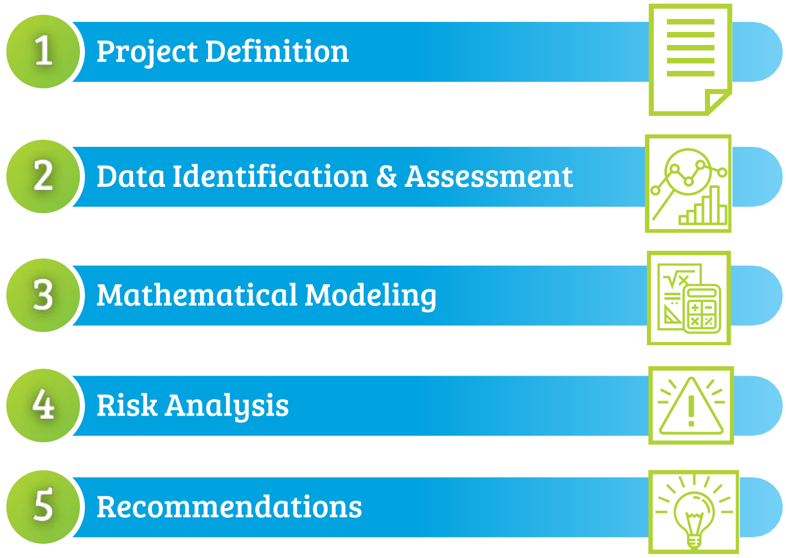
To be great at navigating the choppy waters of the future, you must become great at managing risks. No matter what your interests or career aspirations, you'll want to understand the Actuarial Process, and learn to use it anytime you're in a situation where you need to make a decision involving uncertain outcomes.

Modeling the Future Challenge & The Actuarial Process

A model is a simplified representation of relationships among real world entities, events, actions, and outcomes. To better understand future uncertainties, actuaries create models of those uncertainties and use the models to recommend actions to manage or respond to those risks.

The Modeling the Future Challenge (MTFC) has an "open theme" in which students choose their own project topic. The Actuarial Process Guide ("APG" or "Guide") is designed to guide students through the stages of identifying a project topic, conducting quantitative and qualitative analyses of that topic, and making a recommendation to the target audience–just like actuaries do for their companies and clients.

The Actuarial Process builds on core concepts from scientific inquiry, data analysis, and mathematical modeling to provide a framework through which you can identify, characterize, and manage future risks for real-world situations. The process helps you understand the dimensions of the risks associated with the topic you are researching and make recommendations to manage those risks. It is defined by five overarching parts, seen in the diagram to the right.



The Actuarial Process brings together a wide range of skills, including traditional mathematics and science, critical thinking, logic, and communication.

In this Guide, we highlight methods that students can use to complete an actuarial project and compete in the Modeling the Future Challenge, The Actuarial Foundation's signature competition for students. We provide tips for each part of the Actuarial Process and include supplementary materials on our website to practice key aspects of the process.

The Actuarial Process Guide is directly connected to the Modeling the Future Challenge; however, it also provides a larger benefit by helping you become a better risk manager throughout your education and career. Learning the Actuarial Process can also help students in many academic competitions such as science fairs and other research challenges. Whether a student goes forward to become an actuary or not, completing a project following the Actuarial Process provides valuable life-skills that will help in the college and career choices ahead of them.

While the Actuarial Process defined in this Guide is a broad road map to understanding risks and risk management, it does not cover the full spectrum of what actuaries can address. This Guide is meant to help students produce a strong project for the MTFC and gain a high-level understanding of the kind of risk analysis and modeling that actuaries undertake. This Guide makes several generalizations and simplifications to allow students to complete each step of the process and to produce a polished final project.

Learn Life Skills

Many students with interests in mathematical modeling, problem solving, and data analysis skills enjoy the process of exploring data, developing a strong mathematical model, and analyzing risks. The ultimate goal, however, is not to develop the most amazing math model or extensively detailed risk analysis. ***The point of conducting a risk modeling project is to identify a risk mitigation strategy and effectively communicate to an appropriate audience the positive impact that implementing this strategy will have on the future of your topic.*** Communication of the results is the ultimate goal when undertaking this project and honing effective communication skills (both written and verbal) will serve students well not only in the MTFC, but in the real world as well.

The Actuarial Process

Summaries of the five steps of the Actuarial Process are listed below. The following pages include detailed explanations, specific topic descriptions, examples, and tips for understanding and utilizing each of the steps of the Actuarial Process. Each of the phases of the MTFC has materials that are structured around these five steps to help student teams effectively formulate their own risk modeling projects.

1 Project Definition

Conduct background research and identify a topic for your project by writing a problem statement. The project definition articulates the overall purpose and target audience for your project.

2 Data Identification & Assessment

Research and assess the available historical data for your project topic to develop a math model, conduct a risk analysis, and ultimately form recommendations suggested by your problem statement.

3 Mathematical Modeling

Develop mathematical, computational or analytical models that will transform the data and assumptions into output that is useful for answering your problem statement.

4 Risk Analysis

Use the output from your actuarial model to characterize and define the range of potential risks, as well as the costs and benefits of any potential mitigation strategies.

5 Recommendations

Use the risk analysis to identify risk mitigation strategies and make recommendations to affected stakeholders on how to best manage the identified risks. Conclusions are communicated to your target audience.

The Actuarial Process is often iterative – at any point, you might learn something that causes you to loop back and refine an earlier step and then carry those refinements forward.

1 Project Definition

Modeling projects following the Actuarial Process use mathematics to analyze risks and make recommendations to groups that may be affected by those risks. To start the Actuarial Process and create your Modeling the Future Challenge project, you will first want to understand what kinds of questions can be answered and explore topics that are most interesting to you.

You will need to conduct background research to learn more about the topics that interest you. You will then use this research to narrow your ideas down to one topic. You will define your project by creating a "problem statement" that identifies three critical components of your project. This will provide a framework that will help guide you throughout the rest of the process.

MTFC Project Step 1: Creating a Problem Statement

To start your MTFC project, create a problem statement that:

1. **Identifies a risk** (i.e., a potential economic loss, property loss, opportunity loss, loss of life or health, etc).
2. **Defines who is at risk** and the target audience for the recommendations.
3. **Identifies possible risk mitigation strategies**, at a very high level.

Developing a strong problem statement is an iterative process, but a critically important first step, as it will serve as a template or guide for the entire MTFC project. It is common that after doing some background research, or even starting your analysis, you may want to come back and refine your problem statement based on what you learned. Use your problem statement drafts to help you select the final topic for your project. If you aren't happy with or aren't able to identify the three components of your problem statement, go back and refine them or start again with a new topic.

The following sections define each of the three components of your problem statement. Some examples are provided on the MTFC Resource Library (mtfchallenge.org/resources) to help display how to create a problem statement and what kinds of problems can be addressed by the Actuarial Process.

1.1 Identifying a Risk

You will hear a lot of reference to "risk" in this Guide and throughout the actuarial world. Our lives are filled with risks of all shapes and sizes. What makes the Actuarial Process so powerful is how it uses mathematics to characterize and quantify those risks. With this process and real data you will be able to make sound recommendations to help navigate any risky situation you may face; but first, you must understand what "risk" is.

In short, a risk is a chance for a loss.

It is a chance that an **undesirable event** will occur within a specified period of time with some value (often financial) attached to that event. To characterize risks you need to understand what possible adverse outcomes exist for the topic you are researching. Identifying the possible outcomes will allow you to attach different values of potential loss ("severity") to each possible outcome. The project definition task is to qualitatively describe the scope and likely boundaries of the risks you are investigating. In the modeling and risk analysis parts of the project you will be expanding the quantitative details of the risks you identified.

EXAMPLE PART 1.1.1

Identifying Risk

To illustrate the Actuarial Process, we will use a simplified case study based on the real-world example of driving.

Imagine that you have recently have obtained your driver's license and want to use the family car, but your parents warn you that you will be responsible for anything that might happen while you are driving. They have asked you to work with them to develop an analysis of potential undesirable outcomes during your first year of driving. In this scenario, what are the risks you might identify?

You may determine that there are several types of potential losses if you are involved in an accident:

- There could be damage to the car, ranging from a minor scrape to extensive damage that exceeds the value of the car.
- There could be damage to other people's property (including their car), again ranging from minor to very expensive.
- There could be injury to yourself or others.

In the next step, we will discuss the background information and data potentially needed to quantify these risks.

In mathematical terms, a **risk**, or loss can be broken down into three critical components:

Severity

The severity: the nature, characteristics, and severity (or range of severity) of the undesirable event.

Likelihood

The likelihood (estimated future chance, considering actual historical frequency) the undesirable event occurs.

Uncertainty

The uncertainty as to the severity, likelihood and/or the timing of the event.

EXAMPLE PART 1.1.2

Defining Severity of a Risk

For simplicity in our example, we will focus on only the first outcome (**damage to the family car**) from the example above; similar analysis would need to be applied to the other outcomes to get a complete picture of all the risks associated with driving.

The financial risk for loss comes from the cost of repairing or replacing the car. If it would cost $20,000 to replace the car, this provides a maximum value for the severity of this particular risk in this particular situation. However, you also need to know the cost of repairing the car for a lesser degree of damage. How could you find this cost? You might be able to survey local body shops or find online costs to understand the range of costs they have charged for a variety of repairs that have been done in the past.

Let's say you determine from your analysis that repair costs range from $400 to $25,000. Some repaired cars might have been more valuable than the current $20,000 value of your car; however, for your purposes, you might include all values of $20,000 or more in the same severity bucket.

For your initial problem statement, being able to identify the risk at this level of detail is enough; however, as you move through your project you may find that there are more components to your potential risks than first meet the eye.

Although our example focuses only on damage to the family car, don't forget that there are other potential costs to an accident:

- What could happen to other automobiles?
- What could happen to other property — either privately owned or government owned (for example, roadways, dividers or light poles)?
- Who could be injured and what types of injuries could they suffer? Drivers, passengers, people in other cars, pedestrians
- Are there second-order effects, such as increases in future insurance rates or loss of driving privileges?

In the Actuarial Process, "**frequency**" refers to the number of specific outcomes — either past events or simulated future events — per the total number of observations. "Likelihood" refers to the estimated chance – beforehand - that an event will occur. To model the future, you will need to make estimates about the future likelihood of the specific types of events and outcomes you are investigating. In many cases, understanding the frequency of past occurrences of the same type or similar event or outcome is a good place to start. You then will need to make forecasts or assumptions about changes in the frequency of the events and outcomes in the future.

For example, you could roll a 6-sided die and record the outcome. You don't know what number you will roll, but you also don't know if it is a fair die or not - there is uncertainty that comes with rolling the die! You roll one die and you assume (knowing nothing else) that each side is equally likely to come up but you don't ***know*** that, so repeated tossing of the die is how we establish the probability distribution of the potential outcomes. Inherently, you often are making decisions under conditions of uncertainty since you don't know what is going to happen in the future.

EXAMPLE PART 1.1.3

Defining Likelihood of a Risk

The **likelihood** of a risk (or potential for loss) is typically expressed as a probability or probability distribution that the loss will happen. If there are multiple potential undesirable outcomes, as in our example, you will need to think about the likelihood of each of the different outcomes.

Another important issue to explore is whether the individuals or entities subject to the risk will be subject to identical probabilities or if there are subgroups for which the risk probabilities might be different.

In the car driving example, you might need to consider a number of items to help define the likelihood of the risk:

- What has been the **past frequency of automobile accidents**?
- Are there **classifications** of people, such as younger or less-experienced drivers, that historically have incurred accidents at a higher than average frequency?
- Are there factors that might be causing the frequency to change over time?

In your initial analysis, this is a great start! In your project, look for all the ways you can find to refine the definitions and severity/likelihood calculations of your outcomes to improve the quality of your estimates.

EXAMPLE PART 1.1.4

Identifying Potential Uncertainty of a Risk

As you consider how to **estimate the future severities and likelihoods**, you should also consider ways in which those estimates might not be borne out in the future. Recall that probabilities provide useful information about the range of results for a large number of trials; but very little information about any particular trial or observation. In our example:

- Suppose your likelihood of having an accident next year is 1/10. Of course, you can't have 1/10 of an accident! You either will (10% likely) or won't (90% likely). How will your analysis handle this uncertainty?
- How might your particular risk differ from the average of "similar" people?
- Are the characteristics you identify as "similar" actually the correct ones and actually the root causes of the risk?
- Are you able to distinguish between causes and correlations? What might be the consequences of the answers?

MTFC Tip | How much should be quantified at this point?

For your problem statement, you won't need to quantify your risks using likelihood and severity. Simply identifying the potential risks is enough to get started. However, as you move further into your project you will want to think about how you can quantify risks associated with each of the possible outcomes to your project topic.

1.2 Defining Who Is At Risk

In any situation involving risk, there may be multiple types of parties affected by an undesirable event. People, organizations, companies, or government groups may all face the same undesirable outcome (perhaps with different likelihoods), or they may face different outcomes that stem from the same situation. This is where your critical thinking skills are put to the challenge. It's important to look at the topic you're researching from multiple angles to understand all of the parties that may play a role in the possible outcomes and that may have a potential for loss.

To define who is at risk, you will want to look at your topic from as many viewpoints as possible, consider all of the groups that may be affected by each of the potential outcomes in your project.

You will also need to think about who is the target audience for your recommendations. Considerations for the target audience include how they relate to or interact with sources of risk, and with the parties who are subject to loss from the risk.

Keep in mind!

*There may be a difference between **who is at risk** in a topic and the **audience for your recommendations**.*

In this stage of the Actuarial Process, you are focusing on identifying **who is at risk**. In a later step, you'll identify to whom you will address your recommendation for risk mitigation; each recommendation needs to be made to a specific audience. You can make multiple recommendations to multiple audiences, but they need to be specific to whom you are making a recommendation and why that audience is the target (who is going to take action). The one taking action may not be the one facing the risk.

EXAMPLE PART 1.2.1

Defining Who is at Risk

In our example where your family is considering your ability to drive the family car, who might be the audience for your analysis? Certainly, you, as the potential driver, would be a prime candidate for the audience for your analysis, but are there others?

You might also consider a project looking at the risks from your parents' point of view. What about other drivers or pedestrians? What about the insurance company's perspective? Or the state government? Could they have an impact on the potential outcomes or could they be affected by the possible results of this scenario?

1.3 Identifying Risk Mitigation Strategies

At the beginning of your project – before you begin analyzing data in detail or building mathematical models – it is important to think about how various parties (such as particular categories of individuals, specific industries, governments, schools) could help mitigate the risks you have identified. Visualizing potential types of strategies to mitigate the risks will help you seek out useful data; define the structure of your models and analysis; and work towards describing, evaluating and recommending (or advising against) specific strategies.

There are three categories for risk mitigation strategies:

Behavior Change

Changing the behaviors of people and/or organizations so as to reduce the likelihood of an undesirable occurrence.

Modifying Outcomes

Modifying the outcomes of undesirable events that do occur.

Insurance

Using insurance to absorb some of the financial consequences of an undesirable event.

Section 5 of this Guide provides a discussion of these three categories, and illustrates them using the automobile example.

Your problem statement should include short, general indications of the types of strategies you will be analyzing. Your MTFC project can recommend any type of mitigation strategy; you should consider at least one potential mitigation strategy in each of the three categories above. Do not expect to have the detailed strategies formulated at the beginning of the project: you will learn a lot more as you work through your research, data analysis, and modeling.

In fact, it is important that you not become firmly wedded to a particular mitigation strategy before you have conducted your analysis. Doing so may impair your critical examination of that strategy and your openness to other ideas. As a result of your analysis in later stages of the actuarial process, you should expect that you may reject some of your initial ideas for mitigation, modify others, and add some new mitigation ideas that you did not identify at the beginning of the project.

1.4 Important To Know Before Finding Data & Mathematical Modeling

Before you get too deeply committed to a particular topic, you will want to understand several things about your project topic. Particularly, you will want to explore some probing research questions:

1. What background information about the topic can you find? (size of the industry, existing impacts, how the products, policies, or industry currently operate, etc.)
2. What is changing? Are there existing forecasts for what is expected to change? Are these quantified?
3. What risks may occur from the scenario you are exploring?
4. What data is available? Is the data sufficient to develop a model of the future outcomes? Is it sufficient to reveal how different subgroups are affected differently by the risk?

EXAMPLE PART 1.4.1

Background Research

In our example of the risks involved with a new driver, what background information might you want to know before wrapping up your problem statement? Here are a few example ideas:

1. Relative to the number of cars in the area, how many accidents have there been in the past few years?
2. At a high level, what are the characteristics of the drivers involved in accidents? Are some categories of drivers more frequently involved in accidents than others?
3. What have recent costs or insurance claims been for the broad categories of risk (own car damage, damage to other property, driver injury, injury to others)?
4. What are current state requirements for new drivers?
5. Has there been any research or "natural experiments" – jurisdictions or time periods with different characteristics – that might illustrate the potential effectiveness of some mitigation strategies?

Background research can be a great help in determining how to structure your Problem Statement. In some cases, you might find that there simply isn't enough data or information to explore a topic, or not in the way you thought. However, maybe if you shift your problem statement to a somewhat different perspective, or a different type of mitigation strategy, it will become more straight-forward.

EXAMPLE PART 1.4.2

Wrapping Up a Problem Statement

In our new driver example we can see that there are many ways you might structure your project. There are different groups that may be affected by your being involved in an accident, and there are many ways that those risks could be managed. How would you write your problem statement for this scenario? Here are two different examples of a problem statement using this simple example as a starting point:

1. Having a new driver in the family can expose both the family and the driver to significant risks and costs for the necessary insurance. We explore the costs and benefits of various changes in behavior that can help manage those risks and minimize the related insurance costs.
2. Rapidly rising automobile insurance costs are a sore point for many families, particularly those with relatively new drivers. We explore the main drivers of rising insurance rates and potential incentives that could be offered to consumers to encourage better driving habits or purchasing safer cars.

To conclude part one of the Actuarial Process for your Modeling the Future Challenge project, **you should be able to write a 1 to 3 sentence problem statement that defines your project.** You should also have conducted initial background research to help you identify each component of your problem statement. You should be able to answer fundamental questions about your topic like the size of the industry or field you are examining and the potential for loss. This background research will help you confirm if you have enough information to complete a project on the topic.

MTFC Tip

What Makes a Good MTFC Problem Statement?

1) It identifies a situation in which there is a possibility for a loss (risk).

2) It identifies what the potential risk is (in general terms).

3) It identifies who is at risk.

4) It identifies possible risk mitigation strategies at a very high level.

Remember, that problem statements are not set in stone. As you move forward with the next steps of the Actuarial Process, you can always come back and modify your problem statement based on what you find.

2 Data Identification & Assessment

The second part to the Actuarial Process is to identify the data that will be required to create a strong mathematical model of potential outcomes for your project scenario. Oftentimes in actuarial analysis these datasets already exist; however, in many cases, once you start to explore what data is available, you may find it valuable to go back and revisit your problem statement.

There are three key aspects of identifying data that are important to understand outlined in this step:

1. what types of data will enable a good analysis?
2. where can you find reliable and relevant data sets?
3. how can you assess the reliability of the data you have identified?

The data will be used in the creation of your mathematical model that will enable you to conduct a risk analysis and ultimately, formulate recommendations on risk mitigation to the stakeholders you identified.

A key tool used by actuaries – throughout each stage of the Actuarial Process – is **data visualization.** In data visualization, you create and examine some pictures from your data as you are gathering data for your analysis and becoming familiar with each data set. At this step of the Actuarial Process, **graphical tools such as scatterplots, histograms, or regression analysis can be helpful in understanding your data**; reviewing for gaps and inconsistencies; and identifying questions about the data that may be important for you to explore.

Data visualization will be just as important as you move into subsequent steps of the Actuarial Process and journey through this Guide. Data visualization with help you with further exploratory data analysis, model-building, projections into the future, risk analysis, and examining benefits and costs of several different potential risk mitigation measures. Almost always, a few carefully-selected data visualizations will add clarity and power to your report and presentation, telling a compelling story-at-a-glance about the risk you are analyzing.

2.1 What Types of Data Enable a Good Analysis?

An overarching rule-of-thumb to what makes data valuable is that it should **help you refine the potential outcomes of your scenario or characterize the risks associated with those outcomes**. It can be a challenge to identify quality and appropriate data that will enable a good analysis. Ultimately, “good data” will help you define historical trends and increase the accuracy of predicting future outcomes.

As you think about the data you hope and expect to find (and then actually go about searching for the data), you should recognize that not all data is created equal, nor will it all be useful. Data that will be useful in developing a math model to conduct meaningful risk analysis will generally fall into the following three categories.

Seek out data that helps:

Characterize/refine categories of potential outcomes

The data should allow you to see historical relationships and identify some groups based on characteristics of interest and categories of outcomes.

Define severity or range of loss of potential outcomes

The data should enable you to find insight into what kind of losses (particularly financial) have been incurred historically for the different groupings identified. Identifying trends and the boundaries (range) frames loss expectations.

Define frequency or likelihood of potential outcomes

The data should allow you to see how often certain outcomes occurred in the past. Ideally, multiple years, seasons, or other relevant timeframes should be represented to identify trends and likelihood of future occurrences.

Note that while it’s possible for a single data source to provide insight into each of the three categories above, **it is likely that you will need to find multiple sources to fully cover the categories listed above and characterize the risks of your project topic**.

Take note!

In many cases, graphical tools such as scatterplots, histograms or regression analysis can be helpful in understanding your data, reviewing for inconsistencies, or providing a starting point for developing model assumptions.

EXAMPLE PART 2.1.1

Identifying Data

Let's continue with the new driver example. Regardless of the problem statement, we would need to consider the following data.

Data that helps categorize risks and potential outcomes.

- May include car safety features or driver characteristics such as age, gender, experience, or family income.
- Can you separate single-vehicle vs multiple vehicle accidents?
- Can the accident rate be stratified by driver or vehicle classification?
- Data that helps define historical relationships among key variables related to accidents, such as, medical costs, repair costs, property damage costs, car safety features, location, time of day, etc. – note that this could include both frequency and severity information.

Data that defines historical frequency.

- How many accidents per registered car per year have there been? If not available directly, can it be approximated by a proxy?
- Identifying past trends or enough periods of past data to determine if there is an underlying trend in costs, frequencies or relationships; or if past differences are just random.

Defining the historical range of severity of potential losses.

- Data from repair shops, governmental records, or insurance payouts?
- To the extent that your injuries include deaths, you may need additional data to derive a monetary value.

2.2 Finding Data for Your Project

Your first stop for finding data for your MTFC project should be the MTFC Resource Library (mtfchallenge.org/resources). On the resources page, you will find a list of sample datasets that could be valuable for various topics of projects. Check out our sample datasets first to get a better grasp on what is available. Then you may want to explore other resources if you don't find what you're looking for in the MTFC Resource Library.

There are several places you could look to identify data for your project beyond the samples provided by the MTFC. These include:

1. **Government resources**
2. **Company resources**
3. **Industry associations**
4. **Gathering your own data**

Government resources may be the most easily identified and freely accessible datasets. Many government agencies keep public access data (i.e., the National Crop Insurance Program).

Company data often is difficult to access because many companies keep their data internal and proprietary; however, if you reach out to someone at the company, you may be able to get special educational access to some data that could help with your project.

In some cases, it may be beneficial to consider industry associations for data sources. Many of these non-governmental organizations keep annual records of the size and scope of their industries. This information may be valuable background research, but may also help in refining the risks and recommendations for your project.

A final note is that you may also find it valuable to explore gathering data on your own. Just like with a science fair project, you may be able to take measurements that will help you define possible outcomes for a potential loss. Before diving in to gathering your own data though (which may not be feasible!), make sure to think critically about what is needed and examine what already exists.

Once you have found a data source, it is important to consider how that data will be used in your mathematical modeling and risk analysis. How much data is available? Is there sufficient time frame or history to the data? For example, there is ample data regarding the spread of the coronavirus over the last few years but it may not be ideal for analysis for your project due to the evolving and recent timeframe. However, questions regarding the spread of pandemics could spur research into different documented pandemic datasets.

As described further in the next section, your mathematical model will need to model the likelihood and range of severity of the loss of the particular topic under study. **In order to best support your model, consider the datasets that you have found and the related assumptions you would need to make.** Does an identified data source address historical frequency or severity (or both)? If a data source cannot address both, you may need additional data research to identify at least one source that addresses frequency and one that addresses severity.

2.3 Assessing Data Reliability

Not all data is created equal. Some datasets will have incomplete, incorrect, or error prone data. It is important to check your data before using it in your project. In general, most reputable data sources (such as the federal government) will have some form of data checking themselves to help minimize these issues. However, it is always useful to evaluate the data for your particular project.

There are some areas to consider that may increase your confidence that the data you have is actually useful for your purposes.

1) CLEANING THE DATA

Having accurate data in a workable format is often 90% of the work. Check any data tables for completeness, internal consistency and correctness. Sometimes you can use or create a software program or bit of code to do this. If using a basic program such as Microsoft Excel for your data, this could be as simple as using a command or function to search your spreadsheet for any missing cells, or to identify obvious errors such as having a letter in a field that should only have numbers.

2) ADJUSTING THE DATA

Often, data collected by someone else was not collected with your purpose in mind, and therefore may need to be transformed, aggregated, or adjusted to be useful for your particular analysis. For example, you might have monthly data from one source and annual data from another and would therefore need to define a process for integrating the two.

Another readily known example of adjusting data is from the financial world. Over the years, the value of a dollar changes. Inflation is a general term for the change in overall cost of goods, and there are various published indices that might be used to adjust data from previous years so that it is on the same level as data from today. Similar adjustments may be required for your data; however, not all historical data needs to be adjusted in this way. Choosing which inflation index to use is a good example of an assumption in your work!

Another simple mechanism of adjusting data is to check for outliers. In some situations it may be valuable to remove outliers from your analysis; however, in others outliers may be an important part of the analysis and potential outcomes you are studying. Be sure to think critically about your adjustments as you go.

3) VOLUME OF DATA

The size of your dataset is important to consider in your project. A dataset with many observations of similar events generally will produce a narrower range of statistically-likely estimates of historical frequency or severity – just as observing many coin tosses tell you more about the coin than just a few tosses.

For example, suppose a medical insurer covers 1 million lives and knows that medical costs increased 6% for 2022 to 2023. The insurer wants to predict the costs for 2026 for one company that has just 100 employees. You know that this company's medical costs increased 15% from 2022 to 2023. What cost increase should the insurer use for this company in predicting 2026 costs? Should the insurer use 6%, 15%, or a blend of the two? How should the blend be determined?

Beware building a math model off just a handful of data points! While that may be all the data that is available to you at the time, the model may be overfitted and yield misleading results. This is why exploring other data sources that are related, but may require additional assumptions to connect to your project, is good practice.

4) RELIABILITY

Reviewing the sources of your data and making sure they are valid and trustworthy sources is essential. Consider a situation where you are researching Medicare costs for a project on a new drug treatment. You find data from a company that has great information about costs of treatment, but you also find information that this company was recently convicted of publishing misleading research findings. Should you use this data? Probably not.

Data is seldom gathered for the purpose that you want to use it - the same dataset can be used for multiple reports and studies. You need to make sure that you have the right data to be able to analyze your projects. Just "getting data from government sources" isn't enough to conclude that you should be able to just use the data in your project - you need to determine whether it directly relates to your topic or are there additional assumptions needed?

MTFC Tip | Data Identification Woes?

Sometimes finding the right data can seem like a herculean task, but don't despair! The MTFC provides recommended datasets that can be used in your project on the MTFC Resource Library. It is not required that you use these datasets, they are simply provided as examples that may be valuable depending upon your selected topic. Looking at these recommended datasets is likely to be a good starting point to help understand the kinds of data that will be most valuable to you.

Don't get bogged down in trying to adjust your data or worry too much about analyzing the data reliability early on. Start with the basics of identifying good data and build from there.

AT A GLANCE: DATA FOR A REAL-WORLD PROJECT SCENARIO

Let's consider a project with the following Problem Statement:
"Climate change is expected to increase the number of severe precipitation events in California, posing a risk of increased crop loss in the state's central valley agricultural region. The almond farming industry in CA is at risk of losing billions of dollars due to climate change. We are investigating how the state government could best help mitigate these risks."

In this scenario different outcomes could be explored in various ways, (1) potential differences in climate forecasts, and (2) potential differences in crop losses. For the first, there are different forecasted scenarios for the potential climate change, and for the second we can gather information from the National Crop Insurance Program.

Data that helps categorize risks and potential outcomes.

- Annual or even monthly data on crop losses can be found within the National Crop Insurance Program from the federal government.
- Expected climate change for California is available from The Global Change government group.

Data that relates to historical frequency.

- The National Crop Insurance Program provides data that will allow us to identify the frequency of various sizes of losses in historical data, and use that to project future trends.

Defining the historical range of severity of potential losses.

- Data from the National Crop Insurance Program provides severity of losses for the state of CA.

Note that these data sources are unlikely to be all that is needed for a complete MTFC project. However, initial data searches like this are a great place to start for your proposal that can be discussed and refined with your actuarial mentor in the Project Phase of the MTFC.

MTFC Step 2: Wrapping up Data Identification & Assessment

To conclude part two of the Actuarial Process for your Modeling the Future Challenge project, you should have:

1. Identified one or more datasets that together meet the three categories of data on enabling a good analysis discussed in Section 2.1.
2. Identified any basic needs for cleaning or adjustments in your datasets.
3. Examined the volume and reliability of your data – is the dataset large enough to make a valid analysis and recommendations?

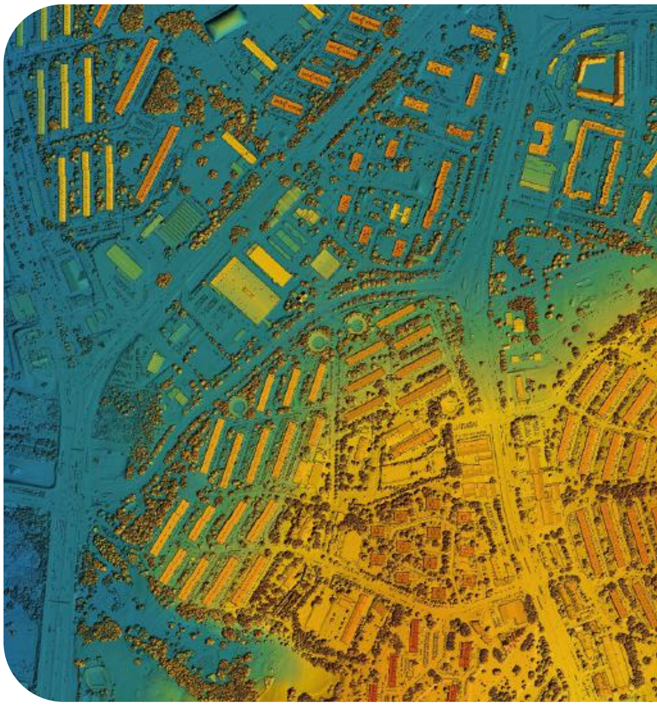
Remember not to get discouraged or distracted by getting too far into the details on your first look at the data. It may take a little time to get to know and understand your data; but once you do, with a little critical thinking about the data, your project will begin to come together in amazing ways!

3 Mathematical Modeling

There is no single template for what makes a good actuarial model. Your model will be unique to your project. There are, however, rules of thumb that can be used to help. Use the information in the following sections to help explore what goes into an actuarial model. There is also a need to have conducted a preliminary risk analysis before creating your mathematical model and thus a thorough reading of the coming Step 4: Risk Analysis will be essential. Preliminary identification of risks will guide your decisions on what you will be modeling and how you will approach the model creation.

Recall at the beginning of Step 2: Data Identification & Assessment, data visualizations were first mentioned and it was noted that they can and should be used throughout each step of the Actuarial Process. Data visualization is a significant tool in guiding the choice of candidate models and potential assumptions. Before you begin constructing models to project the future, you will want to perform exploratory data analysis to understand patterns and correlations, identify whether the frequency or severity of unfavorable outcomes varies measurably from one group to another, and examine for indications of historical trends such as inflation.

Data visualization techniques such as plotting raw data alongside the results of correlations and regressions between different data elements, different data sets, and against time and other category variables (gender, age, state, vehicle horsepower) are relatively easy to perform but can yield useful perspectives to guide you towards – or away from – several model structures and various alternative assumptions. Color-coded geographical displays of data may give you insights into significant differences across regions, or between urban and rural areas in your state. Histograms and scatter plots may help you think about the range of outcomes, as well as the variability and uncertainty of key factors related to your chosen topic. Consider data visualizations as not only a way to communicate your findings, but also as a way to guide you to meaningful model development and analysis.



3.1 What Do Actuaries Want Their Models To Do?

The overarching goal of your actuarial model should be to provide the target audience with the information needed to take action or make a decision about mitigating the risk you have identified. Models will be structured differently depending on the risk mitigation they intend to support. In some cases, the output of a smaller model might become an input assumption for a larger model.

> *Actuarial Models' strengths arise from not predicting only one possible future outcome.*

For example:

- A proposed insurance arrangement might need a model that demonstrates the range of feasible costs of the insurance.
- Modifying outcomes might require that you first model how much of a change in severity could be achieved by the proposed modification and how much the modification would cost, which would then feed into the larger model to estimate the anticipated cost savings.
- Recommending a change in behavior could be supported by a model that shows the effect of plausible changes in the likelihood assumptions.

Well-constructed models will allow you to do a cost-benefit analysis that compares baseline (before) and mitigation (after) cases. In making these comparisons, actuaries sometimes start by combining the likelihood and severity values of all the possible outcomes to identify the "expected value" of loss for each scenario. Expected value is the likelihood of the loss (in a percentage or probability) multiplied by the projected severity of the loss (typically a dollar amount, or other value that quantifies the amount of the loss). To get the full expected value for your scenario you would sum the expected values of loss for each possible outcome.

Expected Value of Loss

Combining the severity and frequency of loss for all the possible outcomes of your scenario will provide you with an Expected Value of the potential loss. This is an important fundamental way of quantifying risk (though it is not the only measure!). Expected Value is the frequency of the loss (in a percentage or probability) multiplied by the severity of the loss (typically a dollar amount, or other value that quantifies the amount of the loss). To get the full expected value for your scenario you would sum the expected values of loss for each possible outcome.

EV = $\sum$ **(each outcome loss x probability of that outcome)**

EXAMPLE PART 3.1.1

Expected Value of Loss

Let's continue our example of looking at the repair costs of an automobile accident. Let's assume that you have identified repair costs in the following buckets, and made the associated forecast or assumption about the likelihood of each loss occurring given that an accident occurs:

- $0 - $1000 (average $500) - 10% of repairs
- $1000 - $5000 (average $3000) - 40% of repairs
- $5000 - $15000 (average $10000) - 30% of repairs
- More than $15000 - total loss of $20000 (average $18000) - 20% of repairs

Multiplying the likelihoods by the cost associated with the range and summing the results gives the expected value of the repair cost of an accident:

$$\$500 \times 0.1 + \$3000 \times 0.4 + \$10{,}000 \times 0.3 + \$18{,}000 \times 0.2 = \$7{,}850$$

This process could be repeated for the other costs of an accident, and the total could be multiplied by the assumed likelihood of an accident within a 6-month or 1-year time period to get the total expected value of the risk of driving during that time period.

It is important to note that Expected value is **not** something you expect to lose (or gain) every time the scenario comes up. It is the value that the average of the gains or losses tend toward over many observations. So in our previous example, we would not expect to lose the expected value on each driver in every 6-month or 1-year period of driving, but over time and a large number of drivers this would be the average loss per driver per period if our assessment of risk is correct.

However, as mentioned in our examples, actuarial models will go far beyond simply identifying an expected value; actuarial models typically will find more detailed ways of characterizing their risks. For example, your model may also benefit from considering confidence intervals and upper and lower bounds to your risks. Your clients (or audience for making recommendations in your report) may want to know within a 95% confidence interval, what is the maximum loss they can expect in the scenario you are studying?

In addition, your model will need to encompass both the time frame for both the risk and any mitigation strategies to become apparent. For example, short-term weather models such as the storm track and "cone of uncertainty" for the hurricane that currently is nearing the coastline might span days or weeks; health care models might span years; and climate change models might span decades or more. You also may wish to project your results further into the future, but keep in mind that longer projections introduce increasing amounts of uncertainty – a wider range of potential outcomes – into your results.

3.2 Assumption Development

Once you have assembled and prepared your data, you will need to determine the assumptions needed to develop the recommendations suggested by your problem statement. **Assumptions are a judgment call, but should be grounded in a rational basis.** Assumptions should answer questions such as:

- What is the appropriate future time period for your analysis? You will need to consider both the time needed for the risk to become apparent and the time needed for any mitigation to take effect.
- Is your data directly relevant to your topic? Do you have to make assumptions about how to adapt the data to your topic?
- How do you expect your data to change over that time period? Will the rate of change be the same as or different from the historical rate of change or trend?
- Are apparent patterns observed in the data true patterns or just random variation? For example, is there a reason for observed cyclicality, or is that just an artifact of randomness in the data?
- How should the uncertainty of likelihood, severity or timing be reflected? What are the appropriate probability distributions or scenarios that should be modeled?

No actuarial model is perfect. Every project will need to make some assumptions about the data, scenarios, possible outcomes, model structure and other factors associated with your project. It is important to understand what assumptions you are making in your model and to identify those in your report. Uncertainties about these assumptions will affect your model and will also be something you will want to note in your MTFC project report. Assumptions can be large, or small, but the more they are supported by rational, critical thinking, the stronger and more persuasive your recommendations will be. **What assumptions will you need? If you need inspiration, look at the bullet list above, or the Example Part 3.2.1 that follows.**

EXAMPLE PART 3.2.1

Assumption Development

Suppose that in addition to considering the risk of your use of the family car, your parents also have asked you to develop a budget for the expenses of your usage over the coming twelve months, and a strategy for how you are going to earn the money to pay those expenses. You might consider the cost of gasoline, the increased insurance expenses, parking fees, and the cost of cleaning or repairs on occasion.

- Cost of gasoline: you will need to estimate how much you will use, and the cost per gallon. In turn, this requires estimating your miles of usage and fuel consumption per mile: can you find some studies of teenage driving, or gather some data from your friends? Can you build a model based on the types and number of trips you plan to make, and the distances involved?
- Cost of cleaning: you might consider options such as: cleaning it yourself, or taking it to the detailing shop down the street. What would each of these alternatives cost today, and how will that change over the months ahead? How often will you incur that expense?
- If you know only the cost of one repair of your car from one automotive repair shop, you may need to assume that all car repair shops would quote the same price. This generalization limits the accuracy of your model. What additional data and/or alternative assumptions could you use?

3.3 What Does An Actuarial Model Look Like?

Models are tools that help answer questions. **A model consists of three components: data and assumptions as input, a calculation engine, and output.** When actuaries create models, they do so with a specific goal in mind. With a strong model, the output when properly analyzed gives useful information. The model results allow one to make informed decisions based on data and clear thinking. As you design your model, be sure that it will provide output that addresses the questions posed in your problem statement and will help your target audience to understand the risks.

There is a wide range of mathematical techniques that can be used as the calculation engine of a model. The modeling methodologies you choose to use must be able to work with the data you have found. You should have an understanding of the mathematics underlying the model calculations or be willing to spend some time learning it. Some common modeling methodologies are listed below to give you a few ideas. Many of these have been used by past MTFC teams in their projects.

> *All models are wrong, but some are useful.*
>
> – George Box

The list is by no means exhaustive and you should feel free to explore other modeling techniques.

- Regression analysis
- Time series
- Probabilistic models – including probability distributions and Monte Carlo simulations
- Tree-based methods
- Neural networks

It is important to note that while there are many mathematical techniques, not all may be appropriate for your project. The mathematical technique(s) you choose need to be able to use the data you have found and to produce output that can answer the questions posed by your problem statement. If you understand the mathematical workings of the model, you will be better able to analyze the output. You will be less likely to misinterpret results or overlook model limitations. A good check is whether you can clearly describe in your project report how and why the mathematics works. The background research your team conducts and guidance from your MTFC actuarial mentor can help you select and use modeling techniques that are good for your project.

3.4 Model Verification and Validation

Once you have built your model of future outcomes, take a step back to verify that the model is complete, consistent, logical and appropriate for your purposes.

- How does the model output align with the problem statement and possible mitigation strategies?
- Do you understand the basic operations, important dependencies, and major sensitivities of the model?
- What are the weaknesses in assumptions, methods or other known limitations of the model that have material implications?
- What are the other limitations of data, time constraints, or other practical considerations that could materially affect the model?
- Is there a logical explanation for modeled results that are similar to or different from other models or prior expectations?
- How would the model have performed against the actual results of the recent past?

As you begin to develop a mathematical model that addresses your problem statement, it is important to be aware of a few common pitfalls of teams approaching mathematical modeling.

COMMON PITFALL: OVERFITTING

Overfitting occurs when a model fits too closely to a training dataset (past occurrences) and cannot reliably predict or generalize to future projections. Many students who are new to modeling unwittingly overfit their model when the analysis tool they are using provides suggestions for different models that offer an impressive fit to the past occurrences.

For example, many software programs offer higher-order polynomial regressions (quintic, quartic, etc.) that "memorizes" past data closely, but does not "understand" the trend in such a way that future projections are possible.

COMMON PITFALL: DISCONNECT BETWEEN MODEL & RECOMMENDATIONS

Another common pitfall of students who are new to risk analysis is missing that the ultimate goal of the project is not to build an amazing math model or conduct a stellar analysis but rather, **the goal is to make recommendations on how to mitigate risk based on the findings from the analysis.** The recommendations that you make should specifically be linked from the mathematical model itself. If you are recommending a particular change to a variable or factor, can you actually change that variable in your model? Making an evidence-based recommendation is crucial to these risk modeling projects, but also is a valuable skill to develop for every report you will complete in any area of life and academic or career pursuits.

COMMON PITFALL: STRIVING FOR MODEL PERFECTION

A third common pitfall is over-investing your time and effort in a single model. **Model perfection is not a useful or attainable goal.** No model is perfect in projecting the future, in explaining variations in the likelihood and outcomes of an event, or in quantifying the benefits and costs of a risk mitigation measure.

Rather than striving to approach near-perfection of one model, it may be more powerful to develop several analyses and models that explore a different dynamic important to your topic, or that rely on different data sets or different explanatory variables, or that use a different modeling technique and some different assumptions. Your resulting portfolio of tools likely will give you some different insights, and may help you to narrow the range of your projections, or to better describe and quantify the uncertainties. They may help you evaluate different risk mitigation measures. Often, the strengths of one model may offset the weaknesses of another, both in your analysis and in your ability to tell a compelling story to your audience.

Does this mean that you must have multiple math models to have a full characterization of the risks? Absolutely not! This is again dependent on your topic, problem statement, math model, and analyses. Consideration of multiple math models warrants discussion with your actuarial mentor to see if it is appropriate for your risk modeling project.

MTFC Step 3: Wrapping Up Your Mathematical Model

In general, your mathematical models for a Modeling the Future Challenge project should help you identify:

- the assumptions and conditions under which your model's outcomes are valid,
- the frequencies (likelihoods) that each potential outcome for your scenario will happen,
- the severities (size) of possible losses,
- expected values of potential loss for your scenario and understand the implications for different subgroups of the population,
- trends in the data and understand how potential outcomes and associated risks may be changing over time, and
- possible risk mitigation strategies, and quantify their effects.

Remember that your model is not expected to be perfect. You will make assumptions to create your model, and you will have uncertainties in the model results. Presenting results acknowledging these uncertainties is important, rather than trying to say that you know exactly what will happen.

4 Risk Analysis

To this point, you have identified risks, found data, and built and run a mathematical model. **You are now ready to ask yourself, what can I learn from the model output?** You can think of the Risk Analysis section as the bridge from prior steps to the final step of making recommendations.

The risk analysis is your opportunity to explain the output of your model to the target audience in their terms. What is the information needed to make a decision? What is the do-nothing, base case scenario? What is the opportunity or effect of the suggested mitigation scenarios? Do the results "feel" right and make intuitive sense, or are they counterintuitive but explainable? How certain or confident are you about the results?

4.1 Analyzing Model Output

A useful model allows you to make statements and form conclusions that can be helpful to the target audience. The types of findings may vary by type of model. For example:

- Regression models quantify the impact of one or more independent variables on a dependent variable.
- Probabilistic models allow one to make statements about the likelihood of certain outcomes.
- Time series models project future outcomes as predicted by past trends.

It is important to examine model output from multiple angles. For example, regression analysis tests include a measure of the strength of correlation between the variables. The higher the correlation, the more confidence you can place in the result, and the more you may decide to rely on the result when considering mitigation strategies. (Warning: beware overfitting! See Section 3.4 above.)

You should also look back at the assumptions you made when developing your model. As noted in Section 3, no actuarial model is perfect. If your model involves simplifications or uses a limited amount of data, you may need to use caution when using its output to make recommendations.

EXAMPLE PART 4.1.1:

Learning From Model Output

Let's look at our car insurance example from the insurance company's perspective, and one risk analysis the company's actuaries might perform. The insurance company's future profits depend on whether the aggregate premiums received exceed the total claims and operating expenses paid. Based on its preliminary data analysis, the insurance company recognizes that claims are lower, on average, for drivers who have taken a defensive driving course, for those who obey speed limits, and for those who don't get too close to vehicles ahead of them.

Based on their modeling, the company estimates that there would be a 25% decrease in average expected claims, with a standard deviation of +/- 15%, for drivers who have both recently completed a defensive driving course and consistently practiced safe driving techniques. Using these results, the company is able to quantify in dollar terms the potential benefits of mitigation strategies that improve driver safety.

MTFC Tip

How Prescriptive is the Actuarial Process?

The Actuarial Process is a framework to provide scaffolding and a starting point for your team. However, the Actuarial Process is **NOT** a rigid structure that requires you to include every point that is included in this Guide as part of your project and analysis. One of the unique features of actuarial science is that creativity in approaching real-world problems is necessary! A hallmark advantage of the MTFC is that actuarial mentors have the opportunity to guide you towards analyses appropriate for your topic and model - modeling is not "one-size-fits-all" and there is no way to write the APG in such a way that it covers all possibilities for analyses or focus areas appropriate to every topic or model. This is where you will have the opportunity to really practice the general framework of the Actuarial Process and (with guidance) compile a one-of-a-kind project report.

4.2 Moving Towards Recommendations

Risk analysis gives you the ability to make comparisons. These can be across modeled scenarios, or between the modeled outcomes with and without mitigation strategies. To help your target audience make decisions and take action, you will need to express both risks and mitigations in the same terms – most commonly financial. If you can quantify both potential losses and the cost of strategies to reduce losses in dollar terms, you will be in a good position to make recommendations.

MTFC Step 4: Wrapping Up Risk Analysis

To wrap up your project's Risk Analysis section, first look back at the risks you identified when defining your problem statement in part 1 of the Actuarial Process. Use the results of your model to quantify the risks as best you can. Think about these questions as you wrap up risk analysis:

1. Can you identify an expected value for losses in the scenario(s) you are researching?
2. What is the distribution of loss? Is it equally likely that you will see a large loss as a small loss?
3. Are there extreme events you need to consider?
4. How will different subgroups be affected by the risk, and by the mitigation strategies?
5. Can you think of any mitigation strategies in addition to the ones you initially considered when writing your problem statement?
6. Can you assign dollar amounts both to potential losses and the costs of possible strategies to lessen the losses?
7. Can you use data visualization techniques to better communicate results to the target audience?

5 Recommendations

The final part of the Actuarial Process is to communicate your analysis and provide real-world recommendations on how the people, companies, governments, or organizations affected, should respond to the risks you identified. Just like with your models, there is no standard template for a recommendation; however, there are rules of thumb you can follow.

Actuarial recommendations must help the affected party respond to the risks you have identified. Recommendations can help mitigate negative outcomes, or accentuate positive ones. Just like the way you should characterize risks in your project, recommendations also are best when they are described in specific terms rather than generalizations, and they are quantified. The people affected by the risks you identify want to know specific plans of action that they could take to best respond to the potential scenarios that may lie ahead, as well as the relative costs and anticipated benefits of those actions.

Your actuarial project will present risk mitigation strategies to help your audience manage risks. Your job is to provide tangible analysis of which mitigation strategies provide favorable trade-offs of cost versus reduction in risk. And, it may be equally useful for your analysis to inform the audience as to any nice-sounding strategies that do **not** provide such favorable trade-offs. Perhaps you will even be able to demonstrate that some current risk mitigation measures are costly but not effective, and should be discontinued.

Take note!

You are **not** required to have a recommendation in **each** of the three risk mitigation categories. But if you don't, your report will be much stronger if you can explain why. Perhaps you can explain about some of the risk mitigation methods that you considered and rejected.

A key role of your models and analysis is to guide your identification, evaluation, selection and recommendation of potential risk mitigation strategies. Historical data and projections regarding the number and severity of automobile accidents involving young drivers at different times of day might lead you to devise some strategies relating to night driving. Your models can be your tools to quantify the potential benefits of these strategies – some of which may be quite promising in changing behaviors or outcomes, while others offer little benefit. At the same time, this work may reveal that you do not have enough information to quantify the costs or side-effects of these strategies. You may need to go back to data sources and further modeling to be able tackle these considerations. You may also discover that you need to do some more work to integrate information from multiple data sources in order to evaluate which portions of the population, or which geographic areas, will be most and least affected by the strategies.

5.1 What Kinds of Recommendations Do Actuaries Make?

Actuaries work in nearly every field to help businesses, organizations, governments, and communities make good decisions and manage their risks. An actuarial project can make recommendations in many areas. Here are a few examples of the kinds of recommendations you might make in your project:

Business Decisions – help businesses decide to take certain courses of action to manage the future risks.

Financial Decisions – help families, businesses, governments, or organizations make financial decisions that help them operate within their appetite and capacity to tolerate various types and levels of risk.

Government Policies – help governments identify which policy decisions will be the best for their constituents, are affordable, and will help them minimize exposure to high risk situations.

Insurance Solutions– provide new insurance products and opportunities to manage the financial consequences of risks that are faced by individuals, governments, companies, or organizations.

While it may be tempting to strive for elimination of all risk, it is important to remember that many risks also have associated potential rewards. You could eliminate all risk of driving a car by never driving a vehicle, but that choice could have consequences for your access to convenience, opportunity, and adventure. And you may find that you have swapped to a different set of risks by choosing to travel by foot, bicycle and bus instead; or by not traveling at all. A business may find ways to mitigate some of the risks of undertaking a major (and costly) research project – but may decide that accepting some of the risks is warranted by the importance of the potential business opportunities that could be enabled by the project's findings. A member of your family might have decided not to invest part of their nest egg in IPO's of Hydrogen Balloons for Travel, Inc. or Amazon, when the future trajectory of the companies was exciting but uncertain.

Remember!

Ultimately, your MTFC project report is only required to make recommendations in <u>one</u> of the three risk mitigation strategy categories. However, it is valuable to outline the rationale behind why a particular strategy was selected and others either disregarded or rejected for your project.

EXAMPLE PART 5.1.1

Identify Risk Mitigation Strategies

Using the same driving example, what are some ideas for risk mitigation strategies in each of these three categories? Note that some mitigation strategies might apply only to some perspectives. It might be hard at first to think of some, but once you've gone through a few examples, you'll find it easier. Here are a few examples for our automobile example:

Behavior Change:

Behavior changes might be required by law or voluntary based on incentives and education.

1. Many states have graduated, supervised licensing programs for younger drivers, or place restrictions on them (for example, no driving at night, or limits on the number and ages of passengers permitted in the vehicle). Some families choose similar constraints voluntarily, after studying accident statistics.
2. Insurance companies may offer a financial incentive - through lower premiums - to install a speed / acceleration / braking monitor and/or phone-locking to encourage safer driving practices.
3. States may require or insurance companies may offer incentives for you to take defensive driving courses that teach and encourage safer driving practices.

Modifying Outcomes:

1. Federal safety standards include items such as front airbags and seat belts that better protect car occupants in the event of a crash; and anti-lock brakes that improve the driver's ability to respond to a hazard on the road ahead. Many car manufacturers have included additional safety features like side airbags in response to consumer demand.
2. Some safety features like blind-spot monitoring, backup cameras or collision avoidance systems may include features of both behavior change (reducing the likelihood of severe events) and modifying outcomes (reducing the severity of those events). In these cases, it is more important to consider the mitigation itself than being overly concerned about how to classify it.

Insurance:

Insurance coverage for automobiles is widely available, and is required in most states. Policies can vary in terms of types and amount of coverage, deductibles, etc. and may depend on the policyholder's risk category, experience, type of car, and included features.

Let's take a closer look at the three categories of risk mitigation strategies.

5.2 Motivate a Change in Behavior

In many situations it's feasible to motivate or mandate changes in the behaviors of people, groups, or organizations. **Behavior changes work by reducing the likelihood of incurring a loss, or reducing the likelihood of incurring a more severe loss.** The target people, groups, or organizations might be those affected by the risk – or they might be causes or sources of a hazardous situation or product.

Examples of behaviors relevant to some MTFC projects in recent years include: driving habits, eating habits, hiking or climbing in dangerous places, daily exercise routines, use of safety equipment, polluting the air or water, preventive maintenance for your car or home, wasteful use of water, smoking and recreational drug use.

Recommending a behavior change?

Your recommendation should specify the behavior it is targeting, outline the incentive or regulation you are recommending, and describe how it would operate to modify behavior and reduce the likelihood of loss.

EXAMPLE PART 5.2.1:

Behavior Change Risk Mitigation Strategy

The risk analysis example in Step 4 indicates that the insurance company has a significant opportunity to provide incentives for the insured population to change their behavior. Specifically, the company could offer a 15% or 20% premium discount to drivers who take a defensive driving course and who install a driving behavior monitor or app; the company's profitability would still be expected to improve because of the greater reduction in claims — even with the reduced premium collection.

The exact amount of the discount will be guided by the expected amount and probability of the reduction in claims versus the expenses of implementing the program. It is also recommended that the company monitor both the acceptance rate and the future claims trend over time to properly calibrate the desired amount of discount going forward.

Note: These numbers are fictional for the sake of the example. An actual MTFC risk analysis and recommendations should be more detailed, including results from the model (impact that the risk mitigation strategy would have on the current trajectory) and cover more than one option or opportunity.

5.3 Modify Outcomes

In many risky situations, it may be effective to alter the consequences of an undesirable event, whether or not the event itself can be prevented. Examples abound: hurricane shutters, improvements in building codes and enforcements for wind resistant buildings, automobile seatbelts, improved football helmets, hard hats, safety glasses, safety harnesses for roofers and window washers, antibiotics for infections, emergency generators, AED defibrillators in public buildings, and so on.

These types of measures prevent or reduce the consequences of an incident, or hasten and ease the recovery and return to normal. If you are having trouble coming up with ideas, consider the safety measures that are used in other situations; are there analogies that might apply to the topic you are analyzing? Consider the various cascading steps, from the occurrence of an undesirable event, to the injury or damage being incurred. What factors contribute to making the outcome better or worse? Who or what can influence those factors?

Recommending to modify outcomes?

Your recommendation for modifying outcomes should explain the measure that you are proposing, who would be responsible for implementing it, and what aspect of the outcome it would affect.

5.4 Insure the Financial Consequences

Insurance is a tool that companies, individuals, families, and governments use to mitigate risk. Insurance policies can be created for anything with value that has a potential for a loss. Some of the most recognized examples include auto, life, health, and home insurance. Insurance protects the policyholder against the financial losses arising out of significant injury or damage.

Insurance works by pooling together the premium payments and financial losses of a large group of people or organizations. As long as there is a small probability that many of the participants will suffer a loss in a given year (their likelihoods of loss are "uncorrelated"), the insurance company can charge a relatively modest cost ("insurance premium") to all the participants, and be able to reimburse the large damages ('insurance claims") suffered by a few of the participants. Insurance premiums are likely to vary from year to year as the frequency and cost of accidents and claims change. However, this variation is quite small compared to the financial uncertainty if you decide to bear all the costs of an auto accident or storm damage to your house, out of your own pocket. In some situations, social (government-sponsored) insurance may also subsidize the cost of insurance to the individual policyholder as a means of achieving other policy goals. In some situations, groups of individuals or organizations may come together more informally to pool their risk without involving an insurance company.

Depending on the topic and perspective you have chosen to analyze, you may be able to make a recommendation that uses well-established insurance products (such as auto or home insurance), or invent a modification to one of the products, or come up with a completely innovative insurance product or structure.

Insurance company actuaries perform risk analyses similar to your MTFC project to develop pricing recommendations to management. In your projects, you might use the results of your model to estimate the total losses from your topic's risk, over the course of the upcoming year.

Recommending insurance?

Based on your analysis of variability in the risk you are studying, consider adding a margin to reach a selected confidence level that the actual total losses in a year will not exceed it.

What does that amount look like if you spread it across everyone in the relevant population? Looking for a way to go "above and beyond" if you're recommending insurance as your risk mitigation strategy? Don't forget to include a provision for the commissions, taxes, and operating expenses paid by the insurance company!

RECOMMENDATION CONSIDERATION: COST-BENEFIT ANALYSIS

For each of your risk mitigation recommendations, try to develop a quantitative analysis of the magnitude of the benefits versus costs of your idea, and incorporate the results along with the other information you are providing about your recommendation. Your audience will want to be confident that the benefits of your recommendation are greater than the costs.

- Leverage your data and model (or tap into information and studies about analogous situations, perhaps from other states) to quantify the extent to which a particular recommendation (or a group of recommendations) will reduce the likelihood, severity and variability of losses that you have estimated in the coming years. If you are not certain of the answer, try a variety of different model structures, confidence levels, and assumptions to develop a range for the estimate of the benefits (reduced losses) of implementing your recommendation.
- In parallel, develop an estimate of the cost of implementing your recommendation. There may be some particularly challenging aspects to this effort. But, can you get a handle on some of the costs? Can you get any insights by looking at information from similar measures that have been implemented for other risks, or in different states? A ballpark estimate, or a range of estimates, can be much more informative than no estimate at all. Your estimate will not be perfect: what are its strengths and weaknesses?

As you analyze different potential recommendations, visual displays of your model results – with and without the recommendation implemented – can be a powerful tool to help you understand the dynamics and potential results of your ideas. Likewise, visual displays will be a powerful tool to help tell the story to your audience.

GENERAL REPORT CONSIDERATION: COMMUNICATION

Communication is the glue that ties together all the parts of the Actuarial Process and provides the context to give your recommendations value and persuasive power. Good communication demonstrates to the target audience that you understand the project; have exercised sound, rational judgment; and can explain your findings in understandable terms. Specifically the written communication should include, in the appropriate sections:

- As described in Step 1, you need a clear problem statement that provides purpose and direction to the project, including identifying the risk, who is at risk, the possible mitigation strategies and the target audience.
- A summary of the data that was actually used, after selection, cleaning and transformations. Tables, charts, histograms, maps and other visual displays may be useful here.
- Clear explanations and rationales for the assumptions made
- Explanation of why the particular models were chosen, how they work, and what they tell you about the future. Visual displays will help!
- Appropriate explanation of any limitations, constraints or uncertainties embedded in the model
- Description of how the recommendations would work and how their benefits warrant expending the expense. Paint a picture with visual displays to make it easy for the audience to follow your thinking and your conclusions.

The clarity and detail of the communication should be aimed at the target audience. Too little detail may leave the impression that your conclusions are not strongly supported. Too much or overly technical detail might confuse your target audience or drown out your essential conclusions. “Just right” detail shows that you understand your topic and its implications, and can explain it in the target audience’s terms.

MTFC Step 5: Wrapping Up Recommendations

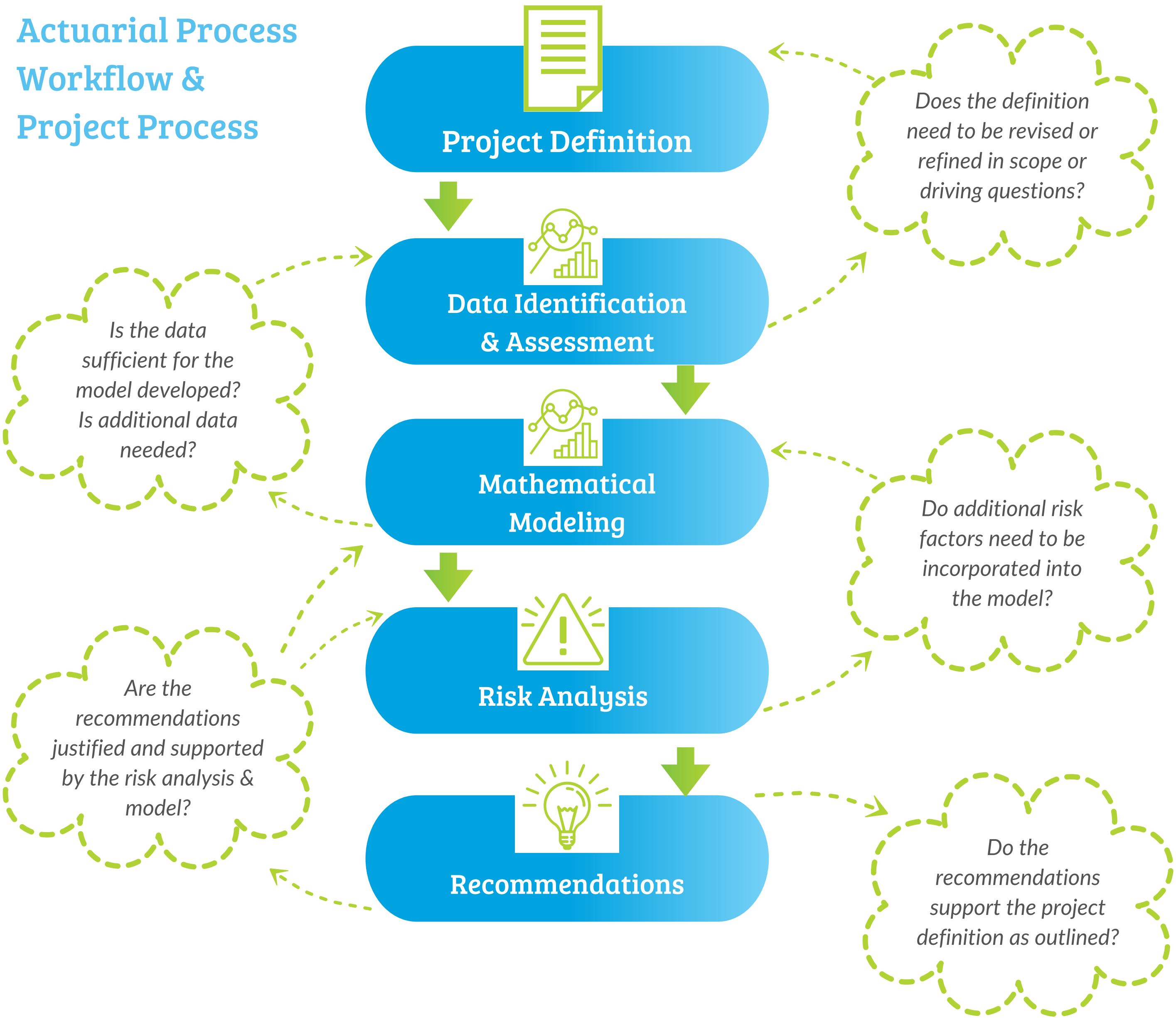
The best recommendations in an MTFC project follow these rules of thumb:

1. Be data driven: make sure that your recommendations extend from the data and mathematical modeling you have produced. The recommendations should be based upon sound math and real data.
2. Be quantified: just like your risks, recommendations are best when they are quantified. Don’t just say that something should change, say how much it should change, and show evidence from your data and math models defending that.
3. Respond to the problem: make sure that your recommendations address the original problem statement you identified in defining your project. There may be many things you think could change associated with the project, but be clear about how those changes will improve the problem and help manage or mitigate risks.
4. Be clear and concise: recommendations, just like your whole projects, are best when they are clearly stated, and not overly verbose. Describe the recommendations in as much detail as possible, but avoid adding unnecessary information.

Revisiting the Actuarial Process

The Actuarial Process provides a framework for identifying, characterizing, and managing risks for real-world situations. As you work through this Guide and your project, it is important to acknowledge that this process may not be direct and linear with final, complete, and polished written products of each stage. Much like any design process, you may find it not only necessary but helpful to revisit previous stages by finding additional data, refining or broadening your project statement, adjusting your model, considering different risk quantification methods, and reevaluating the effectiveness of the recommendations you make. Unlike a design cycle, there are definitive starting and ending points to your Modeling the Future Challenge Project. The steps and stages of the Actuarial Process are all crucial components to your project, but willingness to embrace flexibility and revisiting stages of your project will be a valuable and enriching approach to your work on the project.

Actuarial Process Workflow & Project Process



What is an actuary and what do they do?

An actuary is a business professional who analyzes the financial consequences of risk. Actuaries use mathematics, statistics, and finance to study uncertain future events, most often those involving insurance and pensions. The actuarial career should be considered a business career with a mathematical basis rather than a mathematical career. They use their expertise to help organizations plan for the future, manage financial risks, and ensure the stability and profitability of their operations. Actuaries play a critical role in decision-making processes related to financial planning, insurance policies, pension plans, and investment strategies. Actuaries are experts in:

- Evaluating the likelihood and potential severity of future events,
- Designing ways to reduce the likelihood and severity of undesirable events, and
- Decreasing the impact of undesirable events that do occur.

After working your way through this Actuarial Process Guide, do those three areas of expertise sound familiar? They should! This guide is a greatly simplified approach and introduction to the way that actuaries seek to address risk.

Actuaries tend to fall into two broad categories: Property & Casualty Actuaries and Life, Health, and Pension Actuaries. The largest industry to rely on the skills of actuaries is the insurance industryindustry. But many actuaries work in other environments: private corporations seeking risk evaluation to frame strategic management decisions, consultants designing risk solutions, the government, colleges and universities, banks and investment firms, public accounting firms, labor unions, rating bureaus, and fraternal organizations.

Interested in learning more about who actuaries are and the profession?
Check out actuarialfoundation.org or beanactuary.org for more information!

Sponsors & Volunteers

The Modeling the Future Challenge would not be possible without the commitment of countless volunteers from throughout the actuarial industry, sponsors, and partner organizations. These individuals and organizations commit their time, expertise, and funds to help high school students find the excitement in using math to help groups analyze data, predict future outcomes and navigate their way through the risky waters of the future.

If you know of anyone interested in joining the MTFC as a volunteer, partner, or sponsor, please contact: ***challenge@mtfchallenge.org***.

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