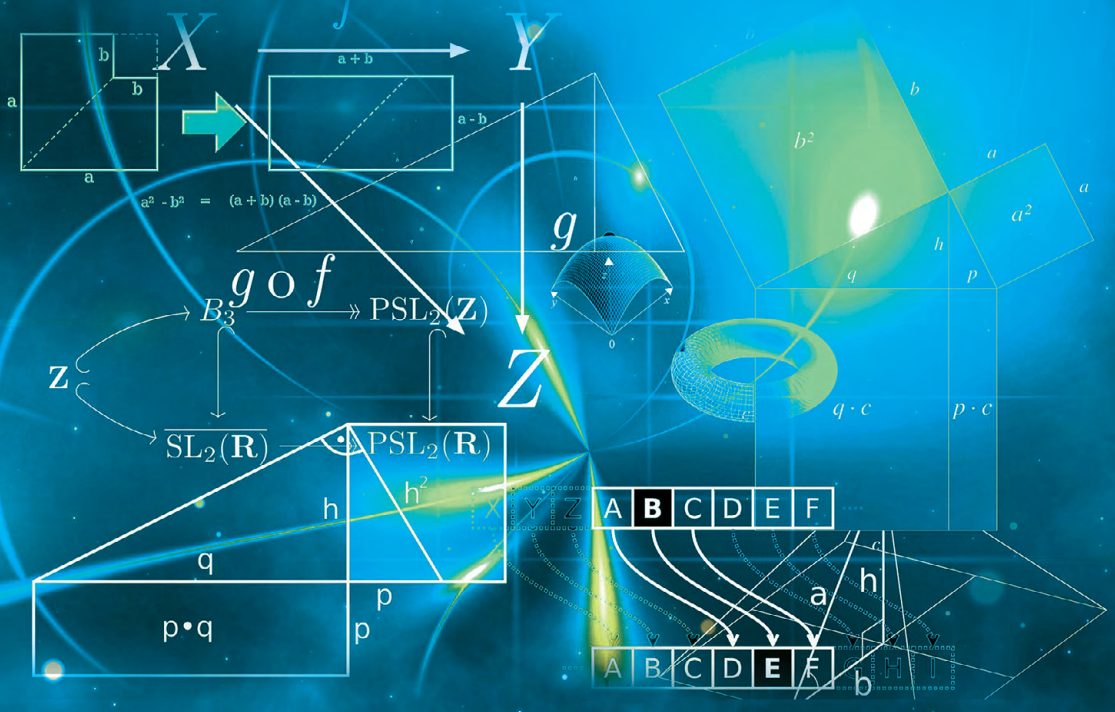
A Program of The Actuarial Foundation

Modeling the Future Challenge



Actuarial Process Guide

The Actuarial FOUNDATION

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

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www.actuarialfoundation.org

About the Actuarial Foundation

The Actuarial Foundation is a 501(c)(3) organization committed to changing lives through math education. Established in 1994, the mission of the Foundation is to enhance math education and financial literacy through the talents and resources of actuaries. The Foundation's vision is an educated public in pursuit of a secure financial future. The Modeling the Future Challenge is the cornerstone educational program of the Foundation. Built upon two years of pilot programs, the MTF Challenge 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 MTF 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. 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 $9,000,000 in awards with NASA, the Lemelson Foundation, the Methuselah Foundation, the SETI Institute, and many others. The Institute of Competition Sciences 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. ICS is using academic competitions to turn education into an exciting challenge for all students, and is bringing its expertise to the Modeling the Future Challenge.

Actuarial Process At-A-Glance

1

Project Definition:

Conduct background research and identify a topic for your project by writing a Problem Statement.

2

Data Identification & Analysis:

Research the available historical data for your project topic and check that you have enough data to develop a strong model and analyze risks.

3

Mathematical Modeling:

Develop mathematical, computational, or analytical models that help you define the outcomes that may be likely for your project topic.

4

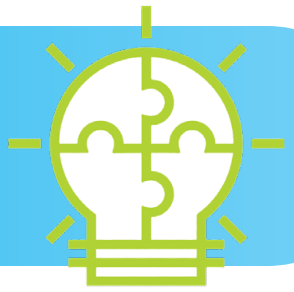
Risk Analysis:

Compare likely outcomes from your actuarial model and use it to characterize and define the potential risks.

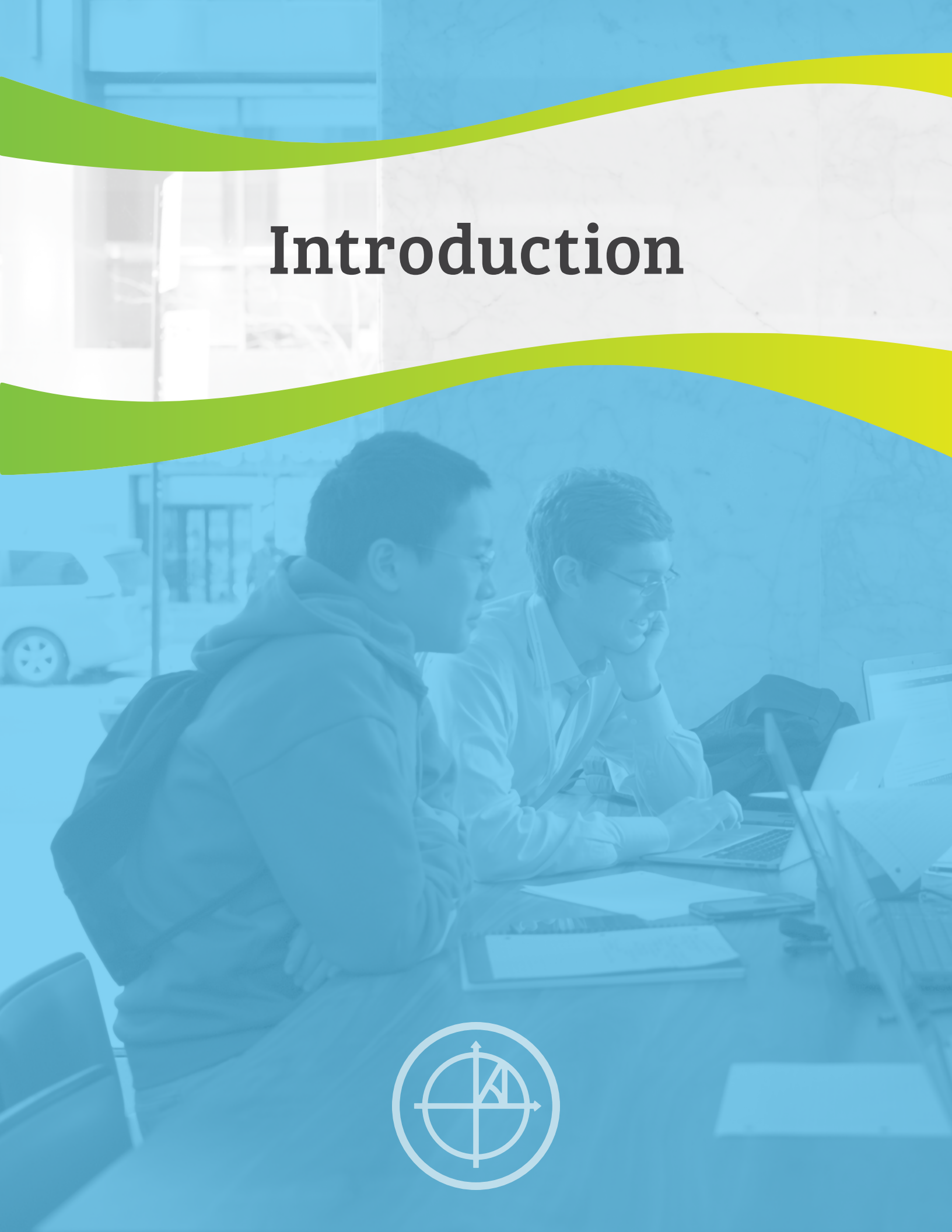
5

Recommendations:

Use analysis to identify risk mitigation strategies and make recommendations to affected organizations on how best to manage those risks.



Introduction



Overview

The Actuarial Process extends your mathematics and science knowledge into the world of data analysis and risk management. It helps you become successful at identifying, characterizing, and managing risks in all aspects of your life, no matter your interests or career.

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 with uncertainty comes risk. Success in many aspects of our lives often relies on understanding how to analyze risks and make sound decisions based upon your analysis. Success isn't about being risk-adverse, it's about understanding probabilities and quantifying potential outcomes to take the right risks.

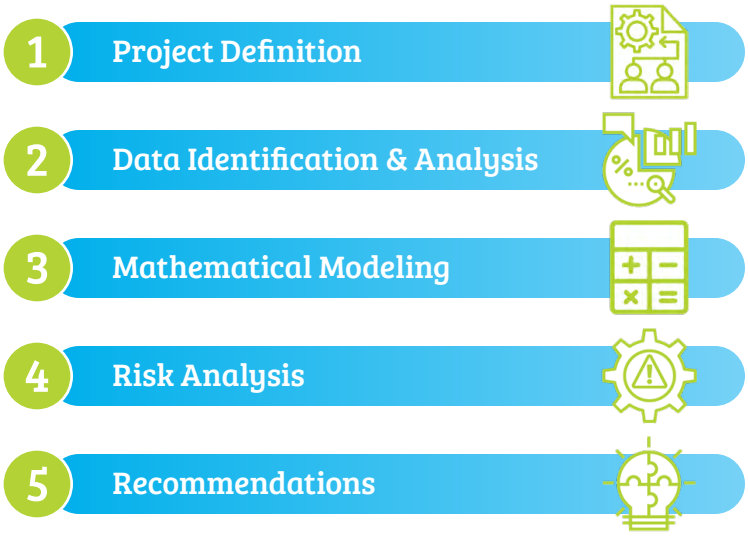
To be great at navigating the choppy waters of the future, you must become great at managing risks. No matter what your interests or career aspirations, you'll want to understand the actuarial process, and learn to use it anytime you're in a situation where you need to make a decision involving uncertain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

Modeling the Future Challenge & the Actuarial Process

The Modeling the Future Challenge (MTFC) tasks students to identify and characterize current or future risks, and to use mathematics to make the best recommendations for how to manage or respond to those risks.

The MTFC launches an "open theme" for the challenge in which students get to choose their own project topic, similar in structure to science fairs. The Actuarial Process is designed to guide students through the stages of identifying a project topic and completing their research report for the MTFC like actuaries do for their companies and clients.

The Actuarial Process is similar in nature to the scientific method. It extends core concepts from scientific inquiry, data analysis, and mathematical modeling to provide a framework through which you can identify, characterize, and manage risks for real-world situations. The process helps you create an accurate depiction of the risks associated with the topic you are researching and to make recommendations to manage those risks. It is defined by five overarching parts:



While the Actuarial Process is dependent upon traditional mathematics and science skills, it also pulls heavily upon 21st century skills such as 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 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. Being able to conduct your own risk analyses using the process will benefit you in nearly any college or career path you choose.

While the Actuarial Process defined in this guide is a broad road map to actuarial research, 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 MTF Challenge and gain a high-level understanding of the kind of risk analysis and modeling that actuaries undertake. Several generalizations have been made in this process that are limiting to the kinds of projects or results that are produced in order to provide a more easily understood process for students to follow.

Teachers and students should use this guide to learn the critical skills associated with the actuarial process. 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.

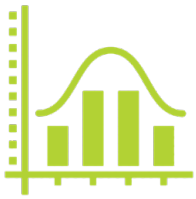
Learn Life Skills

Skills

The following list provides learning objectives and skill sets that will be developed through the Actuarial Process and Modeling the Future Challenge. Not all of these skills will be relied upon for all projects. For example, some projects may use computational analysis and computer coding, while others will not. Students following the Actuarial Process will be able to define their own projects and pull upon skills that are most relevant to them.

1.1 Mathematics (Primarily Statistics & Probability)

1.1.1 Standard deviation
1.1.2 Mean
1.1.3 Distributions
1.1.4 Histograms
1.1.5 Regressions
1.1.6 Conditional probabilities
1.1.7 Independent variables
1.1.8 Expected values
1.1.9 Confidence intervals



1.2 Data Analysis & Computer Science

1.2.1 Basic computer coding skills
1.2.2 Computational analysis techniques
1.2.3 Spreadsheets
1.2.4 Data cleaning

1.3 Science

1.3.1 Research processes & structures
1.3.2 Iterative design
1.3.3 Innovative thinking

1.4 21st Century Skills

1.4.1 Critical thinking
1.4.2 Logic
1.4.3 Communication
1.4.4 Teamwork

> *...completing a project following the actuarial process provides students with valuable life-skills that will help in the college and career choices ahead of them.*

The Actuarial Process

1 Project Definition

Research 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.

Modeling the Future Challenge Project
Step 1: Creating a Problem Statement

To start your MTFC project, define 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.
3) Identifies possible risk mitigation strategies.

Developing a strong problem statement is an iterative process. 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 any of 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 to help display how to create a problem statement and what kind 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 use 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 scenario 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 with some value (often financial) attached to that event. To characterize risks you need to understand what possible outcomes exist for the scenario you are researching. Identifying the possible outcomes will allow you to attach different values of potential loss to each possible outcome.

Example Part 1.1.1: Identifying Risks

Imagine your family is preparing for a week-long vacation to Hawaii. Your parents warn you that if something happens to your mobile phone on the trip, they will not be able to give you another one. With this information, you are trying to decide whether or not to take your phone on the vacation. In this scenario, what are the risks you might identify? First, you will need to define possible outcomes of the scenario.

You may determine that there are three possible outcomes for what happens to your phone on a family vacation to Hawaii:

1) Your phone is fine throughout the duration of your vacation.
2) Your phone gets lost on the vacation.
3) Your phone gets damaged on the vacation.

You have now identified that there are two possible outcomes with a potential for loss in your scenario. However, you will also need to understand how to quantify these risks. What is the value of the potential loss in this scenario? We explore this in the examples below.

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

- The ***severity*** of the undesirable event.
- The ***frequency*** of occurrence of the undesirable event.

In order to define the severity (size) and frequency (likelihood) of potential undesirable events, actuaries use past observations, data, and experiences to construct, validate, and create mathematical models to quantify the risks associated with a research problem.

Example Part 1.1.2:
Defining Severity of a Risk

Continuing the scenario from above, how would you define the severity of risks for each of the possible outcomes? The financial risk for loss comes from the cost of repairing or replacing your phone. If you know that your phone cost $1000, this provides a baseline value for the severity of your potential risk. However, you also need to know the cost of repairing your phone. How could you find this cost? You might think about past times when you needed to repair your phone. You might be able to find online costs for what different companies charge to repair the same phone model you have.

Let's say you find that a local repair shop charges $75 to repair the same phone model as yours. You now have baseline values for the potential losses associated with all of the possible outcomes you defined for this scenario:

1) No loss or Damage = $0 loss
2) Lost phone = $1000 loss
3) Damaged phone = $75 loss

As a baseline for severity, this is a great start. However, for your research project, you may want to consider further analysis of your risks. You may be able to further differentiate the possible outcomes. Is there more than one value of potential loss due to damage? Maybe a heavily damaged phone versus a slightly damaged one? Perhaps there are ancillary losses that may stem from certain outcomes. What could these be? What if you had a business that depended on selling products using your phone? What if you had a team project that required you to be able to talk with your teammates when you returned from vacation? These are potentially valuable lost opportunities from not having your phone.

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

Example Part 1.1.3:

Defining Frequency of a Risk

The frequency of a risk (or potential for loss) is typically displayed as a percentage that defines the likelihood that the loss will happen. Frequency of loss is typically known from past observations, data, or experiences that actuaries have gathered over time. However, if you don't have this information, you can also make assumptions based on your best knowledge at the time. In this example, let's assume that your family has taken 20 vacations since you first got a mobile phone (yes, your family takes a lot of vacations!). This is the information you remember from your past vacations:

1) 16 vacations your phone was fine.
2) 1 vacation you lost your phone.
3) 3 vacations you damaged your phone.

Taking this information, what are the frequencies of loss for the risks you identified?

1) No loss or Damage = 16/20 = 0.80 or 80%
2) Lost phone = 1/20 = 0.05 or 5%
3) Damaged phone = 3/20 = 0.15 or 15%

In your initial analysis, this is a great start! However, actuaries will typically try to identify as much information as they can to improve their numbers. In your project, look for all the ways you can find to refine the calculations of your risks to make them more accurate.

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. 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 quantified 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.

Example Part 1.1.4:

Expected Value of Loss

Continuing our example of taking your phone on vacation in Hawaii. You previously identified three potential outcomes for this scenario:

1) Your phone is fine throughout the duration of your vacation.
2) Your phone gets lost on the vacation.
3) Your phone gets damaged on the vacation.

We also identified the frequencies and severities of the potential losses for each of the possible outcomes. Combining these as noted above we get:

1) No loss or damage to the phone = $0 * 80% = $0
2) Lost phone on the vacation: $1000 * 5% = $50
3) Damaged phone: $75 * 15% = $11.25

Adding these three values provides a quantified Expected Value of the loss in this scenario:

0 + $50 + $11.25 = $61.25

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 gains or losses trend toward over many scenarios. So in our previous example, we would not expect to lose $61.25 every time we took our phone on vacation, but over time, after many vacations, this would be the average loss we expect per vacation if our assessment of risk is correct.

For your ***Problem Statement***, you won't need to define your risks using frequency and severity, or to calculate an expected value of loss. 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 the topic you are researching. This is where Expected Value and other mathematical analyses come into play.

1.2 Defining Who Is At Risk

In any scenario there may be multiple parties at risk. People, organizations, companies, or government groups may all be at risk, or they may have different risks 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 in the scenario.

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

Example Part 1.2.1:
Defining Who is at Risk

In our example where your family is preparing for an upcoming vacation to Hawaii, who might be the audience for your analysis? Certainly, you, as the owner and user of the phone, would be a prime candidate for the audience of your research project; but are there others?

You might also consider a project looking at the risks from your parents' point of view. What about the teammates on projects you have to work with when you return from the vacation? What about the hotel where you are staying? Could they have an impact on the potential outcomes or could they be affected by the possible results of this scenario?

To prepare for writing your Problem Statement you will want to identify as many potential audiences for your topic as you can. Then you can decide which of those audiences you want to conduct your research on and make recommendations to help manage those risks.

1.3 Identifying Risk Mitigation Strategies

It's important to think about how you could help mitigate the risks you identified in your problem statement before you begin building your mathematical model. Understanding potential strategies to mitigate the risks will help define the structure of your models, analysis, and recommendations.

There are three overarching categories for risk mitigation strategies:

1) ***Insurance:*** 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 policy holder against extreme losses. The policy holder pays a little bit of money up front so that they don't have the chance of losing a lot of money later.

2) ***Behavior Changes:*** in many situations it's possible to incentivize changes to behaviors of the people, groups, or organizations involved that will either lower the possibility (frequency) for a loss to occur, or lower the severity of the potential loss. In some cases, the behavior changes may also change the potential outcomes of the scenario so that more severe outcomes become less likely.

3) ***Modifying Outcomes :*** in many scenarios, the parties involved may be able to modify possible outcomes. This will help eliminate high risk possibilities which will in turn help lower the frequency or severity of the overall risk profile of the scenario.

Example Part 1.3.1:

Identify Risk Mitigation Strategies

Using the same phone example, what are some ideas for risk mitigation strategies in each of these three categories? It might be hard at first to think of some, but once you've gone through a few examples, you'll find it easier and easier. Here are a few examples for this scenario:

Insurance:

1) You could ask your parents to sell you an "insurance policy" on your phone so that if you lost or damaged your phone, they would repair or replace it as needed.

2) You could find a third party company that offered an insurance policy to replace your phone if lost or damaged.

Behavior Change:

1) You might note that two out of three times your phone was damaged on vacation was at the pool. A behavioral change risk mitigation strategy could be to stop bringing your phone to the pool.

2) If you lost your phone at the beach, your parents might institute a policy to not allow you to bring it to the beach while on vacation.

Modifying Outcomes:

1) Using a screen guard and phone case has been shown to reduce the number of times a phone needs to be repaired. Buying a screen guard and case could be a risk mitigation strategy to modify the frequency and possibly the severity of loss.

2) You might note from looking at the data about your past vacations that 2 out of 3 times your phone was damaged, it was dropped from the balcony of your 2nd story hotel room. Having your parents only book a ground floor room could be a risk mitigation strategy that modifies the likelihood of this possible outcome.

Your MTFC project recommendations can address any type of mitigation strategy you want to research, or you could analyze and compare multiple strategies. While risk mitigation doesn't get included in your project report until your recommendations section, it is important to consider what strategies might be possible when you are defining your problem statement. Try to identify multiple risk mitigation strategies before moving forward on your research.

1.4 Problems You Can Address with the Actuarial Process

Actuarial research projects can address a wide variety of scenarios and potential risks. Actuaries work in nearly every industry to help companies, organizations, governments, or other groups manage risks. These risks can be many things, but typically fall into potential losses to people or property. Here are some example problem statements from past MTFC themes and other potential topic areas:

Example Topic 1:
Crop Losses Due To Climate Change (MTFC 2019-20 Theme)

1) Climate change is expected to increase the number of severe storms in the Midwest. Iowa's corn farmers are especially susceptible to crop losses due to these severe storms. This project analyzes how the state government of Iowa could implement new policies to help mitigate these losses for their corn farming industry.

2) An increase in flooding expected from climate change over the next three decades will pose significant risks to Missouri's wheat farms. We analyze how farmers in the Mississippi river flood plain can best respond to these expected risks.

3) The top five crops in California's agricultural industry –almonds, walnuts, strawberries, lettuce, and grapes – are all at risk from increasing drought due to climate change. This project models how each type of farmer could best mitigate risks due to these changes.

Example Topic 2:
Future Epidemic or Pandemic

1) As seen with the COVID-19 crisis and many epidemics before this, a severe virus can have devastating effects on economies. Los Angeles small businesses have been hard hit during the COVID-19 economic shutdown. This project analyzes economic risks of a future pandemic and recommends new policy strategies for the city government of Los Angeles to help mitigate economic losses while maintaining adequate health policies.

2) Pandemics have the ability to devastate small and medium sized businesses. In this project we examine how a local restaurant owner can use innovative insurance plans to best plan for and potentially mitigate losses from a future pandemic?

3) The United States saw millions of people become hospitalized and over 150,000 die due to the COVID-19 crisis. The United States is at significant risk of seeing future pandemics at this scale. This project analyzes the impact of various COVID-19 mitigation strategies and examines recommendations for both a national and local strategy to lower the burden on the healthcare system.

Example Topic 3:
Healthcare and Loss of Life Due To Drug Addictions

1) Opioid additions in the United States continue on an upward trend posing significant costs to the healthcare industry. We examine how the federal government could institute new policies to help modify behavior of young adults before they get addicted.

2) Pittsburgh, PA has seen an incredible increase in the number of opioid overdoses in its uninsured population of young adults within the last decade. This trend is expected to continue without additional intervention. The city's hospitals are spending significant dollars on treating these patients who are not able to pay their bills. We examine methods of reducing the loss expected to Pittsburgh's hospitals from increasing opioid overdoses.

Example Topic 4:
Property Loss from Flooding

1) Towns along the Mississippi river are at an increasing risk of flooding due to climate change. During each flood, the local town government is forced to spend significant money to repair the damage to the city's streets and infrastructure. In this project, we examine new policies and insurance plans that the city could adopt to help protect against a devastating loss in an extreme flood.

2) Homes built in the Mississippi River flood plain are having a harder time securing affordable flood insurance due to the increasing likelihood of floods and extreme precipitation from climate change. In this project we examine new options for how local governments and non-profit organizations could help home owners with innovative insurance options.

Example Topic 5:
Future Cures and Healthcare

1) Health insurance companies lose millions of dollars each year paying for treatments of end stage kidney disease. New renal denervation treatments may help shorten the time that patients are in the hospital. We examine how insurance companies could update policies to encourage the use of this new technology.

2) Diabetes cost the US billions of dollars in health care expenses. There is an increasing trend in the number of people with diabetes in the US. We will analyze how the federal government could support the development and implementation of future stem cell therapies that expected to come to the market for diabetes treatment.

Modeling the Future Challenge Process Tip: What Makes a Good MTFC Problem Statement?

1) It identifies a scenario 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.

1.5 Important To Know About Your Problem Statement Before Starting Your Mathematical Modeling

Before you begin finding data and developing your mathematical model to project future trends and analyze your risks, you will want to understand several things about your research problem. Particularly, you will want to explore:

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 data is available? Is it enough to develop a model of the future outcomes?
4) What risks may occur from the scenario you are exploring?

Example Part 1.5.1: Background Research

In our example, taking a family vacation in Hawaii, what background information might you want to know before wrapping up your problem statement? Here are a few example ideas:

1) How many people have lost or damaged their phones at the hotel we are staying at?
2) How many times have people in our family lost or damaged phones on vacations?
3) Are there any correlations between the type of vacation and losing a phone?
4) How many people lose or damage their phones on vacations to Hawaii?
5) Are there any correlations between the type of person that loses their phone? (gender, age, job, etc.)
6 How much does the average phone cost to repair or replace? Are some phones more likely to be damaged than others?

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 problem in the way you thought. However, maybe if you shift your problem statement to a slightly different audience, or a different type of mitigation strategy it will become more straight-forward.

Example Part 1.5.2:

Wrapping Up a Problem Statement

In our Hawaii vacation example we can see that there are many ways you might conduct a research project even in this simple scenario. There are different groups that may be affected by you damaging or losing your phone, and there are many ways that those risks could be managed. How would you write your problem statement for this scenario?

Here are examples of a problem statement using this simple scenario as a starting point.

1) Hotel Aloha in Hawaii took a survey of their visitors for the last 5 years and noticed an above average number of phones being damaged at their pool. The hotel worries that this could damage its reputation and result in lost future bookings. We analyze ways that the hotel could help its guests reduce the risk of damaging or losing their phone during a stay at the hotel.

2) Losing a phone on vacation will result in significant loss to our family not only in terms of the value of the phone, but also in productivity after returning home. We explore a family phone insurance plan that will ensure that we have the long-term funds to replace damaged phones and remove the risks of having to pay full price for a new phone.

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 research 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 researching and the potential for loss. This background research will help you confirm if you have enough information to complete a project on the topic.

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 & Analysis

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 to the scenario you are researching. Often times in actuarial research 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: (1) what types of data will enable a good analysis, (2) how do you ensure data reliability, and (3) where can you find relevant data sets?

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 may be helpful to consider data in these five categories:

1) Defining historical trends
2) Projecting future trends
3) Separating potential outcomes
4) Defining the severity of potential losses
5) Defining the frequency of potential outcomes

Example Part 2.1.1:
Identifying Data

Let's follow the example Problem Statement from above where we are working with Hotel Aloha. The hotel is concerned about an increasing trend of lost phones at their hotel and is worried about damage to their reputation and future sales. What data would we want to find for this scenario in each of the five areas mentioned above?

In this scenario we would consider the following data:

1) ***Data that helps define historical trends*** – does Hotel Aloha keep records on the number of phones lost at their hotel? What about insurance companies that fund phone replacement insurance plans? Are there records of claims on those policies?

2) ***Data that helps projecting future trends*** – is there information about how phone prices or the number of phones lost at the hotel are changing over time? Can you project that into the future?

3) ***Data that helps separate potential outcomes*** – is there information about what type of phone user is more likely to lose the phone? Or other information about how or where the phone was lost? You could use this information to help separate out the potential outcomes and refine your models.

4) ***Defining the severity of potential losses*** – do you have data on the price of phones? Is the price changing? What about how many of each type of phone are typically brought to Hotel Aloha?

5) ***Defining the frequency of potential outcomes*** – Is there information on how many people visit the hotel each year? How many of them bring phones with them? You could use this information with the number of insurance claims on lost phones or records from the hotel to determine a frequency of lost phones – what percentage of phones are lost from all the hotel guests.

2.2 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 efficacy 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 three main areas to consider that may increase your data efficacy:

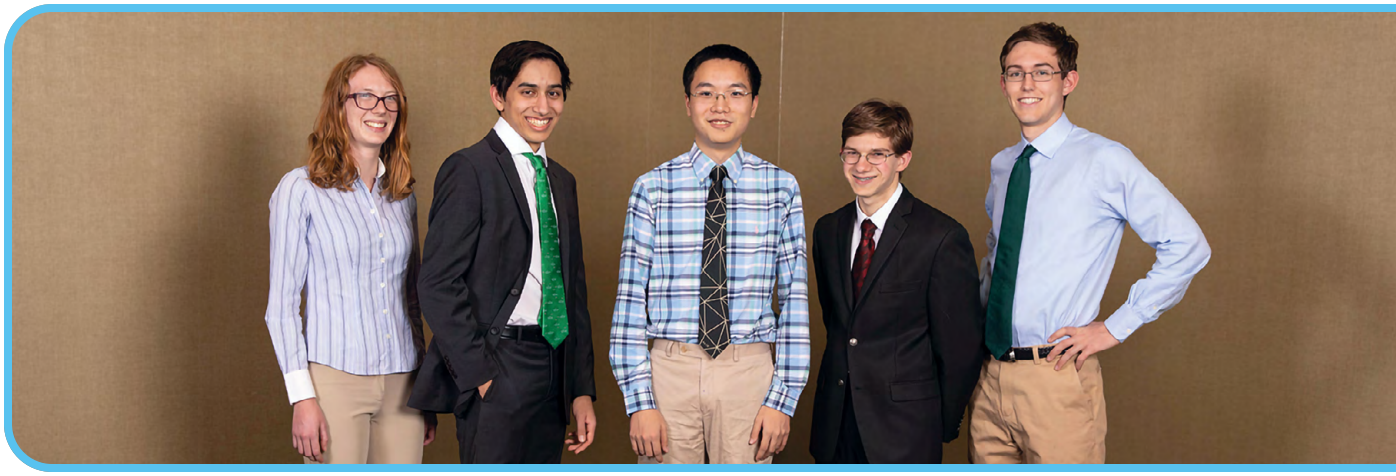
1) Cleaning the Data.

Having accurate data in a workable format is often 90% of the work. Check any data tables for completeness 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 reviewing your spreadsheet for any missing cells, or obvious errors such as having a letter in a field that should only have numbers.

2) Adjusting the Data.

One of the most readily known examples of adjusting data is from the financial world. Over the years, the value of the dollar changes. This is typically known as "inflation." In 1950, the cost of a Coke was $0.05. Today it is between $1 and $2. Inflation is a general term for the change in overall cost of goods, and has a known value on which people studying finances and economics can 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.

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) Data Credibility

The size of your dataset is important to consider in your project. There needs to be sufficient data in order to draw firm conclusions. Actuaries use the concept of "credibility" to express how well the dataset can be used to make projections.

For example, suppose a medical insurer covers 1 million lives and knows that medical costs increased 6% for 2018 to 2019. The insurer wants to predict the costs for 2020 for one company that has just 100 employees. You know that this company's medical costs increased 15% from 2018 to 2019. What cost increase should the insurer use for this company in predicting 2020 costs? Should the insurer use 6%, 15%, or a blend of the two? How should the blend be determined?

There are many mathematical ways of determining this. However, the baseline concept that you should enter your project with is that data credibility varies based on the size of the dataset (your "N" value in most statistics texts). Typically, the larger the dataset, the more credible it is. Once you have this concept down, you'll be able to build upon it to make more advanced adjustments based on data credibility.

4. Efficacy

Reviewing the sources of your data and making sure they are valid and trust worthy sources. 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 fraud. Should you use this data? Probably not.

Modeling the Future Challenge Tip: Data Identification

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. 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 credibility early on. Start with the basics of identifying good data and build from there.

2.3 Finding Data

Your first stop for finding data for your MTFC project should be the MTFC website. 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 our existing links.

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) Gathering your own data
4) Industry associations

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 is often hard to access because many companies keep their data internal and proprietary; however, if you have a relationship with 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, 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, make sure to think critically about what is needed and examine what already exists.

A final source of information and data to consider are industry associations. 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.

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 year but 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 frequency and severity of the loss and risk of the particular topic under study. In order to best support your model, consider the datasets that you have found. Does an identified data source address frequency or severity (or both)? If a data source cannot address both, you will need additional data research to identify at least one source that addresses frequency and one that addresses severity to be able to adequately quantify risk.

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 we would consider the following data:

1) ***Data that helps define historical trends*** – can we find annual or even monthly data on crop losses? Yes, after some research we can see that the National Crop Insurance Program from the federal government has this data.

2) ***Data that helps projecting future trends*** – is there information on what the expected climate change is for California? Yes, the Global Change government group has information about how the climate is changing.

3) ***Data that helps separate potential outcomes*** – in this scenario different outcomes could be explored in two 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 this information from the National Crop Insurance Program.

4) ***Defining the severity of potential losses*** – yes, data from the National Crop Insurance Program provides severity of losses for the state of CA.

5) ***Defining the frequency of potential outcomes*** – yes, 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.

Modeling the Future Challenge Project
Step 2: Data Identification

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 five points on enabling a good analysis discussed above.

2) Identified any basic needs for cleaning or adjustments in your datasets.

3) Examined the credibility of your data – is the dataset large enough to make a valid analysis and recommendations?

Remember not to get bogged down, or discouraged by getting too far in 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 below 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 section on 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.

3.1 What do Actuaries Want Their Models To Do?

The over-arching goal of your actuarial model should be to determine, with the most accuracy possible, the frequency (likelihood), severity (size), and other characterizations of the potential risks for your project.

Actuarial models may also explore how the data is changing over time and identify if there are any trends in the data that will affect future outcomes and risks. Models will typically combine the frequency and severity values of your possible risks to identify the "expected value" of loss for scenario. However, as mentioned in our examples, actuarial models will go far beyond simply identifying an expected value and will find more detailed ways of characterizing their risks.

> *"Actuarial Models deal in probabilities, not firm numbers."*

Your model may also benefit from considering confidence intervals and upper and lower bounds to your risks. For example, 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?

3.2 What Does An Actuarial Model Look Like?

There is no standard template for how to create an actuarial model for your project. Every project is unique and your model will need to be specially designed to work with the data you have and the scenario you are researching.

Models can be computational (using computer programs and algorithms), or they can be purely mathematical. Whatever structure you use, your model will take data as an input and use various computations to produce results that will help identify the expected values of risks for your scenario. Models also often extend their analysis to examine multiple mitigation strategies to help quantify how adopting each strategy could lower the risk for future losses and compare which strategy is best.

3.3 Making Assumptions for Your Model

No actuarial model is perfect. Every project will need to make some assumptions about the data, scenarios, possible outcomes, and other factors associated with your project. These assumptions themselves can lead to uncertainties in your model and will be something you will want to note in your Modeling the Future Challenge projects. Assumptions can be large, or small, but the more accurate your data and model is, the better its results and the more accurate your recommendations will be.

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

It is important to understand what assumptions you are making in your model and to identify those in your report. For example, if you only know the price of one type of mobile phone, you may need to assume that all cell phones cost the same price. This generalization limits the accuracy of your model, but if you did not make that assumption you would not be able to have a model in the first place without more detailed data.

Modeling the Future Challenge Project
Step 3: Wrapping Up Your Mathematical Model

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

- Identify the frequencies (likelihoods) that each potential outcome for your scenario will happen.
- Identify the severities (size) of possible losses.
- Identify expected values of potential loss for your scenario.
- Understand the distribution of potential outcomes.
- Identify trends in the data and understand how potential outcomes and associated risks may be changing over time.
- Identify 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

Risks are at the core of every actuarial project. When boiled down to its basics, your actuarial model should provide insights about how to characterize and analyze the risks associated with your problem statement. But what is a risk? This can be defined in many ways, but at its most fundamental, ***a risk is a potential for loss.***

When you first start defining your project, you will want to think about what potential risks there might be and who could be at risk. However, your mathematical model will help you characterize and quantify those potential risks for the people, businesses, or organizations related to your project. As you complete the section, it may be advisable to revisit your mathematical model to ensure that you have a model that will allow you to analyze risk. These two stages of the Actuarial Process will be a process of adjustment and refining to ensure that the model informs the risk analysis and that the risks assessed have actually been modeled.

Make sure to understand the concepts of ***Severity, Frequency, and Expected Values*** that have been mentioned earlier in this guide before attempting to further characterize and quantify your risks. In a risky scenario, there will usually be more than one possible outcome with different levels of risk attached to each. To get a complete calculation of your Expected Value of risk for a scenario you will need to understand all possible outcomes.

4.1 Fundamentals of Characterizing & Quantify Risk

The simplest and perhaps most fundamental way to quantify a risk is with an ***Expected Value*** (See previous examples for how to calculate the expected values of a risk). However, most actuarial projects will want to go deeper than this to create a better picture of the potential future outcomes, and to help make valid recommendations to the organizations that could help mitigate those risks. Here are a few tools and concepts that may be useful in your risk analysis:

- ***Standard Deviation & Variance:*** this may be one of the first things you learn in your high school statistics course, but it is one of the most powerful tools you have in understanding risks and recommendations. Knowing the standard deviation or variance of possible outcomes will help you define your possible risks beyond just having an expected value.
- ***Confidence Intervals:*** understanding how likely it is for possible outcomes to lie within certain ranges will be useful in many analyses.
- ***Histograms:*** using histograms to display the possible outcomes of your project is valuable to help you see the distribution of your potential results and risks. Histograms will easily show you how your data are distributed.
- ***Projecting Trends:*** it can be valuable to assess whether there are trends in the historical data, and if so to make projections of future trends. An easy-to-create trend projection is a linear regression model. However, it should be noted that it is dangerous to extrapolate a linear regression model when predicting future trends. This may be useful for some projects; however, it cannot be used for all (or even most) data. You may want to explore additional ways to project the trends in your data that will be more accurate or appropriate than linear regressions.
- ***Distribution of Results:*** building upon your understanding of standard deviation and variance, understanding the distribution of potential outcomes will be important for your overall characterization of risks. This helps you identify extreme events, or the potential for very high losses, but with a very low probability of occurring.

Example Part 4.1.1:
Risk Analysis Beyond Expected Values

Consider the following two (very simplified) scenarios. Both could exhibit the possible outcomes for Hotel Aloha's potential lost booking revenue due to damaged or lost phones at their hotel:

> ***Scenario 1:*** potential outcomes include: a 50% chance of a $1,000 loss and a 50% chance of having no loss (a $0 loss).
>
> ***Scenario 2:*** potential outcomes include: a 0.5% chance of a $100,000 loss and a 45% chance of a $1,000 loss, and a 54.5% chance of no loss (a $0 loss).

Both scenarios produce an expected value for loss of $500. However, the distributions of potential losses are very different. The recommendations you might make to be able to reduce the risks or potential losses will likely be very different for these two situations. For this reason, it is important to be able to characterize your risks using more than just an expected value.

Modeling the Future Challenge Project
Step 4: Wrapping Up Risk Analysis

To wrap up your project's Risk Analysis section, first consider what kinds of risks you identified when defining your problem statement in part 1 of the Actuarial Process. Use the data you have found, and the mathematical models you have created to characterize and quantify the risks as best you can. Think about these questions to help you wrap up risk analysis (but don't limit your analysis to just these):

1) Can you identify an expected value for your losses in the scenario you're researching?
2) What is the distribution of loss? Is it equally likely that you will see a very large loss as a very small loss?
3) Are there extreme events you need to include? Very small possibilities for very large losses?
4) Can you identify a range for your expected losses? For example can you be 95% confident that losses in a future year will be between a certain range?
5) Can you identify any trends in the data that may indicate the severity or frequency of losses is changing over time?
6) How else can you characterize the possible outcomes to your scenario and potential losses from those outcomes?

5 Recommendations

The final part to the actuarial process is to convert your analysis into real-world recommendations on how the people, companies, governments, or organizations affected, should respond to the risks you identified. Just like with your model, 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 characterized risks in your project, recommendations are also best when they are quantified and in specific terms rather than generalizations. 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 ahead of them.

Use the information in the following sections to help understand how to identify and define specific, quantified recommendations for your actuarial project.

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 on taking a certain course of action to minimize the future risks.
- ***Financial Decisions*** – help businesses, governments, or organizations make financial decisions that will lower their exposure to high risk endeavors.
- ***Government Policies*** – help governments identify which policy decisions will be the best for their constituents, and will help them minimize exposure to high risks.
- ***Mitigating Risks with Insurance*** – provide new insurance products and opportunities to minimize risks for individuals, governments, companies, or organizations.

Remember the risk mitigation strategies mentioned in section 1.4 (insurance, behavior change, and modifying outcomes). Your actuarial project will use one or more risk mitigation strategies to help the audience you are addressing manage risks. When analysis reveals that recommendations do not call for changes, critically consider what possible changes could have an impact on future outcomes which could in turn demand revisions that may influence recommendations. If or when this happens, consider what additional data might be needed.

On the other hand however, a valid recommendation to make based on the modeling and risk analysis is one that advises the stakeholders to continue with the current approach and strategies that have already been implemented. Evidence and justification to back that recommendation as to the effectiveness of current implemented strategies should be included.

5.2 How Does Insurance Help Mitigate Risk?

The simplest way of understanding how insurance helps to mitigate risk is that it reduces the range of possible losses for a policy holder. Insurance policies are used in many industries, some of the most common of which are auto, health, home, and life insurance. When considering recommendations involving insurance policies, consider how an insurance policy will be able to better protect your audience from the potential risks you have modeled.

See our Modeling the Future Challenge Basic Training Modules on risk and insurance for more detail.

Modeling the Future Challenge Project
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.

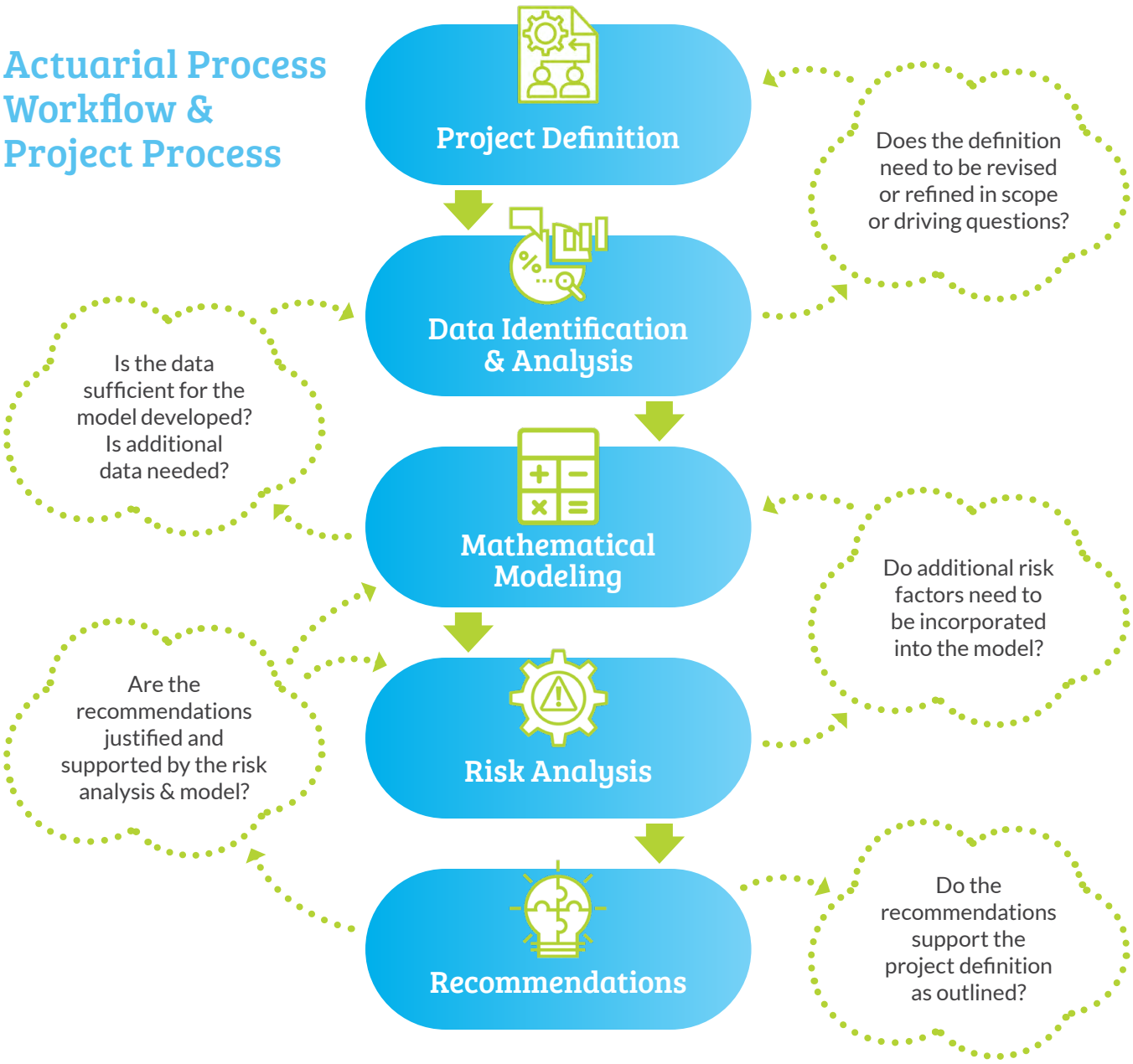
3) Respond to the problem: make sure that your recommendations address the original problem statement you identified in defining your project. There may be many things you think could change associated with the project, but be clear about how those changes will improve the problem and help manage or 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 this 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



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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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