MTFC Quest Scenarios 2023

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Team ID #	16425
Proposal Topic Title	A Proposal for a Mathematical Model for the Impact of Changing Hummingbird Populations on

Mission 1 Ski Resort Prompts:

These prompts can be found on pages 11-12 of the Scenario Quest. Additional information on Data Identification and Analysis can be found on pages 11-22 of the Actuarial Process Guide

1.1:

- Beyond the ski resorts themselves, groups that are at risk for profit loss include the skiers, companies that provide transportation and machinery for ski resorts, hotels near the resort, ski and sports equipment shops, as well as other nearby businesses. Local towns would consequently be at risk, as they would receive less revenue in taxes, given lower profits from the private sector. These conclusions were reached by considering the stakeholders associated with ski resorts, and considering the possible consequences that could result from ski resorts losing profits.

1.2:

- On a climatic level, two major variables that could be considered are snowfall and ski season timeframe. Excessive snowfall may incur loss due to insurance payments made for higher injury rates due to more avalanches and other dangers. Meanwhile, short ski reasons and less snow, factors which are likely correlated, would lead to lower profits. It would be fruitful to investigate other metrics including insurance, employee pay, operational costs, and with that, the information on the machinery, among other factors.

1.3:

- Possible insurance policies may include buying warranties that are able to cover instances of machine breakdown due to aging or abnormal climate conditions caused by global warming. There are many behavior changes ski resorts can undergo to counter decreased revenue. These measures include lengthening the ski reason in conjunction with increasing the use of artificial snow, and placing warning signs for hills where skiers could easily get injured due to their more dangerous conditions brought about by climatic instability. One way outcomes can be modified is through the obviating the costs from having to cover for the health payments of injured skiers. A ski resort could have customers sign a waiver before skiing, where, if the customer gets injured, they shall agree to pay back the resort for any necessitated healthcare payments.

Mission 2 Ski Resort Prompts:

2.1:

- What insurance plans cover for the largest range of sources of revenue loss for ski resorts while maximizing profits (i.e., what plans are simultaneously the most comprehensive and cheap)?
- How are modified weather conditions, the frequency and severity of injuries, as well as annual ski resort revenue, all correlated with one another?

2.2:

- The provided dataset contains past historical trends, namely regarding the revenue of the three resorts. It also separates outcomes by sorting each year from 2003-2022 as either having "typical", "light", or "heavy" levels of snowfall. In providing annual profits, both the severity and frequency of revenue loss with respect to snowfall level can be indirectly defined through analyzing the relationship between profit and snowfall level. In fact, future annual profits can be projected using a linear regression model based off the historical data. The dataset's utility lies in forging this analysis and capacity to predict. However, in order to assess profit loss and mitigation strategies more holistically, other relevant variables, such as costs incurred by insurance policies, the rates of skiing accidents and machine breakdown, among other factors, could be included.

2.3:

- The sample size is $n = 20$ for each of the three ski resorts in the dataset. Quantitative variables mainly include the annual revenue of each resort, while categorical ones primarily include the type of snowfall level each year. The year and ski resort act more as identifier variables for the data. The average profits were $752,000, $811,150, and $724,400 for the Alpine Arena, Mountain Meadows, and White Haven ski resorts respectively, with respective standard deviations of about $191,000, $176,000, and $170,000. Using a frequency distribution table would be helpful in determining the probability of each level of snowfall occurring. Another useful tool for this dataset would be histograms. This would allow for the nature of the distribution of annual profits for each resort (i.e. skew and modality) to be discerned. However, one major limitation of these data is the use of snowfall amount as a categorical variable. Snowfall level can easily be quantified. Only then could a correlative relationship between revenue and snowfall be better established.

Mission 3 Ski Resort Prompts:

3.1

- The article “A georeferenced agent-based model to analyze the climate change impacts on ski tourism at a regional scale” by Pons et al. describes an agent-based climate change model which analyzes the effect of climate change on ski resorts. The model has four scenarios, the first two being an increase in temperature by either 2 °C or 4°C in the winter season, and the next two analyze the effects of snowmaking to increase snow depth in the first two scenarios. The model then classifies ski resorts into three groups; high vulnerability, low vulnerability, and resilient. Climate projections of future snow depth and potential snowmaking capacity at the mean elevation of the resort as well as the daily attendance of skiers at each ski resort are used as input data for the model (Pons et al., 2014).

- The article “The Impacts Of Climate Change On Ski Resorts And Tourist Traffic” by Tepfenhart et al. utilizes a discrete choice model as well as traffic models to analyze the impact climate change is having on the flow of tourists to ski resorts and the traffic they experience for resorts across the Upper Danube river valley. Snowfall amounts are correlated with the length of time spent in traffic jams. The article finds that, given the changes snowfall in this region shall experience due to global warming, traffic jams of tourists traveling to ski resorts in this area are to increase in the coming years (Tepfenhart et al., 2007).

- The mathematical techniques found in these and other articles include discrete event simulation, whereby a model’s changes are illustrated through a series of steps. Similarly, some of these studies utilized discrete choice models, a form of regression analysis where options that may be chosen within the given situation, and their likelihood of being chosen, are described. Unlike continuous models, these discrete models deal with categorical data. For example, the choice to get or not to get insurance is discrete; there is no numerical link between the two. Another major technique used in these studies was mutli-agent based modeling and linear programming.

3.2

Snowfall Level	Typical	Light	Heavy
# of Years (out of 20)	14	4	2
Probability of Occurring	0.7	0.2	0.1

Resort	Overall Mean Profit ($1000)	Mean Profit for Years of Typical Snowfall ($1000)	Mean Profit for Years of Light Snowfall ($1000)	Mean Profit for Years of Heavy Snowfall ($1000)
Alpine Arena	752	786	451	1116
Mountain Meadow	811	886	483	945
White Haven	724	799	505	645

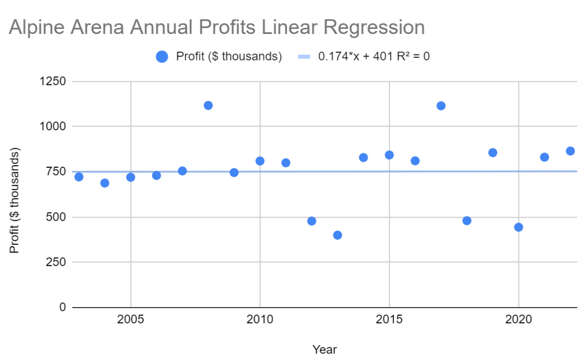
Based off the table above, it is clear that the mean profit for years of light snowfall differs from that of years with typical amounts of snowfall. Specifically, profits are lower during years of light snowfall. The overall mean profits are $752,000, $811,000, and $724,000 for the Alpine Arena, Mountain Meadow, and White Haven ski resorts, respectively. Meanwhile, the corresponding average profits for years of light snowfall are $451,000, $483,000 and $505,000.

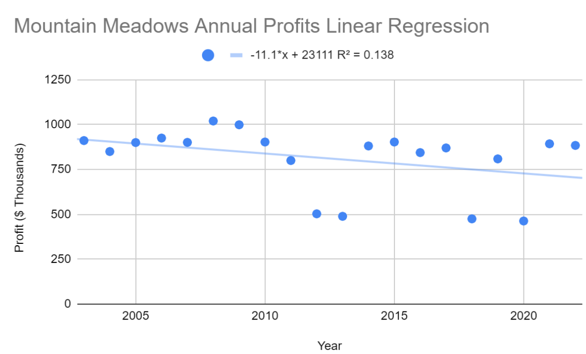
	Mean Profit for Years of Typical Snowfall ($1000)	Mean Profit for Years of Light Snowfall ($1000)	Mean Profit for Years of Heavy Snowfall ($1000)	Expected Profit ($1000)
Alpine Arena	786	451	1116	
Probability of Occurring	0.7	0.2	0.1	752

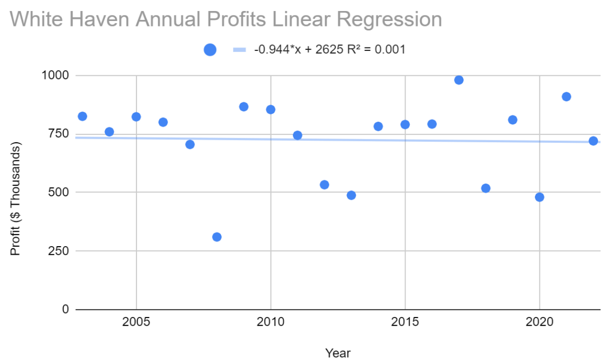
	Mean Profit for Years of Typical Snowfall ($1000)	Mean Profit for Years of Light Snowfall ($1000)	Mean Profit for Years of Heavy Snowfall ($1000)	Expected Profit ($1000)
Mountain Meadow	886	483	945	
Probability of Occurring	0.7	0.2	0.1	811.3

	Mean Profit for Years of Typical Snowfall ($1000)	Mean Profit for Years of Light Snowfall ($1000)	Mean Profit for Years of Heavy Snowfall ($1000)	Expected Profit ($1000)
White Haven	799	505	645	
Probability of Occurring	0.7	0.2	0.1	724.8

3.3:







Out of all of the ski resorts, the linear regression for the Mountain Meadows resort indicates that it is likely to lose profits in upcoming years. Compared to other two linear regressions, which have slopes near 0, the slope for this linear regression is -11.1, meaning that over time, profits are expected to decrease.

One assumption we must make for these models is that the profits for years of light and heavy snow, despite being divergent from that of years of typical snowfall, do not significantly impact the linear regression lines. Another assumption that must be made is that annual profit is independent of each year. That is, the profit of one year does not impact that of another.

Mission 4 Ski Resort Prompts:

4.1:

- When looking at years of atypical snowfall for the Mountain Meadows resort, it is clear that the revenue in 2017, which was a year of heavy snowfall. Whereas Alpine Arena and White Haven resorts had profits of $1,115,000 and $980,000 respectively, Mountain Meadows had a revenue of only $870,000, which is within the range of profits the resort saw for typical years. The profits mentioned for Alpine Arena and White Haven were far above their respective ranges of annual profit during typical years. Hence, this outlier is not impacting all resorts equally. A possible cause for this lower revenue could have been that higher revenue from greater ski attendance was canceled out by a possible accident that necessitated insurance coverage or some other costs on part of the resort.

4.2:

- These probabilities provide insight exclusively into the frequency of profit loss for Mountain Meadows. This is because any probability of any given event occurring is a measure of the frequency of that event, and this value does not speak to the severity of a risk.
- These probabilities provide insight exclusively into the severity of profit loss for Mountain Meadows. This is because the annual profits are strictly quantitative values that can be compared with each other as well as subtracted from one another in order to assess severity, without any insights on risk frequency being delineated.
- While there may not be any profit loss, the degree to which revenue is made under certain conditions, namely years of light snow, is lower. However, in order to account for the frequency of such an event occurring, multiplication by the probability of a year of

light snow occurring must first be done. By capturing the mean profits of different scenarios through their respective probabilities, where the mean profits differ by weather condition, meaning some events have a lower amount of profit, loss can be accounted for.

Mission 5 Ski Resort Prompts:

5.1

- It is highly clear from the linear regression model, as well as an analysis of the various tabular data describing revenue for Mountain Meadows ski resort, that there is a projected downward trend in revenue. Presently, for every year in the regression model, it is predicted that profit shall decrease by $1,100. Moreover, the tabular data from 3.2.2 indicate the significant vulnerability to loss Mountain Meadows' revenue faces during years of light snow, which has a 1 in 5 chance of occurring.

5.2

- Possible behavior changes could include lengthening the ski season, as well as increasing the use of artificial snow. Both actions would allow skiers to more easily travel on ski resorts, increasing profits. However, this would likely incur additional operational costs, whether it be having to pay employees greater dividends, operate the machinery for longer, which would cancel out potential profit gained from longer operation times and more artificial snow.
- Two possible courses of action to take to modify outcomes include making skiers take liability for the health costs they incur for any injuries. Additionally, building safer courses would change outcomes by obviating chances for accidents.
- Insurance would provide a solid safety net financially for the ski resort business in cases of dire need for capital. With global warming poised to reduce ski resort profits, Mountain Meadows could stand to benefit from a source of capital should its finances reach a point where the company cannot operate optimally.

5.3

Without Insurance:

	Mean Profit for Years of Typical Snowfall ($1000)	Mean Profit for Years of Light Snowfall ($1000)	Mean Profit for Years of Heavy Snowfall ($1000)	Expected Profit ($1000)
Mountain Meadow	886	483	945	
Probability of Occurring	0.7	0.2	0.1	811.3

y = Profit without insurance ($)

SD(y) = $\sqrt{\Sigma(y - \bar{y})^2 P(y)}$

SD(x) = $\sqrt{(886 - 811.3)^2 * 0.7 + (483 - 811.3)^2 * 0.2 + (945 - 811.3)^2 * 0.1}$

SD(x) = 165

Using Insurance:

	Mean Profit for Years of Typical	Mean Profit for Years of Light Snowfall ($1000)	Mean Profit for Years of Heavy

	Snowfall ($1000)		Snowfall ($1000)
Mountain Meadow	856	553	915
Probability of Occurring	0.7	0.2	0.1

x = Profit with insurance ($)
E(x) = $\sum xP(x)$
E(x) = ((0.7*856)+ (0.2*553)+(0.1*915))
E(x) = 801.3

SD(x) = $\sqrt{\sum(x - \bar{x})^2 P(x)}$

SD(x) = $\sqrt{(856 - 801.3)^2 * 0.7 + (553 - 801.3)^2 * 0.2 + (915 - 801.3)^2 * 0.1}$
SD(x) = 125

Without Insurance:

	Mean Profit for Years of Typical Snowfall ($1000)	Mean Profit for Years of Light Snowfall ($1000)	Mean Profit for Years of Heavy Snowfall ($1000)	Expected Profit ($1000)	Standard Deviation ($1000)
Mountain Meadow	886	483	945		
Probability of Occurring	0.7	0.2	0.1	811.3	165

With Insurance:

	Mean Profit for Years of Typical Snowfall ($1000)	Mean Profit for Years of Light Snowfall ($1000)	Mean Profit for Years of Heavy Snowfall ($1000)	Expected Profit ($1000)	Standard Deviation ($1000)
Mountain Meadow	856	553	915		
Probability of Occurring	0.7	0.2	0.1	801.3	125

The expected value for revenue without insurance is $811,300 with a standard deviation of $165,000. Meanwhile, while the expected profit with insurance is only $801,300, the standard deviation is $125,000. With a smaller standard deviation, the insurance plan would stabilize profits, aiding stability in business operations, albeit at a slightly lower level of revenue.

Hummingbird Project Prompts

Mission 1 Hummingbird:

- Our team is proposing to investigate recent changes in the migratory patterns of hummingbirds. Hummingbird populations are most prevalent throughout the Americas. Hummingbird migratory patterns are a crucial facet of crop pollination, food webs, overall ecosystem health, and are a contributing factor to the stability in agricultural production, which many markets rely upon for sales. Thus, as climate change modifies hummingbird migration patterns, it is important to note what impacts that will have on the climate and environment. A particular focus on floral industry profits shall be placed.

- Rising temperatures and other climatic patterns in recent years have led to modifications in flight patterns, timings, and destinations for hummingbirds. This leads to the desynchronization with flower blooming periods, offsetting the amount of pollination and the vitality of certain plants. Economically, this could destabilize productivity for the sectors relying upon selling crops pollinated by hummingbirds, namely the floral and agricultural industries. This is problematic for food access along the food supply chain, and sales. It is important that businesses are able to adapt to a changing supply of crops and flowers. Ideally, stability among ecosystems and industry yields are maintained.

- Possible risk mitigation strategies for this issue include habitat conservation, insurance, and actions taken against climate change. Habitat conservation is already being used to preserve crucial and unique ecosystems around the world, but further increase of this would stand to benefit the hummingbirds; by preserving their habitats, it becomes easier for them to maintain consistent migratory patterns throughout the years. In addition, insurance can be implemented to help protect businesses and organizations against the deadly outcomes of factors such as crop loss. As hummingbirds help to pollinate flowers, the compensation of farmers who contribute to the floral industry would be vital in supporting them economically, even amidst the changing migration patterns of hummingbirds. While on a larger scale, the last proposed strategy involves greater action taken against climate change. Whether it be through increased advocacy or government support, stifling the effects of climate change combat the damage that has been done to migration patterns over time.

Mission 2 Hummingbird:

Driving questions:

- How have the migration patterns and times of hummingbirds changed over the years?
- How has climate change impacted the habitats of hummingbird species?

Ideal datasets would include info of migration patterns over many years, including data from the 1900s all the way up until present-day. Additionally, looking at data on different species of hummingbirds can help to provide a better understanding of hummingbirds overall. There may already be studies conducted on how climate change affects migration patterns and habitats of various organisms, so such studies with info specific to hummingbirds would be useful.

Potential data sources:

- "How Climate Change Affects Hummingbirds' Feeding Behavior": This article provides data on snowfall, and rising sea levels and temperatures. It also mentions tracking hummingbird migrations and changing blooming periods for plants, with nectar being a major source of food for hummingbirds. This data can serve as a strong base for forming correlative relationships between parameters being altered by climate change and hummingbird migration. It would also be useful in the sense that it provides the raw climate data (*How Climate Change Affects Hummingbirds' Feeding Patterns*).
- "Citizen-science data provides new insight into annual and seasonal variation in migration patterns": This study was a pioneer in establishing data on changing migration patterns in hummingbirds. This source would serve as a major basis for raw data on the hummingbird migrations themselves. This data could then be connected to other parameters that impact the migration patterns as we continue our investigations (Supp, 2015).
- "Climate change and shifting arrival date of migratory birds over a century in the northern Great Plains": This study focuses on the phenology of the hummingbird migration patterns themselves, looking at data collected over the last century in the Northern Great Plains. Thus, in addition to the spatial trends from other sources of data, we would attain the temporal trends for hummingbird populations (at least in this specific area). This is another important piece of information to consider when looking at how hummingbird populations are changing (Travers, 2015).

Mission 3 Hummingbird:

- General search results returned many useful insights for both collective bird migration and hummingbird migration patterns based on climate change. We observed the use of citizen science data in modeling these patterns is particularly noteworthy as they appeared across multiple sources. Another search result yielded Makarov Modeling, a strategy that implements math that we are still unfamiliar with.
- Another statistical technique found from research in other articles is principal component analysis. In a study with many different variables, principal component analysis helps to compress variables into vectors; this is useful in identifying the variable with the greatest magnitude, and therefore, greatest importance. This would be useful as there are many different factors that affect the migration patterns of hummingbirds. Beyond identifying driving parameters, the use of advanced regression models and other predictive models is to be used for modeling financial impact on the floral industry. Spatial and temporal models for hummingbird population dynamics are also to be used.
- Our goal is to model floral industry profit loss due to changing hummingbird migration patterns. By creating a model that takes into account important parameters about hummingbird populations as it relates to flower blooms, and in turn, floral industry profits, this can be achieved. As driving parameters are identified, modified values can be input into the model to assess change in floral industry profits.

Mission 4 Hummingbird:

<u>Phenology and Conservation:</u> Hummingbirds are being threatened due to habitat and food loss. Because of warming temperatures, flowers bloom earlier, affecting hummingbird migration patterns. If hummingbirds arrive after flower blooms, they leave them without pollinators, which can negatively affect flower population growth. Therefore, flower companies should plant later and change their planting schedule based on the changing climate. Habitat loss also alters hummingbird migration. By conserving habitat conditions, migration patterns shall return to their original state, stabilizing profits.

<u>Insurance:</u> Most farmers have commercial property insurance, which protects crop loss from natural disasters and revenue loss due to price declines. If the floral industry has insurance, crops can be classified as assets. This would allow the floral industry to receive compensation for the profit lost due to the change in hummingbird migration patterns reducing crops.

<u>Climate Change Actions:</u> The floral industry should inform their policyholders (farmers) to save extra crops for the next year. Due to global warming, hummingbirds migrate later, therefore, not enough flowers bloom during one season. Additionally, they should inform them to buy an insurance policy to help them pay for the equipment and storage of the flowers. More investment in the flower industry is necessary.

Mission 5 Hummingbird:

The most optimal risk mitigation strategy is the habitat conservation method. This method would positively impact hummingbird migrations, which is also directly related to the business's profits. Habitat conservation directly affects hummingbirds as it utilizes their migration patterns to help maximize profit and tries to mitigate the change caused by climate change. Climate change actions affect the flowers less as the farmers should plan to plant the flowers later, which causes the flowers to bloom like they used to. However, farmers should still have commercial property as another risk mitigation strategy. This will ensure that any losses induced by crop damage will be insured. Specific metrics such as profit loss, migration times, and the number of flower blooms would help decide the best risk mitigation strategies.

A possible consequence of our recommendations could be related to high expenses. Habitat conservation may require a lot of financial support, which makes it harder to develop. However, if more and more people become involved with taking action against climate change, habitat conservation will ultimately benefit. Research will also be needed to check if plants can be planted later and still bloom and if hummingbirds will be drawn to the nectar.

Through these recommendations and the focus on habitat conservation as an ideal risk mitigation strategy, a successful outcome would entail the restoration of hummingbird migratory patterns. Doing so would not only assist the patterns and fitness of hummingbird species, but also provide a foundation for assisting other pollinators and migratory animals. Overall, the proposed strategies can greatly help in restoring ecological balance in areas and lead to more stable ecosystems, which benefits both wildlife and humans alike.

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