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Design of a Climate Related Financial Risk Tool

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Author Note: Joseph Privitera, Ovidio Castillio, and Mikeal Lockard are graduating seniors at George Mason University. They are all pursuing their bachelor's degrees in systems engineering at George Mason's College of Engineering and Computing. This senior design project is supervised by Professor Lance Sherry and PhD student Jomana Bashata of GMU's SEOR department. For requests, contact any of the authors at the emails shown above.

Abstract: Climate change has caused an increase in both frequency and severity of storms. These storms are putting enterprises' assets at a much higher risk of damage. A decision support tool to help enterprises better understand and adapt to these climate related risks was developed. Using RCP data, this tool calculates the probability of a certain climate event occurring, and helps users make the important decision regarding their assets such as whether to upgrade existing assets, or repair assets after being damaged. A case study for Warrenton Airport (KHWY) to validate the design of this tool.

Keywords: Representative Concentration Pathway (RCP), Climate Change, Financial Risk, Decision Support Tool

1. Introduction

Climate change is an observed phenomenon that is typically characterized by an increase in temperatures and precipitation. This can lead to an increase in damages related to climate events like damages from storms. In the year 2020 alone, there has been $152.6 billion dollars' worth of damages done from severe weather (Smith, 2021). In the past five years there has been $29.4 B worth of property damage which was not covered by insurance (Lindsey, 2022). These costly damages will only get worse as climate change progresses. Many enterprises have a knowledge gap in that they do not anticipate increased climate volatility causing more damage to their assets. Their analyses are based on historical data, which doesn't accurately reflect the climate projection that the earth is following, and are therefore, not prepared. This is especially true with smaller enterprises who do not have a large analytics team that can help analyze weather risks and budget accordingly for these increased risks of asset damage. The focus of this project is to fill the knowledge gap and help the user to fill their budget gap by making accurate cost predictions based on damage from climate events. For this project, a case study was done for Warrenton Airport (KHWY).

2. Context Analysis

Climate change has major impacts on infrastructure with increased risk of disasters. These disasters include: drought, flooding, wildfires, extreme temperatures, severe storms, and high winds. Severity of these climate impacts are driven by Representative Concentration Pathway (RCP) values, where each value represents a climate scenario. They predict global temperature increases up to the next 100 years based on Earth's current greenhouse gas emissions including CO2, Methane, and Sulfur. As the scenario gets worse, the RCP value increases. This causes increases in global temperatures, which has a large effect on global tides, currents, and storms. These climate impacts come with large financial risks to enterprises. RCP projections can be pulled from LOCA data (Pierce, Cayan, and Thrasher, 2014). LOCA stands for "Localized Constructed Analogs". It is a statistically downscaled projection for climate data. The original projections have fairly rough spatial projections that put locations 100 miles apart within the same projection grid. LOCA localizes these predictions into a grid as small as a 7x7 km grid. This allows for a much finer resolution when making projections based on spatial data.

These weather disasters have the potential to cause large financial damage to human assets and infrastructure. An example of this will be shown later in the paper, for Warrenton Airport. Some assets and locations are more vulnerable than others and may also be more important. Billion-dollar industries with many physical assets, like the airport industry, are making financial decisions based on historical climate data rather than the predicted RCP scenarios. That means that current budgeting is not adequate to cover the damages to come. This could lead these enterprises into a financial hole, or even bring them to the point of bankruptcy. As the frequency and severity of disasters increase, enterprises are at even higher risk of financial devastation. In the decades to come, Assets at risk of damage need to either be reinforced/upgraded or repaired as they are broken.

2.1 Representative Concentration Pathways

The concept of representative concentration pathways (RCPs) accounts for different scenarios of how much carbon is in the atmosphere. Since global temperatures have direct correlation with greenhouse gasses, climate predictions must be made based upon the concentration of those gasses in the atmosphere. A representative concentration pathway is a scenario of concentration of greenhouse gasses in the air. There are four generally modeled RCP scenarios: RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5. The label of each RCP scenario reflects the level of radiative forcing it uses within the model. The radiative forcing is measured in Watts per square meter (W/m2). For example, RCP 2.6 is a model where the radiative forcing is a parameter with a value of 2.6W/m2 (Kolp, Riahi, 2009). These values are determined by calculating the values of radiative forcing for each greenhouse gas. Each RCP prediction is independently modeled and unique in its predictions.

After looking at all four RCP values, the ones of interest are 4.5 and 8.5. Observed trends show that the earth is past RCP 2.6, making it irrelevant to use for prediction. RCP 6.0 yields predictions that do not show a significant difference when compared to both 4.5 and 8.5. Thus, it is shown that RCP 4.5 and 8.5 are the most relevant predictions to take into consideration. To understand how GHG emissions relate to climate events, the two charts below show the impact on global temperature and sea level for each RCP scenario. Figure 2 depicts global temperature predictions based on each RCP scenario.

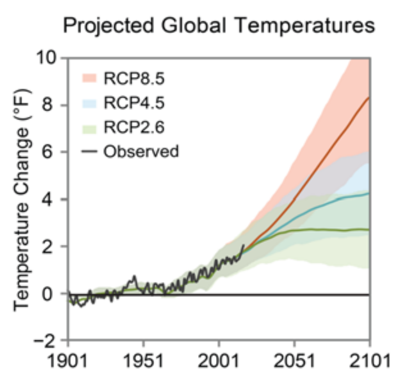

Figure 1. Estimated change in global air temperature for each RCP scenario (Wuebbles, Fahey, Hibbard, DeAngelo, Doherty, Hayhoe, Horton, Kossin, Taylor, Waple, and Weaver, 2017)

2.2 Stakeholder Analysis and Tensions

There are five stakeholders identified. The enterprise manager is the main one as they will be the end user of the system. Their knowledge of the enterprise will enable them to input relevant data into the system. Secondary stakeholders would be electric companies, local and federal governments, and customers of the enterprise. Each of these are ultimately affected by or affect the issue of the small enterprise’s underprepared budget. Their interaction with the enterprise affects the manager, who is in charge of all aspects of the enterprise. Table 1 depicts a summary of the stakeholder analysis and tensions.

Table 1. Stakeholder Tensions

Stakeholder	Objective	Tension
Small Enterprise Manager	To define budget based on risk	Want short process for financial approvals and low risks to assets
Federal Agency	Provide Regulations, grants	Federal regulations may limit enterprises abilities
Local Govt.	Provide Regulations, provide funding and collect more taxes	Low budget for operations and the airport is self sufficient
Customers	Want ready access to do business with enterprise	Do not want the enterprise to be closed, want low prices
Electric Companies	Provide power, make profit, cheaper fuels	Profit limited by government regulations

3. As-is Process

Currently, the process of making financial decisions regarding airport assets is based upon previous budgets that were influenced by historic climate predictions. This historical data is accurate, but it is not a good model to use as the climate begins to change. The airport manager makes the budget based upon historical asset damage and usage. However, as precipitation and temperature begin to rise, that isn't going to be an accurate prediction anymore. Rising temperatures in the coming decades will increase utility costs and cause failure of electrical components of airport assets. The manager will have assets begin to fail, causing a halt in operations and upsetting customers. as an enterprise of Fauquier County, the airport will affect the county revenue and harm commercial operations. The power company that supplies the airport will also lose income as the airport will not be using power while out of operation.

This process has a cost performance gap. The cost performance gap is that enterprises have financial shortfalls in their budget to cover repairs/upgrades due to underestimated climate events. By extension, this is also a knowledge gap as the enterprise does not anticipate these shortfalls. This is mainly because the current predictions use historical data, which does not accurately reflect earth's projection when it comes to climate change. This leads to the following problem statement: enterprise managers will under-estimate costs of asset repair or replacements. This problem statement lends to two need statements. The first one is that There is a need to identify trends and probabilities of extreme climate events occurring. There is a need to analyze the financial risks of climate related events for enterprises and infrastructure in areas of concern.

4. Concept of Operations

The Climate Related Financial Risk Tool provides the airport manager the ability to predict financial risk to assets with a simple user interface. Warrenton-Fauquier Airport will perform the usual daily operations, like performing maintenance on assets, selling fuel, and renting out space for aircraft storage. The manager will need to decide whether the assets need upgrades and how much it will cost. Now, the user (manager) can bring the tool's output data and predictions to the county to get approvals for upgrades and repairs. The user can minimize shortfalls in the operational budget by upgrading assets instead of repairing them as they break. The airport will be able to save on utilities and better prepare budgets for the upcoming years, based on future temperature projections. The user will be able to make financial decisions backed by data, simulations, reliable probabilities and better predictions. The original as-is process of making decisions with no climate projection data, is improved with the easy analysis provided by the tool.

5. Requirements

5.1 Mission Requirements

- MR.1 The tool shall provide financial impact analysis of climate related financial risks on enterprise assets/operations.
- MR.2 The tool shall use reputable climate data to compare historical and future projections.
- MR.3 The tool shall use RCP 8.5 and 4.5 specifications for calculations of future climate projections.
- MR.4 The tool shall calculate risks of assets and compare costs of upgrading or repair when damaged.
- MR.5 The tool shall provide the financial impact (in dollars) of each risk.

5.2 Functional Requirements

The functional requirements are derived from the functional architecture built for the tool. The system's functions are decomposed from the overall function: Provide financial risk analysis. This function represents the primary function that the system must perform. It is broken down into six top-level functions. These functions represent the basic process that the tool goes through to complete its overall function. The first top-level function is establishing connection to the internet from the host server that the website will be hosted on. The second function is to import climate projections that the tool will use to make its risk predictions. The third function is requesting user input. The user will need to bring a LOCA file for their location, and specify event details that are relevant to their assets (year, event type, asset cost, etc.) The fourth function is that the tool will evaluate the climate data based on what inputs the user chose, and make statistical calculations on the probability of the chosen weather disaster occurring. The fifth function is to calculate the recommended budget based on Monte Carlo Simulation. The user's inputted asset costs are used alongside the disaster probabilities to determine how much the user should budget each year. Finally, the sixth and last top-level function of the tool is to display the results to the user. This includes a recommended decision based on the model analysis, probability of disaster occurring, and supporting graphical data. The tool functions are depicted in figure 2.

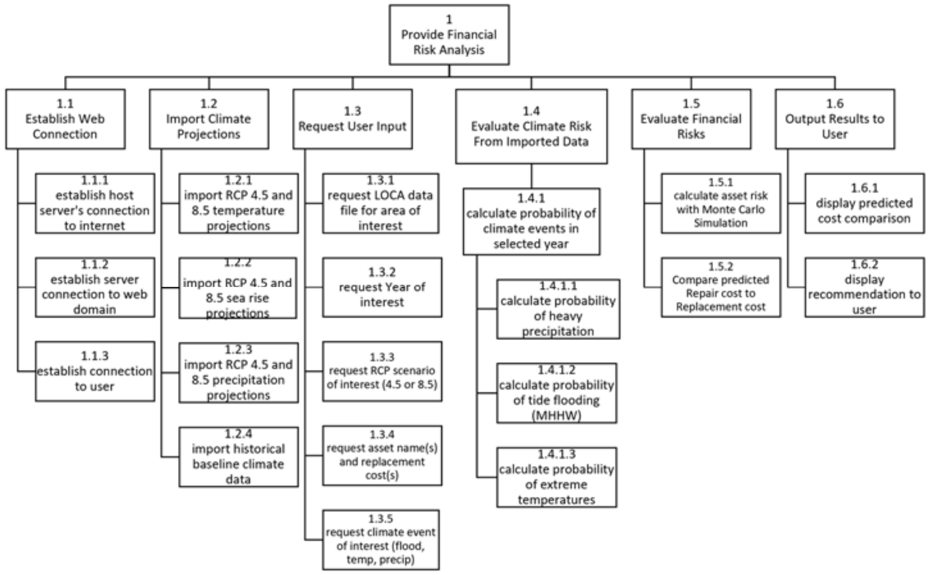

Figure 2. Functional Architecture

6. Design

The tool will not require any programming experience. It will have an intuitive graphical user interface (GUI) which will include all the inputs the user must provide. These inputs will include: the desired RCP scenario, the desired period of analysis, the reinforcement costs for the asset, the damage repairs costs for the asset, and the revenue lost when the asset is damaged. The tool uses a Monte Carlo simulation to calculate the damage repair costs and lost revenue costs of the period of analysis. The tool outputs charts that show the range of costs for worst-case, most likely and best-case scenarios relative to the reinforcement costs. The tool will calculate the financial costs, probabilities, including the thresholds, all displayed over time in a simple graph. The design of the tool's GUI is shown in figure 3.

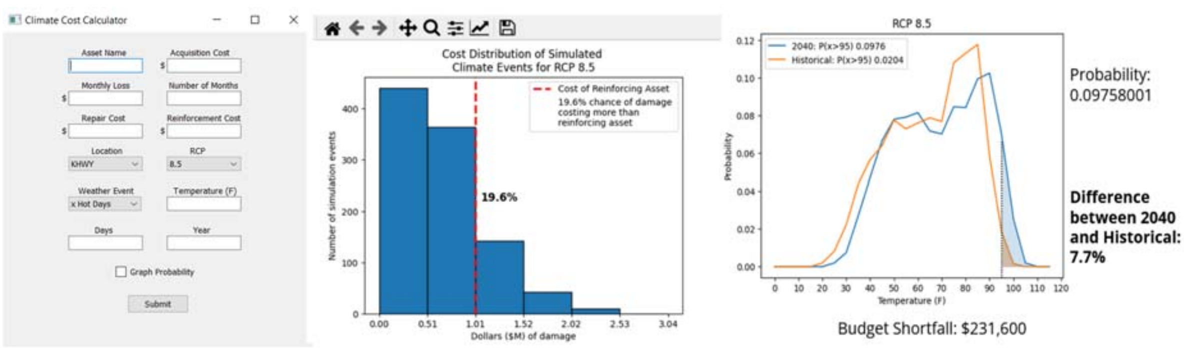

Figure 3. Tool's GUI and Output

This tool uses a Monte Carlo simulation to generate the cost distributions. It leverages calculated probabilities of climate events that were derived from RCP 8.5 LOCA data (Pierce, Cayan, and Thrasher, 2014).This simulation sums the cumulative number of climate events that occur given a probability of occurrence. This simulation runs 1000 times to simulate the expected amount of damage that would occur for the user specified asset in the next 30 years. The result is measured to see if the cumulative repair costs over the years exceed the cost of reinforcing the asset.

7. Implementation

The tool is programmed using Python code, with various functions to perform various tasks. The code takes all the user inputs and runs three main functions to produce an output to the user. There are three main classes in this tool. The ClimateCostCalc Class covers calculations regarding reading the data frame, calculating the probability of a climate event occurring, and plotting the probabilities area under the curve. The Ui_MainWindow class is responsible for creating the GUI. This class uses the PyQt5 GUI framework to create the GUI. This class is also responsible for storing all the user inputs that are entered in the GUI. The RepairSim class is responsible for running the monte carlo simulation. This class also generates the histogram plot and the ruin model plot.

8. Verification

The tool's functional requirements are verified with a test plan for each requirement. Each function that the tool performs is verified that the function is performed, given the parameters of the function. For functions that are binary in nature, verification just needs to assess whether or not the function was performed. For functions involving calculations, each calculation is independently performed outside of the tool. Then, each calculation that the tool performs must match the independent calculation within a two percent tolerance. If it does not match the calculation, then the test result is a failure. There are a total of 26 functional test plans with an initial passing rate of 67% and the current passing rate is 86%.

9. Validation (Case Study)

Warrenton Airport (HWY) is a small airport located within Fauquier county, Virginia. It has multiple assets at risk of damage from climate change. The assets of concern in this case study are the runway, and the Localizer/ILS (instrument landing system). Overall, Magnitude of temperature and precipitation are increasing in Warrenton, VA. This puts assets at the HWY airport at an increased risk of damage. A simple linear regression performed in this study shows that average temperature in the area has increased by about five degrees in the last decade (Pierce, Cayan, and Thrasher, 2014). Using LOCA data, a probability curve was built of temperature on a given day in 2040 is 100 degrees Fahrenheit. From this probability curve (shown on the right side of figure 2), it is derived that historically, the probability of any given day in Warrenton being 100 degrees Fahrenheit or more is .1%. That probability is very small, which means it almost never reaches above that temperature. However, under the "worst-case" scenario, the probability of a given day being over 100 degrees Fahrenheit is 3% in the year 2040. What this means is there is a large increase in that probability. That means that there will be many more days over 100 degrees Fahrenheit in the future. By extension, that means the Warrenton airport assets are at higher risk to damage due to extreme temperatures.

A study of 6 assets were performed for KHWY that were at risk of damage by extreme temperatures or extreme precipitation. The assets of concern are the Instrument Landing System (ILS), runway, fuel truck, fuel tank, terminal, and facility utilities (Air conditioning and water/sewage). A risk analysis was done on all six of these assets to determine when it is cheaper to reinforce the assets, rather than repair them as they break. The data supporting the calculations comes from RCP 8.5 predictions of the Warrenton airport in the year 2040. The summary of the assets in this case study is depicted in figure 4.

Asset Name	Acquisition Cost	Monthly Loss	Repair Cost	Reinforcement Cost	Weather Event	Probability of weather event	Percent chance of damage costing more than reinforcing asset
Fuel Tank	$35,000	$32,000	$7,500	$10,000	Probability of any day having above 1 inch of precipitation	1.3%	33.2%
Utilities	$100,000	$100	$50,000	$70,000	Probability of any day being greater than 100F in 2040	2.7%	20.5%
ILS	$3,000,000	$500	$500,000	$1,000,000	Probability of any day being greater than 100F in 2040	2.7%	19.6%
Terminal	$15,000,000	$600	$1,000,000	$1,500,000	Probability of any day being greater than 100F in 2040	2.7%	19.5%
Fuel Truck	$50,000	$0	$10,000	$12,500	Probability of any day having above 1 inch of precipitation	1.3%	7.6%
Runway	$2,500,000	$100	$250,000	$750,000	Probability of there being 20 or more days greater than 100F in 2040	2.1%	1.7%

Figure 4. Analysis of Warrenton Airport asset Costs

10. Business Plan

The Climate Related Financial Risk Tool follows a yearly subscription model for customers to purchase a license. The license cost is $1500 per year. The customer focus is small enterprises like airports, and electric cooperatives. The total market potential is $1,965,000 per year. With a 10% annual penetration rate, sales of the tool are projected to yield $2.25 million over 5 years. The ROI is 450% and break even is 2 years.

11. Conclusion

Following the systems engineering V-model, a Climate Related Financial Risk Tool was developed to help small enterprise managers make good financial decisions regarding their assets. As climate change increases global temperatures and precipitations, major assets are at increased risk of damage. The aim of this tool is to help managers decide upon upgrading assets, or leaving them and repairing any damages. The enterprise manager is an expert in the enterprise budget, but not climate change. The tool helps to fill that gap by performing the climate analysis for the user. Tool is designed with an easy to use Python GUI and its calculations have gone through independent verification to ensure accurate outputs. The design of the tool is validated by the case study performed for Warrenton Airport where an analysis was done for six of the airport's assets.

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