Team Go Comets

Storslysia Relocation Social Insurance Program

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Objectives and Executive Summary

Storslysia is a country vulnerable to the perils of climate change. An increase in climate-related hazard events has plagued the country and compelled them to enlist Team Go Comets’ help. Using housing and demographic data, historical hazard data, economic data, and projected emissions data, Team Go Comets developed a social insurance program to encourage and facilitate the relocation of Storslysia’s population to safer regions within the country.

Our social insurance program for relocation will help Storslysia manage its exposure to displacement risk arising from catastrophic climate-related events. Our program will:

1. Encourage proactive movement of the population
2. Reduce Storslysia’s climate catastrophe-related displacement costs
3. Maintain a budget of less than 10% of Storslysia’s gross domestic product (GDP) each year with a high degree of certainty

We have found that implementing our program will reduce the expected losses associated with climate disasters by 20%. More importantly, an estimated 1,713,838 out of 6,953,424 citizens will relocate out of dangerous regions over the duration of our program, and consequently fatalities, injuries, and displacement due to climate disasters will be reduced.

We recommend that additional funds be put into spreading public awareness of the climate situation in Storslysia to supplement the relocation incentives in our model. To monitor the success of our program, the portions of Storslysia’s population in designated dangerous regions and the number of fatalities and injuries caused by climate catastrophes can be observed to have a statistically significant decline over both our short-term timeframe of 10 years, and our long-term timeframe of 130 years.

Section 1: Program Design

All citizens of Storslysia will be covered by the social relocation insurance program. Thus, we recognize that certain requirements need to be fulfilled for a filed claim to be approved.

The objective of the insurance program is two-fold: encouraging relocation from regions susceptible to increased climate catastrophes and providing air for catastrophic climate-related displacement. Therefore, to be eligible for the full benefits of our program, we will require
residency within a designated safe region by a set timeframe of 10 years. Designated safe regions, regions 1 and 3, were determined by our economic and hazard rate metrics.

- The hazard rate metric determined which regions were more prone to catastrophic events, further detailed in Appendix B1.
- The economic metric helped determine the economic capacity of each region, further detailed in Appendix B2.

Additionally, to incentivize relocation within the first 10 years, any citizen voluntarily relocating out of a designated dangerous region to a designated safe region will be eligible for stipend.

- All relocation unrelated to catastrophic climate-related displacement within the initial 10-year period will be considered as voluntary relocation.
- All relocation after the initial 10-year period will be considered as involuntary relocation.

Our program will also only provide financial aid to claims filed due to catastrophic climate-related events. Specifically for our policy, we define a catastrophic climate-related event as one causing widespread damage to insured property, including any incidents of injury or fatality to the insured. Such events include coastal storms, drought, flood, fog, hail, extreme heat, hurricane, landslide, lightning, severe storm, tornado, wildfire, wind, and winter storm.

Coverage
The program’s coverage benefits will alter after the set timeframe of 10 years. For the initial 10 years of the program, full financial reimbursement for all financial aid claims in all regions will be provided at an initial limited budget. After the 10 years, the full financial reimbursement for financial aid claims up to 10% of Storslysia’s GDP will only be provided to citizens residing in designated safe regions.

Applicants with approved voluntary relocation claims will receive compensation for relocation costs in the form of a relocation stipend along with temporary housing for 2 months.

- Relocation stipend is equivalent to 1 month living expense of region 1 or 3.

Applicants with approved financial aid claims will receive either compensation for property damage, injury, and fatality, temporary housing for two months, or both depending on eligibility.
• Property damage is defined as all external and internal damage to residential property caused by a catastrophic event.

• Injury benefits include all medical fees and related costs to the injury/injuries caused directly by the catastrophe event.

• Fatality benefits include a year’s worth of salary compensation in the form of a single lump sum or monthly annuities. This benefit will be provided in addition to a pre-existing life insurance policy benefit.

Incentives
As mentioned earlier, the program’s coverage benefits will be the main incentive for relocation. For the timeframe of 10 years, citizens of Storslysia will be motivated by the opportunity to avoid future expenses:

• Relocation within the first 10 years will result in additional relocation stipend.

• Relocation out of designated dangerous regions will ensure that the likelihood of being affected by a catastrophic climate-related event is minimized.

• Relocation to a designated safe region will ensure that they receive full financial aid in the case that they are affected by a catastrophic climate-related event.

After the 10 years, as full financial reimbursement for financial aid claims up to 10% of Storslysia’s GDP will only be provided for the designated safe regions, this will serve as a longstanding incentive for people to continue relocating to designated safe regions.

Other suggestions to Storslysia’s government is for continued education of Storslysia’s population regarding the country’s climate situation. Increased public awareness will help supplement our model’s relocation incentives.

Short- and Long-Term Timeframes
For our program, we have designated 10 years and 130 years for our short- and long-term timeframes for evaluation, respectively. Ten years was chosen as the short-term timeframe to embody the impact of relocation on the program’s costs as the majority of voluntary relocation is expected to occur within this timeframe. Our model returns that approximately 857,147 citizens
will relocate during the short-term timeframe. Further analysis of the relocation data is detailed in Appendix D3.

For the long-term timeframe we have chosen 130 years, as over the period we will observe the effects of climate change on our program. Specifically, we have modeled for different climate change scenarios to monitor the impact each scenario has on our relocation program, further detailed in Appendix D1. Our model will provide estimates for the number of housing to be provided during the 130 years along with the number of people who have relocated after the initial 10 year period which will be considered as involuntary relocation. Our model shows that approximately 1,713,838 citizens will relocate during the long-term timeframe. The analysis of the economic impact is detailed in Appendix D1.

Section 2: Data and Data Limitations

Storslysia’s task force gave data to our consulting group to aid in the creation of a social insurance product. The data that was provided includes: hazard events, historic census and economic data, historic inflation and interest rates and analysis of Shared Socioeconomic Pathways (SSP). SSPs are different global socioeconomic projections dependent on the world’s greenhouse gas emission levels.

- We estimated the missing transportation and warehousing receipts/revenue for 2017 by using a multivariate regression on the sum of region population for 2019-2021 and the sum of GDP for 2019-2020 to get a value of 1,605,298 (in thousands of Storslysia currency)
- We estimated the inflation factor in 2003 by using a Monte Carlo simulation 1000 times of the 4 years around the year to fix the value. We fixed the improper values before we did any regression analysis to avoid outliers.
- We had one loss event that was an outlier, a hurricane in 1989. We decided to keep this loss event as we treat all loss events as independent, therefore a similar event may occur in the future.

In order to complete our models, we needed to have a strong basis for population growth and annual healthcare spending per capita. External data from Macrotrends and Our World in Data
were obtained and used for our calculations. The applications of these data on our program are described in Appendices A5, C1, and C5, respectively.

The way that the value of the insurance product would be measured would be through estimating the number of losses that would be prevented by our insurance product, and the profitability of the main insurance part of our product. There are two categories of loss mitigation: losses avoided through preemptively moving people away from loss heavy regions and those mitigated through the more typical insurance function. These measurables give Storslysia the tools to observe the performance of this insurance.

Some of the models we developed would need to be regularly updated to ensure they are running as accurately as possible for loss modeling. Long term predictions can be very inaccurate, and updating will increase the quality of the short-term estimates through more relevant data and long-term through additional years to model with.

**Section 3: Assumptions**

Several assumptions were made in the program development process. Assumptions are an inherent part of any development process, as they allow developers to make certain predictions and estimations based on the available information. By identifying and documenting these assumptions, we ensure they are taken into consideration throughout program implementation, that any potential risks or uncertainties are properly addressed, and that any future updates or modifications to the program may consider these assumptions. Assumptions were partitioned into three categories: climate, economic, and social assumptions.

**Climate Assumptions**

The most impactful assumption on the outcome of our program regards climate change. The effect of climate change on natural disasters in the future depends on a multitude of uncontrollable variables, such as legislation, public opinion, international conflict, and industrial development. The SSPs give us potential outcomes for how we treat climate change in the coming decades. To ensure the capability of our program to remain within the cost constraints, we chose to simulate our program for all SSPs to see how the pathways affect the costs of our program, and guarantee we meet the relocation and financial goals for the harshest scenario.
Economic Assumptions

Inflation rate is critical to projecting our costs and benefits through time. After observing that regressions and time series do not fit the inflation data well, we assumed a constant inflation rate equal to the average of the inflation rates from 1960 to 2021.

When simulating hazard events in the future, we group benefits from injury, fatality, and property damage. This is because there is a limited number of nonzero injuries and fatalities data, making the data less credible, and the trend of injuries and fatalities is negative, meaning they will have a negligible effect on costs toward the end of the program’s timeframe.

Social Assumptions

Data pertaining to relocation rates in anticipation of rising climate-catastrophe frequency is extremely limited. To circumvent this, we created several scenarios to model the worst-, middle-, and best-case scenarios for ultimate relocation rates estimated from real-world evacuations due to and in advance of natural disasters. The annual relocation rates were taken from a logistic model to take herd movement into account. This process is described in more detail in Appendix A6.

We assumed Storslysia’s population would grow at a rate similar to developed countries, meaning a slow and steady rise. This process is described in more detail in Appendix A5.
Section 4: Risk and Risk Mitigation Considerations

The costs associated with displacement risk due to increasing climate catastrophes are contingent on several severe risks that may significantly affect our results. We performed a risk analysis to illustrate the significance of key risks below.

Risk Matrix

1. Extreme Climate Change: The handling of climate change in the present has an observable impact on the frequency of hazard events and thus the costs of our program. To mitigate the effect of poor handling of climate change, this potential was fully incorporated into and addressed in our model.

2. Poor Relocation: A less-than-expected relocation rate from the population will result in increased injuries, fatalities, and property damage from natural disasters. Though several features of the program incentivize relocation, it is recommended that the government of Storslysia publicize the importance of voluntary relocation and the risks associated with immobility.

3. Excessively Catastrophic Events: An exceptionally impactful disaster may disrupt program implementation, cause extreme inflation, or result in severe damage to infrastructure and people. Though the occurrence of such a catastrophic event cannot be
controlled, the likelihood and severity of this risk can be reduced by mitigating the potential of the previous two risks.

**Section 5: Pricing/Costs**

**Future Loss Cost Simulation**

The simulation model utilized to estimate future loss cost is outlined in Appendix A. It involves several factors, including the frequency and severity of hazard events, the trending of frequency and severity, the projected population count, and relocation rates. The simulation is run 1,000,000 times to provide a reliable estimate of future loss under each Shared Social Pathways (SSP) scenario.

**Economic Cost Improvement**

![SSP2 Total Loss with Relocation Program vs. No Relocation Program](image)

*Figure 3: This figure compares the SSP2 total losses incurred with our program and without. The dark blue bars representing expected costs with our program are noticeably shorter than the light blue bars representing expected costs without our program.*

Our relocation plan is expected to reduce total future economic costs of injury, fatality, and property damage from 2021 to 2150 by 21.02%, or up to 24.42% under the mid-case scenario of SSP2. The average loss cost improvement by our program is P3.746 trillion, representing the difference between the total loss under no relocation and the sum of total loss under relocation with the cost of the program. To obtain further details, please refer to Appendix D1.
Capital Requirement

In order to ensure the financial stability of the program, it is imperative to determine the necessary economic capital with a high degree of certainty. The short-term costs of the program will involve covering temporary housing and hazard assistance for all six regions for the first 10 years, at a rate of up to 2.5% of the country's GDP per year while we accumulate the budget for the relocation stipend. During the first 10 years, a relocation stipend of \( \text{P3645.71} \) will be paid to individuals who relocate to regions 1 or 3. From year 11 to year 130, temporary housing and hazard assistance will be provided up to 10% of the country's GDP.

Under the model simulation, the total cost of the program will average 3.17% of Storlysia's annual GDP every year under the mid-case scenario SSP2, while the worst-case scenario under SSP5 could cost as much as 7.96%. To obtain further details, please refer to Appendix D2.

![Long-Term Annual Program Cost as % of GDP Under SSP2](image)

*Figure 4: This graph shows that the long-term annual program costs are always under 10% of Storslysia's GDP.*

Conclusion

Extensive research and development suggests that the financial assistance and support provided by our program will reduce the expected costs associated with climate disasters by 20%, and relocate an estimated 1,713,838 out of 6,953,424 citizens out of dangerous regions over the duration of our program. Our program is affordable, comprehensive, and easily implemented. It addresses all climate concerns and poses little risk to the government of Storslysia.
Appendix A: Future Loss Cost Model

\[ F_x \sim \text{Negative Binomial}(size = n_x, mu = \mu_x) \]
\[ p_x \sim \text{Bernoulli}(p = Pr[HazardLoss_i > 0]) \]
\[ \text{NonZeroLoss}_x \sim \text{Gamma}(shape = a_x, rate = \theta_x) \]
\[ \text{Severity}_{i,x,t,n} = p_x \times \frac{e^{\text{NonZeroLoss}_x}}{\text{NonZeroLoss}_x} \]
\[ \text{SingleLoss}_{i,x,t,n} = \text{Severity}_{i,x,t,n} \times (1 + \text{SevTrend}_x)^t \]
\[ \text{PopAdjFactor}_{x,t,n} = \left( \frac{\text{Population}_{t,n} \times \text{RegionPop\%}_{x,t,n}}{\text{Population}_0 \times \text{RegionPop\%}_{x,0}} \right) \]
\[ \text{LossInYear}_{T,x,t,n} = (\sum_{i=1}^{F_x} \text{SingleLoss}_{i,x,t,n}) \times \text{FreqTrendFactor}_t \]
\[ \text{PopAdjFactor}_{x,t,n} \]
\[ \text{TotalLoss}_n = \sum_{t=1}^{130} \sum_{x=1}^{6} \text{LossInYear}_{T,x,t,n} \]

Figure 5: Formulas used in the future loss cost model

Notation

- \( F_x \) – frequency distribution for the number of hazard events of a region in a given year
- \( p_x \) – Bernoulli variable with \( p \% \) chance that the hazard loss will be greater than zero
- \( \text{HazardLoss}_i \) – loss from property damage, injury and fatality, detail described in Appendix C
- \( \text{NonZeroLoss}_x \) – severity distribution of each region when the hazard loss is greater than zero
- \( \text{Severity}_{i,x,t,n} \) – severity of a given hazard for a region in year \( t \)
- \( \text{SevTrend}_x \) – selected severity trend for a region
- \( \text{SingleLoss}_{i,x,t,n} \) – trended severity of a given hazard for a region in year \( t \)
- \( \text{Population}_{t,n} \) – Storslysia’s projected future population in year \( t \)
- \( \text{Population}_0 \) – Storslysia’s initial population in 2021
- \( \text{RegionPop\%}_{x,t,n} \) – a region’s population expressed as a percentage of the total population in a given year \( t \)
RegionPop$_{x,0}$ – a region’s population expressed as a percentage of the total population in 2021

PopAdjFactor$_{x,t,n}$ – adjustment factor for cumulative population gain or loss for a region in a given year $t$

FreqTrendFactor$_t$ – frequency trend for each SSP scenarios, given in the case material as the Risk Amplification Factor

LossInYear$_{x,t,n}$ – total loss for a region in a given year $t$

TotalLoss$_n$ – total loss cost for a single simulation

Sub Notation

$i$ represents a hazard event in a year, with values from 1 to $F_x$.  

$x$ represents a region number, with values from 1 to 6 for each region.  

$n$ represents the n-th simulation, with a total of 1,000,000 simulations.  

$t$ represents the year in each simulation, with values from 1 to 130, representing years 2021 to 2150.

Model Description

The Future Loss Cost Model follows a set of procedures to simulate the total future HazardLoss from 2021 to 2150. As part of these procedures, the model determines the component of each individual hazard event's loss using the formula outlined in Appendix C. This formula provides a systematic approach for calculating the loss associated with each event, taking into account the relevant parameters from property damage, number of injury and number of fatality from an event. By using this formula, we can accurately model the total future loss cost for the program, which is essential for ensuring that we can effectively manage the associated risks.

$F_x$

The model generates the number of hazard events for each year by using randomly generated negative binomial values. These values are based on the size and mu parameters of each region and are detailed in Appendix A1. This approach allows us to accurately simulate the frequency of hazard events for each region over time.

$p_x / NonZeroLoss_x / Severity_{i,x,t,n}$

For each hazard event generated by the model, there is a probability of $(1-p)\%$ that the hazard loss will be zero. On the other hand, there is a probability of $p\%$ that the $Severity_{i,x,t,n}$ of a given hazard event will be generated using the $NonZeroLoss_x$ distribution. This distribution follows a gamma distribution with shape and rate
parameters specific to the region. These parameters are detailed in Appendix A3, and the probabilities for zero loss severity are discussed in Appendix A2. By using those procedures, we can accurately model the Severity\textsubscript{i,x,t,n} of each hazard event each region may face.

\textit{SingleLoss}_{i,x,t,n} / SevTrend_{x}

Once Severity\textsubscript{i,x,t,n} has been determined, a severity trend (SevTrend\textsubscript{x}) is applied to calculate the amount for a SingleLoss\textsubscript{i,x,t,n}. This trend is detailed in Appendix A4. By applying this trend to the severity, we can accurately model the impact of trends on hazard losses over time. This is crucial for assessing the program's long-term risk and ensuring that we can adequately manage the associated costs.

\textit{PopAdjFactor}_{x,t,n}

To account for changes in population over time, the model incorporates a population adjustment factor (PopAdjFactor\textsubscript{x,t,n}). It is calculated as the product of Storslysia's future population at a given time \(t\), as detailed in Appendix A5, and the percent of population in a region at that same time \(t\), accounting for relocation as described in Appendix A6. This factor is then divided by the initial population in the region to accurately estimate the potential financial impact of hazard events over time with relocation. By using this adjustment factor, the model can provide a more precise evaluation of the long-term financial risks associated with a region increasing or decreasing its population.

\textit{LossInYearT}_{x,t,n} / FreqTrendFactor_{t}

To calculate the total loss for a region in a given year (LossInYearT\textsubscript{x,t,n}), the model adds up all SingleLoss\textsubscript{i,x,t,n} for each hazard event that occurred in that region during the year. The LossInYearT\textsubscript{x,t,n} amount for each region in a given year is then multiplied by the frequency trend factor (FreqTrendFactor\textsubscript{t}), also known as the Risk Amplification Factor. This factor is specific to each SSP scenario and can be found in the case material “Frequency Projection Model of Minor, Medium, and Major Hazard Events Per Year, as a Function of SSP Scenario”. Additionally, it applies the PopAdjFactor\textsubscript{x,t,n} to account for differences in population size across regions. By using this formula for LossInYearT\textsubscript{x,t,n}, we can accurately estimate the total loss for each region in a given year.

\textit{TotalLoss}_{n}

In summary, the total future loss cost (TotalLoss\textsubscript{n}) for a single simulation is calculated by summing up the total loss for all regions over a 130-year time period. This calculation takes into account the severity and frequency trends of hazard events, as well as changes in population and relocation patterns as described in the various appendices of the model documentation.
To simulate each SSP scenario, we have run all four sets of the frequency trend factors for all simulations. This enables us to accurately model the impact of different scenarios on the program's outcomes.

A.1: Hazard Frequency by Region
To determine the frequency model \((F_x)\) that best fits the data, we compared the Poisson distribution and Negative Binomial Distribution for all six regions using the goodness-of-fit technique on estimated parameters using MLE.

After careful consideration, we selected the Negative Binomial distribution as the preferred frequency model.

\[
f_X(u) = \frac{\Gamma(u+n)}{\Gamma(n)u!} p^n (1 - p)^u
\]

Above shows the density function of Negative Binomial Distribution with size parameter \(n\) and probability parameter \(p\). The table below displays each region's parameters for its Negative Binomial Distribution.

Figure 6: Histograms of hazard frequency data with overlayed Poisson density curves in red and Negative Binomial density curves in blue. These illustrate that a Negative Binomial distribution best fits the data.
A2: Probability of Zero Loss Hazard Event

The concept of p% refers to the probability of a hazard event resulting in no loss. It is a measure of the likelihood that an event will cause no hazard loss.

This probability is treated separately from the probabilities of non-zero losses to improve the accuracy of estimating the severity of such losses. The chart below shows the probabilities of a hazard event causing zero loss in each region.

<table>
<thead>
<tr>
<th>Region</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size Parameter</td>
<td>2.225</td>
<td>1.686</td>
<td>1.002</td>
<td>1.637</td>
<td>1.449</td>
<td>1.266</td>
</tr>
</tbody>
</table>

*Figure 7: Size and probability parameters for Negative Binomial distributions fitted with maximum likelihood to each region’s hazard frequency data.*

*Figure 8: Each region’s probability of a random hazard event causing zero loss.*

By taking into account the probability of zero loss hazard events, severity models can better evaluate the potential risks and impacts of different levels of hazards in different regions.
A3: Severity Distribution of Nonzero Loss Hazard Event

To determine the severity distribution of non-zero loss hazard for each region, we first combine the injury, fatality, and property damage losses using the formula introduced in Appendix C. Any zero loss data will be treated according to the method described in Appendix A2.

Next, we apply a log transformation to the data to facilitate visualization and model fitting. The transformed data will be brought back to its original scale in the future loss cost model from Appendix A by raising it to the power of e.

We fit both Normal (red line) and Gamma distributions (blue line) to all six regions using the MLE method, ultimately choosing the Gamma distribution as our severity model. While both distributions showed similar fits for five of the regions, Region 2 displayed a clear skewness in the density of the log-transformed hazard loss. Additionally, we found that the Normal distribution had a light tail that did not provide enough density for extreme events, leading us to select the Gamma distribution fitting for all regions.

The table below shows the shape and rate parameters of the Gamma distribution for each region.

Figure 9: Histograms of log-transformed nonzero hazard loss data with overlayed Normal density curves in red and Gamma density curves in blue. These illustrate that a Gamma distribution best fits the log-transformed data.
A4: Hazard Loss Severity Trend

Severity trends are a crucial component of predicting future loss costs, as they reflect the appreciation of loss costs over time. To reduce volatility, the hazard loss for each region is grouped by year and a ten-year rolling average method is employed. The methodology used to define hazard loss is outlined in Appendix C, and this analysis specifically focuses on the trending of hazard loss. To ensure consistency across all regions, hazard loss in this case is scaled by housing units. Overall, this approach provides an adjustment for hazard loss over time and is an important consideration when estimating future losses.

Figure 10: Shape and rate parameters for Gamma distributions fitted with maximum likelihood to each region’s log-transformed nonzero hazard loss data

<table>
<thead>
<tr>
<th>Region</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate Parameter</td>
<td>1.546</td>
<td>1.895</td>
<td>1.383</td>
<td>2.036</td>
<td>1.881</td>
<td>1.497</td>
</tr>
</tbody>
</table>

Figure 11: Plots of regional hazard loss data with trend lines fitted with exponential regression.
Trend Rate Regression
After collecting all the rolling averages, an exponential regression was performed for each region by plotting the hazard loss per housing unit against year \( t \). The resulting plots are shown above, displaying the fitted exponential trend for all years for each of the six regions as well as the countrywide trend.

Trend Rate Selection
The severity trending rate selected in the model was adjusted for some regions.

- For region 1, the hazard data was found to be too volatile and had some spikes at the last point, so the countrywide severity trending rate was used instead.

- For regions 4 and 6, the indicated trend factors were both less than one. As the trend rate becomes negative, the future trended value at the end of 130 years would be unreasonably low. Thus, a trending ratio of 1.000 was chosen for no trend.

<table>
<thead>
<tr>
<th>Region</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Countrywide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicated Trend</td>
<td>1.01339</td>
<td>1.06023</td>
<td>1.03183</td>
<td>0.99760</td>
<td>1.00718</td>
<td>0.98222</td>
<td>1.01963</td>
</tr>
<tr>
<td>Selected Trend</td>
<td>1.01963</td>
<td>1.06023</td>
<td>1.03183</td>
<td>1.00000</td>
<td>1.00718</td>
<td>1.00000</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.24%</td>
<td>0.00%</td>
<td>1.78%</td>
<td></td>
</tr>
</tbody>
</table>

Figure 12: Table showing the indicated and selected severity trend by region. Countrywide trend is used for region 1 that has volatile loss experience; negative trend rate in region 4 and 6 is adjusted to no trend.

A5: Population Growth Model
Population size projections for Storslysia were needed for our model. Due to the limited data provided, we decided to use population size data provided by Our World in Data to come up with estimates for Storslysia’s future population sizes. Population predictions are complicated as they utilize metrics such as fertility, mortality, and migration trends. Our population size projections will be based purely on population size data analyzed.

Analyzing Storslysia’s economic data that was provided, we assumed that Storslysia fit into the category of a developed country, as Storslysia’s GDP per capita rivaled that of countries listed as developed countries by the United Nations Development Programme in 2021. The 66 countries were listed as developed in 2021 and we created 3 sets:

1. All 66 countries
2. 41 countries with population size greater than 5 million in 2021
3. 29 countries with population size greater than 5 million in 1950.

The different sets were created to monitor the effects of countries with small population sizes on the population growth rate, as smaller population sizes are less predictable when performing
growth rate projections. Population size data from 1950 to 2021 for these 66 countries was then collected from Our World in Data and organized in two ways.

For the first method, the population size data for each set was taken as is, and a yearly total of the population size of all countries was calculated. The growth rate for each year was taken by dividing the total population size of the current year by the total population size of the previous year. This was then plotted onto a scatterplot, and we used logarithmic regression to project future population size values.

For the second method, the population size data for each set was taken and the yearly growth rate for each country was calculated by taking the current year’s population size and dividing by the previous year’s population size. The average growth rate of all the countries listed was calculated for each year. This was then plotted onto a scatterplot and we used logarithmic regression to project future population size values.
The six logarithmic regression scenarios were then used to project the population sizes for Storslysia used for our future loss cost simulation model.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
<th>2025</th>
<th>2026</th>
<th>2027</th>
<th>2028</th>
<th>2029</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population Size (PS)</td>
<td>18,484,891</td>
<td>18,588,771</td>
<td>18,690,717</td>
<td>18,790,693</td>
<td>18,888,662</td>
<td>18,984,587</td>
<td>19,078,434</td>
<td>19,170,168</td>
<td>19,259,755</td>
</tr>
<tr>
<td>PS (&gt; 5 million in 2021)</td>
<td>18,408,884</td>
<td>18,436,179</td>
<td>18,460,990</td>
<td>18,483,309</td>
<td>18,503,127</td>
<td>18,520,438</td>
<td>18,535,234</td>
<td>18,547,511</td>
<td>18,557,265</td>
</tr>
<tr>
<td>PS (&gt; 5 million in 1950)</td>
<td>18,446,033</td>
<td>18,510,571</td>
<td>18,572,643</td>
<td>18,632,245</td>
<td>18,689,351</td>
<td>18,743,940</td>
<td>18,795,989</td>
<td>18,845,477</td>
<td>18,892,383</td>
</tr>
<tr>
<td>Population Growth (PG)</td>
<td>18,524,115</td>
<td>18,666,228</td>
<td>18,805,373</td>
<td>18,941,368</td>
<td>19,074,432</td>
<td>19,204,189</td>
<td>19,330,661</td>
<td>19,453,773</td>
<td>19,573,451</td>
</tr>
<tr>
<td>PG (&gt; 5 million in 2021)</td>
<td>18,418,484</td>
<td>18,453,892</td>
<td>18,485,320</td>
<td>18,512,746</td>
<td>18,536,156</td>
<td>18,555,534</td>
<td>18,570,868</td>
<td>18,582,151</td>
<td>18,599,375</td>
</tr>
<tr>
<td>PG (&gt; 5 million in 1950)</td>
<td>18,399,065</td>
<td>18,415,952</td>
<td>18,429,769</td>
<td>18,440,511</td>
<td>18,448,172</td>
<td>18,452,751</td>
<td>18,454,245</td>
<td>18,452,655</td>
<td>18,447,984</td>
</tr>
</tbody>
</table>

**Figure 14:** Scatterplot of population growth rate calculated using method 2 fitted with a logarithmic regression line.

**Figure 15:** Sample of annual population sizes for all scenarios projected from the trend lines obtained from methods 1 and 2.
A6: Relocation Rate Projections

To model relocation rates through time, a logistic function was implemented. This was to characterize not only the mass herd movement within the short-term timeframe, but also relatively small movement throughout the long-term timeframe due to involuntary relocation.

First, ultimate relocation rates were determined. These are the percentages of the portion of the country’s population in each of the designated dangerous regions (regions 2, 4, 5, and 6) we expect to relocate to the designated safe regions (regions 1 and 3). The hazard safety of each region is explained in detail in Appendix B1. Using data from evacuation rates during hurricanes for those not within critical evacuation zones and relocation rates following natural disasters, we determined several cases for relocation. For region 4, the region most susceptible to losses due to climate catastrophes, we extrapolated ultimate relocation rates to be a random percentage between 15% and 40%. Ultimate relocation rates for regions 2, 5, and 6 were calculated as those for region 4 rescaled by the relative hazard score between region 1 and region 4. In other words, we expect that as the losses due to hazard events in a region decrease, the relocation rates decrease.
Next, we determined intermediary cumulative relocation rates by fitting a logistic function to three points: zero percent relocation at the present, the ultimate relocation rate at the end of our long-term timeframe in 130 years, and a random percentage between 0.001% and 99.999% of the ultimate relocation rate at the end of our short-term timeframe in 10 years. The random percentage of ultimate relocation by the end of our short-term timeframe allows us to account for different mobilization speeds from the citizens of Storslysia in our predictive model.

<table>
<thead>
<tr>
<th></th>
<th>Region 2</th>
<th>Region 4</th>
<th>Region 5</th>
<th>Region 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Relocation Rate</td>
<td>0.370634</td>
<td>0.400000</td>
<td>0.273482</td>
<td>0.399191</td>
</tr>
<tr>
<td>Minimum Relocation Rate</td>
<td>0.138988</td>
<td>0.150000</td>
<td>0.102556</td>
<td>0.149697</td>
</tr>
</tbody>
</table>

*Figure 17: Maximum and minimum ultimate relocation rates for designated dangerous regions.*

Last, the annual relocation rate was determined by dividing the current year’s cumulative relocation rate by the previous year’s cumulative relocation rate for a randomly simulated case. The populations in region 2, 4, 5, and 6 used this method to compute outbound relocation, and those relocated citizens were partitioned randomly between regions 1 and 3.

### Appendix B: Region Comparison Metrics

#### B1: Hazard Safety Scores
Based on the severity of hazard events at the minor, medium, and major levels, each region is assigned a hazard event score.

To determine the score, the severity of events at each level is evaluated against corresponding percentiles (50th, 90th, and 99.5th) using hazard loss data from Appendix C. The resulting severity ratio at each percentile is compared to the countrywide severity ratio at the same percentile, providing a measure of the region's dangerousness at each level.

<table>
<thead>
<tr>
<th>Region</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Countrywide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minor Event Severity Ratio</td>
<td>0.760</td>
<td>1.101</td>
<td>0.519</td>
<td>3.570</td>
<td>1.879</td>
<td>4.905</td>
<td>1</td>
</tr>
<tr>
<td>Medium Event Severity Ratio</td>
<td>0.591</td>
<td>1.340</td>
<td>0.487</td>
<td>3.527</td>
<td>1.323</td>
<td>3.567</td>
<td>1</td>
</tr>
<tr>
<td>Major Event Severity Ratio</td>
<td>0.211</td>
<td>4.438</td>
<td>0.520</td>
<td>2.322</td>
<td>0.433</td>
<td>0.853</td>
<td>1</td>
</tr>
</tbody>
</table>

*Figure 18: Minor, medium, and major hazard event severity ratios for each region. A higher ratio indicates the region more prone to disasters.*

To assess the overall safety of a region, we calculate the average of three ratios and scale the result to a 100-point scale for clarity. A higher score indicates a safer region. In this case, we
found that regions 1 and 3 are much safer than the others, as they have lower severity levels across all three metrics compared to the countrywide average.

![Harzard Safety Score for Each Region](image)

Figure 19: Bar chart of each region’s hazard safety score. We can observe that regions 1 and 3 are the safest, while regions 2, 4, 5, and 6 are comparatively more dangerous.

B2: Economic Capability Scores
To compare the economic capacity of each region, we developed an economic metric. This was accomplished by first calculating total living expenses by summing the total transportation, warehousing, health care, social assistance, accommodations, food, and retail.

<table>
<thead>
<tr>
<th>Region</th>
<th>Total accommodation and food services sales, 2017 (₱1,000)</th>
<th>Total health care and social assistance receipts revenue, 2017 (₱1,000)</th>
<th>Total transportation and warehousing receipts revenue, 2017 (₱1,000)</th>
<th>Total Living Expenses, 2017 (₱1,000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region 1</td>
<td>22342094</td>
<td>51556220</td>
<td>13500228</td>
<td>208043088</td>
</tr>
<tr>
<td>Region 2</td>
<td>36406400</td>
<td>26864638</td>
<td>2862506</td>
<td>170795058</td>
</tr>
<tr>
<td>Region 3</td>
<td>17508375</td>
<td>70145543</td>
<td>3929251</td>
<td>178494517</td>
</tr>
<tr>
<td>Region 4</td>
<td>2774258</td>
<td>6658061</td>
<td>2234577</td>
<td>27814884</td>
</tr>
<tr>
<td>Region 5</td>
<td>2611585</td>
<td>9541905</td>
<td>2307892</td>
<td>32061921</td>
</tr>
<tr>
<td>Region 6</td>
<td>151132</td>
<td>697773</td>
<td>1605298.21</td>
<td>4696135.21</td>
</tr>
</tbody>
</table>

Figure 20: Table of 2017 assorted living expenses and their total in thousands of ₱.

Next, we estimated the regional population in 2017 using a linear regression of 2019-2021 data.
Then, we divided the total living expenses by the estimated census for 2017 to calculate the individual living expenses in 2017. Last, we rescaled these values by dividing the minimum of the individual living expenses by each value to get an economic capability metric between zero and one, where zero is the worst and one is the best.

We immediately observe that the regions determined to be safest by the hazard safety scores are less affordable than regions 4, 5, and 6. Providing some stipend to people that elect to relocate to regions 1 or 3 will incentivize relocation.

Figure 21: Table of 2019-2021 population data and projected 2017 population data.

<table>
<thead>
<tr>
<th>Region</th>
<th>Census, July 1, 2019</th>
<th>Census, July 1, 2020</th>
<th>Census, July 1, 2021</th>
<th>Estimated Census, July 1 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region 1</td>
<td>5414700</td>
<td>6306408</td>
<td>6406008</td>
<td>4555410</td>
</tr>
<tr>
<td>Region 2</td>
<td>3251492</td>
<td>4212348</td>
<td>4388948</td>
<td>2210412</td>
</tr>
<tr>
<td>Region 3</td>
<td>4614048</td>
<td>4993764</td>
<td>5019884</td>
<td>4267378</td>
</tr>
<tr>
<td>Region 4</td>
<td>1110012</td>
<td>1010676</td>
<td>995544</td>
<td>1210446</td>
</tr>
<tr>
<td>Region 5</td>
<td>1289472</td>
<td>1266672</td>
<td>1257096</td>
<td>1319644</td>
</tr>
<tr>
<td>Region 6</td>
<td>323820</td>
<td>307884</td>
<td>313836</td>
<td>330156</td>
</tr>
</tbody>
</table>

Figure 22: Table of various numbers used to calculate the economic metric.

Figure 23: Bar chart of each region’s economic capability score.
Appendix C: Hazard Loss Calculation

The hazard loss is composed of components from property damage, injury, and fatality. We group property damage with the expected loss cost from injury and fatality because over 90% of hazards have zero injuries and fatalities, making them difficult to model with low credulity issues. Additionally, the trend for injury and fatality for more than half of the regions is negative, meaning the future trended value at the end of 130 years would be unreasonably low. Thus, losses were combined at an aggregate base for analysis.

Figure 24: Scatterplots of fatalities and injuries per population with trend lines for regions 1 and 3. We can observe that the trend rate for each of these graphs is negative, meaning the trended values after 130 years would be unreasonably low.

To calculate property damage, we first adjust it for historical inflation after properly treating errors in the given inflation data. Next, we derive the expected loss cost from injury and fatality...
for each historical hazard event using Appendix C1 and C2, and multiply it by the number of
injuries and fatalities from each event. The Hazard Loss is then the sum of inflation-adjusted
property damage and the loss cost from injury and fatality.

\[ \text{HazardLoss}_i = \text{PropDmg}_i + 7321.81 \times \text{Injury}_i + 40532.63603 \times \text{Fatality}_i \]

Notation

- \( \text{PropDmg}_i \): inflation adjusted property damage caused by a hazard event
- \( \text{Injury}_i \): number of fatalities caused by a hazard event
- \( \text{Fatality}_i \): number of fatalities caused by a hazard event
- \( \text{HazardLoss}_i \): Sum of inflation adjusted property damage and expected lost cost arise from injury and fatality caused by a hazard event

C1: Fatality Benefit Calculation

Our relocation insurance program recognizes that provision of life and health insurance is not our primary objective. However, as a social insurance, we believe that we have an obligation to provide a limited degree of fatality benefit. The fatality benefits were obtained by taking the provided 2020 per capita income (PCI) data for Storslysia for each of the 6 regions and multiplying it by the percentage of the population for each region in relation to the full population size of Storslysia. This results in the weighted average of the PCI for each region, which we then combined to obtain the total PCI.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6,306,408.00000</td>
<td>34.84636</td>
<td>45,482.00000</td>
<td>15,848.82192</td>
</tr>
<tr>
<td>2</td>
<td>4,212,348.00000</td>
<td>23.27553</td>
<td>38,381.00000</td>
<td>8,933.38181</td>
</tr>
<tr>
<td>3</td>
<td>4,993,764.00000</td>
<td>27.59328</td>
<td>40,937.00000</td>
<td>11,295.86243</td>
</tr>
<tr>
<td>4</td>
<td>1,010,676.00000</td>
<td>5.58454</td>
<td>28,186.00000</td>
<td>1,574.05813</td>
</tr>
<tr>
<td>5</td>
<td>1,266,672.00000</td>
<td>6.99906</td>
<td>32,418.00000</td>
<td>2,268.95434</td>
</tr>
<tr>
<td>6</td>
<td>307,884.00000</td>
<td>1.70123</td>
<td>35,948.00000</td>
<td>611.55739</td>
</tr>
<tr>
<td>Total</td>
<td>18,097,752.00000</td>
<td>100.00000</td>
<td>221,352.00000</td>
<td><strong>40,532,63603</strong></td>
</tr>
</tbody>
</table>

*Figure 25: Table of various numbers used to calculate the total per capita income in Storslysia.*

C2: Injury Benefit Calculation

Due to insufficient population size and healthcare spending data, we analyzed data of countries with comparatively similar GDP per capita sizes to Storslysia to obtain an estimated healthcare spending metric for Storslysia.

Storslysia’s GDP per capita for 2020 was calculated by taking the GDP for 2020, converting to USD ($) and dividing by the total population size.
Countries with GDP per capita ranging from over and under 30% of Storslysia were considered, resulting in a total of 25 countries. Of note, we excluded countries with populations less than 5 million because we found their GDP per capita too erratic and volatile to short term population variations. Additionally, Hong Kong was omitted due to the lack of healthcare spending data.
For each of the remaining 17 countries, population size, GDP, and healthcare spending per capita data from 2015 to 2019 were obtained from Macrotrends. We could only calculate until 2019 as healthcare spending was only provided until 2019.

![2019 Healthcare Spending % of GDP per Capita](image)

*Figure 28: Bar chart showing 2019 data for ratio of healthcare spending to GDP per capita from countries with a similar GDP per capita to Storslysia, with a black line drawn at the average of 10.27%.*

The average of the percentages for each year was obtained and linear regression was performed to calculate the percentage of healthcare spending per capita for 2020. The estimated healthcare spending per capita value was calculated by then multiplying the 2020 GDP per capita with the healthcare spending per capita value that was obtained. The healthcare spending per capita value was then converted back to Storslysian currency (Ꝕ).
Appendix D: Long-Term Predictions

To support the efficacy of our model, we have made several long-term predictions demonstrating that we have accomplished our objectives.

D1: Future Loss Cost Improvement of All SSP Scenarios

To calculate the improvement, we subtracted the total hazard loss without the relocation program from the sum of the relocation stipend and the total hazard loss with the program. This provides an accurate assessment of the economic cost savings achieved through the implementation of the relocation program.

The more severe the climate scenario, the greater the total future losses due to property damage, injury loss, and fatality loss. Therefore, there is greater economic savings by implementing measures to mitigate these losses.

Below are comprehensive tables that detail the economic benefits of the relocation program over a 130-year period under each SSP scenario. The tables show both the actual dollar amount and the percentage of improvement achieved by implementing the program.

<table>
<thead>
<tr>
<th>Year</th>
<th>Average % of GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>10.12</td>
</tr>
<tr>
<td>2016</td>
<td>10.29</td>
</tr>
<tr>
<td>2017</td>
<td>10.20</td>
</tr>
<tr>
<td>2018</td>
<td>10.16</td>
</tr>
<tr>
<td>2019</td>
<td>10.27</td>
</tr>
</tbody>
</table>

Avg. for 2020 from Linear Regression: 10.22

Healthcare Spending per Capita (in $): 5,542.62

Healthcare Spending per Capita (in 'P): 7,321.81

Figure 29: Table of average healthcare spending to GDP per capita ratios for 2015-2019 and projected 2020 average calculated using linear regression. The bottom two values give the estimated healthcare spending per capita in USD and Storslysia currency.

Figure 30: Table of loss cost dollar improvement by SSP scenarios for our relocation program.
The capital requirements for the relocation program are designed to ensure that the country becomes debt-free with a high level of certainty. The program's policy only covers up to 10% of the country's GDP based on requirements, which helps to keep the hazard assistance program under our budget.

Relocation stipend payments will also be within the 10% GDP budget for the first nine years, but may exceed the budget in the tenth year. However, the program only pays out 2.5% of GDP, and not much relocation payment is expected during the first nine years, which encourages the government to save budget for any excess payments required in the tenth year.

The table below shows the long-term cost of the program as a percentage of Storslysia's GDP under various SSP scenarios.

<table>
<thead>
<tr>
<th>SSP</th>
<th>Min.</th>
<th>1st Qu.</th>
<th>Median</th>
<th>Mean</th>
<th>3rd Qu.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSP1</td>
<td>24.59%</td>
<td>23.34%</td>
<td>23.29%</td>
<td>20.93%</td>
<td>23.30%</td>
<td></td>
</tr>
<tr>
<td>SSP2</td>
<td>24.42%</td>
<td>23.48%</td>
<td>23.41%</td>
<td>21.00%</td>
<td>23.36%</td>
<td></td>
</tr>
<tr>
<td>SSP3</td>
<td>29.87%</td>
<td>23.88%</td>
<td>23.75%</td>
<td>21.45%</td>
<td>23.68%</td>
<td></td>
</tr>
<tr>
<td>SSP5</td>
<td>31.81%</td>
<td>24.25%</td>
<td>24.09%</td>
<td>21.94%</td>
<td>24.04%</td>
<td></td>
</tr>
</tbody>
</table>

D3: Estimated Relocation

As we have designated each region as either safe (regions 1 and 3) or dangerous (regions 2, 4, 5, 6) through our hazard safety and economic capability scores detailed in Appendices B1 and B2, respectively, the success of our relocation program can be measured by the number of people who relocate from designated safe regions to designated dangerous regions.

We can see from our model simulation report that the expected number of people who will relocate voluntarily within the first 10-year period from designated dangerous regions to designated safe regions is 857,147.
This is significant as the population size of the designated dangerous regions combined is 6,953,424.

<table>
<thead>
<tr>
<th>Region 2</th>
<th>Region 4</th>
<th>Region 5</th>
<th>Region 6</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>4,386,948</td>
<td>995,544</td>
<td>1,257,096</td>
<td>313,836</td>
<td>6,953,424</td>
</tr>
</tbody>
</table>

This is significant as the population size of the designated dangerous regions combined is 6,953,424.

<table>
<thead>
<tr>
<th>Expected Number of People Relocating</th>
<th>857,147</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Population Size for Regions 2, 4, 5, 6</td>
<td>6,953,424</td>
</tr>
<tr>
<td>Relocation Percentage of Total Population Size</td>
<td>12.33%</td>
</tr>
</tbody>
</table>

Thus, 12.327% of the population will relocate to the designated safe regions within 10 years. The economic implications of the relocation can be seen in Appendix D1.

<table>
<thead>
<tr>
<th>Min.</th>
<th>1st Qu.</th>
<th>Median</th>
<th>Mean</th>
<th>3rd Qu.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>953,199</td>
<td>1,459,968</td>
<td>1,713,813</td>
<td>1,713,838</td>
<td>1,967,582</td>
<td>2,472,060</td>
</tr>
</tbody>
</table>

Of note, there is a wide range regarding the possible number of people relocating to regions 1 and 3 during and after the initial 10 years. This is due to our relocation rate projections accounting for the different rates at which people will be relocating, which is further detailed in Appendix A6.
Appendix E: R Code for Future Loss Cost Model

```r
set.seed(1)
for (num_sim in 1:1000000) {
  ### Relocation rate
  r6 <- runif(1, min = 0.1025559321, max = 0.2734824856)
  r5 <- runif(1, min = 0.1389877698, max = 0.3706340529)
  r4 <- runif(1, min = 0.15, max = 0.4)
  r2 <- runif(1, min = 0.00001, max = 0.999999)


  ### find incremental population increase for region 1 and 3
  reloc_pop
  region6_relocation < region5_relocation < region4_relocation < region2_relocation

  ### New population count by year
  logist(b6, c6, r6, x)

  logist(b5, c5, r5, x)

  logist(b4, c4, r4, x)

  logist(b2, c2, r2, x)

  ### parameter c for each region for a run
  c2 <- parm_c(c2)
  c4 <- parm_c(c4)
  c5 <- parm_c(c5)
  c6 <- parm_c(c6)

  ### parameter b for each region for a run
  b2 <- parm_b(p2, s = 10, b = 0.1025559321)
  b4 <- parm_b(p4, s = 10, b = 0.15)
  b5 <- parm_b(p5, s = 10, b = 0.3706340529)
  b6 <- parm_b(p6, s = 10, b = 0.4)

  ### curves for each region
  region2_relocation_rate <- logist(b2, c2, r2, x)
  region4_relocation_rate <- logist(b4, c4, r4, x)
  region5_relocation_rate <- logist(b5, c5, r5, x)
  region6_relocation_rate <- logist(b6, c6, r6, x)

  ### New population count by year
  region2_relocation <- data.frame(year = ssp_factor$Year, reloc = sum(pop_split_region1 + population[1])

  region4_relocation <- data.frame(year = ssp_factor$Year, reloc = sum(pop_split_region1 + population[3])

  region6_relocation <- data.frame(year = ssp_factor$Year, reloc = sum(pop_split_region1 + population[5])

  region6_relocation_rate <- data.frame(year = ssp_factor$Year, reloc = sum(pop_split_region1 + population[5])

  region6_relocation_rate <- data.frame(year = ssp_factor$Year, reloc = sum(pop_split_region1 + population[5])

  runif(1, min = 0.1025559321, max = 0.2734824856)

  runif(1, min = 0.15, max = 0.4)

  runif(1, min = 0.1389877698, max = 0.3706340529)

  runif(1, min = 0.00001, max = 0.999999)


  ### number of years into future
  x <- 1:130
  s <- 10

  ### Split between population gained by region 1 or 3 every year
  split <- runif(10)

  ### Split between population gained by region 1 or 3 every year
  split <- runif(10)

  ### find cumulative population increase for region 1 and 3
  cum_pop_region1 < cum_pop_region3

  for (num_sim in 1:1000000) {
    ### find cumulative population increase for region 1 and 3
    cum_pop_region1 < cum_pop_region3

    for (i in 1:130) {
      ### find cumulative population increase for region 1 and 3
      cum_pop_region1 < cum_pop_region3

      r1_loss_by_year <- rep(0, 2)
      r2_loss_by_year <- rep(0, 2)
      r3_loss_by_year <- rep(0, 2)

      if (j < r1_total_zero) {
        zero_count <- 0
        zero_loss_generate <- runif(r1_freq[i], min = 0, max = 1)

        if (j < r1_total_zero) {
          zero_count <- zero_count + 1
          r1_loss_by_year[i] <- sum(exp(rgamma(r1_freq[i], shape = sev_table$parm_shape[1], rate = sev_table$parm_rate[1])))
        }
      }

      if (j < r2_total_zero) {
        zero_count <- 0
        zero_loss_generate <- runif(r2_freq[i], min = 0, max = 1)

        if (j < r2_total_zero) {
          zero_count <- zero_count + 1
          r2_loss_by_year[i] <- sum(exp(rgamma(r2_freq[i], shape = sev_table$parm_shape[2], rate = sev_table$parm_rate[2])))
        }
      }

      if (j < r3_total_zero) {
        zero_count <- 0
        zero_loss_generate <- runif(r3_freq[i], min = 0, max = 1)

        if (j < r3_total_zero) {
          zero_count <- zero_count + 1
          r3_loss_by_year[i] <- sum(exp(rgamma(r3_freq[i], shape = sev_table$parm_shape[3], rate = sev_table$parm_rate[3])))
        }
      }
    }
  }
}
```
### pop no change

pop_adj_r1 <- pop_nochg_r1 * population[1]/sum(population) * select_pop / population[1]
pop_adj_r2 <- pop_nochg_r2 * population[2]/sum(population) * select_pop / population[2]

### SSP1

r1_ssp1_total_loss <- r1_loss_by_year * pop_adj_r1 * ssp_factor$SSP1 * sev_trend_by_year$r1
r2_ssp1_total_loss <- r2_loss_by_year * pop_adj_r2 * ssp_factor$SSP1 * sev_trend_by_year$r2
r3_ssp1_total_loss <- r3_loss_by_year * pop_adj_r3 * ssp_factor$SSP1 * sev_trend_by_year$r3
r4_ssp1_total_loss <- r4_loss_by_year * pop_adj_r4 * ssp_factor$SSP1 * sev_trend_by_year$r4
r5_ssp1_total_loss <- r5_loss_by_year * pop_adj_r5 * ssp_factor$SSP1 * sev_trend_by_year$r5
r6_ssp1_total_loss <- r6_loss_by_year * pop_adj_r6 * ssp_factor$SSP1 * sev_trend_by_year$r6

SSP1_total_loss[num_sim] <- sum(r1_ssp1_total_loss, r2_ssp1_total_loss, r3_ssp1_total_loss, r4_ssp1_total_loss, r5_ssp1_total_loss, r6_ssp1_total_loss)

### Result under different SSP scenario

### SSP1

r1_ssp1_control <- r1_loss_by_year * pop_nochg_r1 * ssp_factor$SSP1 * sev_trend_by_year$r1
r2_ssp1_control <- r2_loss_by_year * pop_nochg_r2 * ssp_factor$SSP1 * sev_trend_by_year$r2
r3_ssp1_control <- r3_loss_by_year * pop_nochg_r3 * ssp_factor$SSP1 * sev_trend_by_year$r3
r4_ssp1_control <- r4_loss_by_year * pop_nochg_r4 * ssp_factor$SSP1 * sev_trend_by_year$r4
r5_ssp1_control <- r5_loss_by_year * pop_nochg_r5 * ssp_factor$SSP1 * sev_trend_by_year$r5
r6_ssp1_control <- r6_loss_by_year * pop_nochg_r6 * ssp_factor$SSP1 * sev_trend_by_year$r6

SSP1_control[num_sim] <- sum(r1_ssp1_control, r2_ssp1_control, r3_ssp1_control, r4_ssp1_control, r5_ssp1_control, r6_ssp1_control)

### Calculate Running balance & Budget under SSP1

reloc_expense <- reloc_pop[1:10] * 3645.713879

for (i in 1:10) {
  ### Loss for the first 10 years is capped at 2.5% of GDP for all regions
  sspl_loss_paid_by_year[i] <- min((r1_ssp1_total_loss[i] + r2_ssp1_total_loss[i] + r3_ssp1_total_loss[i] + r4_ssp1_total_loss[i] + r5_ssp1_total_loss[i] + r6_ssp1_total_loss[i]) * 0.25 * plan_payment[i])
  sspl_loss_paid_by_year[i] <- slp_loss_paid_by_year[i] * (1 + proj_inflation)**i
  ### amount of budget left off from loss payment
  sspl_budget_by_year[i] <- plan_payment[i] - sspl_loss_paid_by_year[i]
}

### amount of relocation expense each year

sspl_relexp_by_year[i] <- reloc_expense[i]
sspl_relexp_by_year_cv[i] <- sspl_relexp_by_year[i] * (1 + proj_inflation)**i
### Calculate Running balance & budget under SSP2

for (i in 1:130) {
  sspl_loss_paid_by_year[i] <- min((r1_ssp1_total_loss[i] + r3_ssp1_total_loss[i]) * plan_payment[i], sspl_budget_by_year[i])
  sspl_loss_paid_by_year_cv[i] <- sspl_loss_paid_by_year[i] * (1 + proj_inflation)**i
}

### Calculate Running balance & budget under SSP3

for (i in 1:10) {
  ssp2_loss_paid_by_year[i] <- min((r1_ssp2_total_loss[i] + r3_ssp2_total_loss[i]) * plan_payment[i], ssp2_budget_by_year[i])
  ssp2_loss_paid_by_year_cv[i] <- ssp2_loss_paid_by_year[i] * (1 + proj_inflation)**i
}

### Calculate Running balance & budget under SSP3

for (i in 1:10) {
  ssp3_loss_paid_by_year[i] <- min((r1_ssp3_total_loss[i] + r3_ssp3_total_loss[i]) * plan_payment[i], ssp3_budget_by_year[i])
  ssp3_loss_paid_by_year_cv[i] <- ssp3_loss_paid_by_year[i] * (1 + proj_inflation)**i
}

### Calculate Running balance & budget under SSP2

for (i in 1:10) {
  ssp2_loss_paid_by_year[i] <- min((r1_ssp2_total_loss[i] + r3_ssp2_total_loss[i]) * plan_payment[i], ssp2_budget_by_year[i])
  ssp2_loss_paid_by_year_cv[i] <- ssp2_loss_paid_by_year[i] * (1 + proj_inflation)**i
}

### Calculate Running balance & budget under SSP3

for (i in 1:10) {
  ssp3_loss_paid_by_year[i] <- min((r1_ssp3_total_loss[i] + r3_ssp3_total_loss[i]) * plan_payment[i], ssp3_budget_by_year[i])
  ssp3_loss_paid_by_year_cv[i] <- ssp3_loss_paid_by_year[i] * (1 + proj_inflation)**i
}
### SSP3 run summary

\[
\text{ssp3\_loss\_paid}[\text{num\_sim}] \leftarrow \text{sum}(\text{ssp3\_loss\_paid\_by\_year})
\]
\[
\text{ssp3\_CV\_loss\_paid}[\text{num\_sim}] \leftarrow \text{sum}(\text{ssp3\_loss\_paid\_by\_year\_cv})
\]
\[
\text{ssp3\_CV\_program\_cost}[\text{num\_sim}] \leftarrow \text{sum}(\text{ssp3\_loss\_paid\_by\_year\_cv})
\]
\[
\text{ssp3\_relexp\_by\_year}\]

### SSP5

\[
\text{r1\_ssp5\_total\_loss} \leftarrow \text{r1\_loss\_by\_year} \times \text{pop\_adj\_r1} \times \text{ssp\_factor}\text{SSP5} \times \text{sev\_trend\_by\_yearr1}
\]
\[
\text{r2\_ssp5\_total\_loss} \leftarrow \text{r2\_loss\_by\_year} \times \text{pop\_adj\_r2} \times \text{ssp\_factor}\text{SSP5} \times \text{sev\_trend\_by\_yearr2}
\]
\[
\text{r3\_ssp5\_total\_loss} \leftarrow \text{r3\_loss\_by\_year} \times \text{pop\_adj\_r3} \times \text{ssp\_factor}\text{SSP5} \times \text{sev\_trend\_by\_yearr3}
\]
\[
\text{r4\_ssp5\_total\_loss} \leftarrow \text{r4\_loss\_by\_year} \times \text{pop\_adj\_r4} \times \text{ssp\_factor}\text{SSP5} \times \text{sev\_trend\_by\_yearr4}
\]
\[
\text{r5\_ssp5\_total\_loss} \leftarrow \text{r5\_loss\_by\_year} \times \text{pop\_adj\_r5} \times \text{ssp\_factor}\text{SSP5} \times \text{sev\_trend\_by\_yearr5}
\]
\[
\text{r6\_ssp5\_total\_loss} \leftarrow \text{r6\_loss\_by\_year} \times \text{pop\_adj\_r6} \times \text{ssp\_factor}\text{SSP5} \times \text{sev\_trend\_by\_yearr6}
\]

\[
\text{SSP5\_total\_loss}[\text{num\_sim}] \leftarrow \text{sum}(\text{r1\_ssp5\_total\_loss}, \text{r2\_ssp5\_total\_loss}, \text{r3\_ssp5\_total\_loss}, \text{r4\_ssp5\_total\_loss}, \text{r5\_ssp5\_total\_loss})
\]

### Calculate Running balance & Budget under SSP5

\[
\text{r4\_ssp5\_control} \leftarrow \text{r4\_loss\_by\_year} \times \text{pop\_nochg\_r4} \times \text{ssp\_factor}\text{SSP5} \times \text{sev\_trend\_by\_yearr4}
\]
\[
\text{r5\_ssp5\_control} \leftarrow \text{r5\_loss\_by\_year} \times \text{pop\_nochg\_r5} \times \text{ssp\_factor}\text{SSP5} \times \text{sev\_trend\_by\_yearr5}
\]
\[
\text{r6\_ssp5\_control} \leftarrow \text{r6\_loss\_by\_year} \times \text{pop\_nochg\_r6} \times \text{ssp\_factor}\text{SSP5} \times \text{sev\_trend\_by\_yearr6}
\]

\[
\text{SSP5\_control}[\text{num\_sim}] \leftarrow \text{sum}(\text{r1\_ssp5\_control}, \text{r2\_ssp5\_control}, \text{r3\_ssp5\_control}, \text{r4\_ssp5\_control}, \text{r5\_ssp5\_control}, \text{r6\_ssp5\_control})
\]

### SSP5 run summary

\[
\text{ssp5\_loss\_paid}[\text{num\_sim}] \leftarrow \text{sum}(\text{ssp5\_loss\_paid\_by\_year})
\]
\[
\text{ssp5\_CV\_loss\_paid}[\text{num\_sim}] \leftarrow \text{sum}(\text{ssp5\_loss\_paid\_by\_year\_cv})
\]
\[
\text{ssp5\_CV\_program\_cost}[\text{num\_sim}] \leftarrow \text{sum}(\text{ssp5\_loss\_paid\_by\_year\_cv})
\]
\[
\text{ssp5\_relexp\_by\_year}\]
References


