Storslysia Social Insurance Program for Relocation

Amanda Lao (z5310522), Emma Liu (z5208502), Farah Maudud (z5308812), Kangnan Wang (z5309389) and Wa'ddah El-Ardenli (z5310487)

ACTL4001/5100 ASSIGNMENT

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Introduction

Swift has been tasked to help Storslysia manage exposure to displacement risk arising from catastrophic climate-related events. Storslysia is a diverse country with different geographic regions subject to different threats due to catastrophic climate-related events which means residents of high-threat areas are at risk of permanent displacement.

We have been hired to design a social insurance program to manage exposure to catastrophic climate-related events and impacts of mass displacement. Our proposed program focuses on proactive, voluntary relocation and involuntary relocation into lower risk areas, as by undertaking relocation, hazard risk is reduced rather than merely transferred to insurance companies and the government.

Main Objectives

The proposed social insurance program has two main objectives:

1. Incentivise voluntary relocation for individuals currently living in high-risk regions to move into lower risk regions.
2. Provide support to individuals facing property damage arising from hazards, covering either involuntary relocation costs or rebuilding costs and incentivizing relocation to lower risk regions for these individuals.

These two objectives work together in reducing the impacts of displacement from climate-related catastrophes for the residents of Storslysia.

The performance of the program is measured and monitored through key metrics including participation rate, cost effectiveness and impact on vulnerable populations (full metrics and explanations in Appendix 6). These metrics will be continuously monitored over time, with the reporting frequency which reviews the program once every calendar year to ensure the program is still achieving its main objectives sustainably and equitably.

Through thorough analysis, design, modelling and implementation, Swift found that the implementation of the Social Insurance Program:

1. Reduced costs across different Shared Socioeconomic Pathways (SSP) emission scenarios up to 21% in the short-term (up to 2025)
2. Reduced costs across different SSP emission scenarios up to 39% in the longer term (up to 2050)
3. Maintained costs under 10% GDP for all SSP Scenarios up to 2050

Further research and monitoring are recommended to maintain the program's effectiveness.

Assumptions

Provided below are the definitions and assumptions used for this project:

- Short term refers to the 5-year period from 2020 (2020-2025)
- Long term refers to the 30-year period from 2020 (2020-2050)
- No total population growth
- GDP growth is consistent with inflation (0.02%) across SSPs for Storslysia
- Temporary housing cost growth is consistent with inflation.
- Severity projections of property damage remain unchanged across SSP scenarios. This is since frequency projections are already a function of SSP.

- The severity of property damage grows consistently over time with inflation.
- The percentage of people who voluntarily and involuntarily relocate is a function of the discount applied to the purchase of a new property.

Assumptions with most significant impacts on Economic Costs and Capital (Appendix 6 for full)

- Inflation rate for 2022 onwards sits at a constant 2% p.a. Appendix 3 shows consistent inflation over the past 30 years around this.
- Cost of property damage of one person per year is the reciprocal of the population of 2021 (5.4×10^{-6}) as each person contributes equally to average hazard property damage.
- The cost of replacing household goods is 58% (of the sum of property damages) on average, assuming uniformity.
- Material and labour costs assumed to be 35% (of the sum of property damages) on average, assuming uniformity between 0 and 100%, with a 50% government-enforced ceiling.
- Each hazard event that occurs is independent.
- 0.1% of the population of a region will experience a single recorded hazard event, on average, which is a fraction of those affected by hazard events worldwide in 2021 (1%). This is adjusted sensibly for the reduced average severity of hazards in Storslysia compared to worldwide (CRED., 2021).
- Migration rates for involuntary relocation are constant across different SSP scenarios and follows a survey conducted in high-risk regions in Australia (King et al., 2014).
- 5% of a region's affected population will relocate following minor and medium severity hazards.
- 20% of a region's population will relocate following major severity hazards.
- Citizens act rationally and those who either voluntarily or involuntarily relocate under the program, move to regions with a lower risk profile than their current region to receive a discount.

Program Design

The following program design aims to balance the concerns of government, insurers and residents of Storslysia. Its purpose is to reduce costs for Storslysia by net movement of residents to lower risk geographic regions which can be achieved via investing into encouraging resident voluntary relocation in anticipation of catastrophic events and involuntary relocation in response to catastrophic events.

Regions, ranked from lowest to highest risk (see method in Appendix 9)

	Region 4	Region 6	Region 3	Region 1	Region 5	Region 2	
Lowest	*1*	*2*	*3*	*4*	*5*	*6*	*Highest*

Criteria a resident must satisfy to make a claim following a hazard event

For a resident of Storslysia to file a claim, the following requirements must be satisfied:

- The property must be under the claimant's name.
- The claim is the first of the year by the claimant.

For a resident of Storslysia to file a claim for involuntary relocation support, additionally:

- The property must be damaged by a hazard event that is covered by the policy. This includes any of the hazards listed in Appendix 2.

- The claim does not fall under property fraud, such as intentionally setting fire to or vandalizing the property.

For a resident of Storslysia to file a claim for involuntary relocation discounts, additionally:

- They are relocating to an area of lower risk, and not rebuilding

Coverage of claim and limitations

In the event of a claim following a hazard event, the claimant may either remain in their property or involuntarily relocate.

- For those who remain in their property, the program will cover the costs of property damage, material and labour costs to rebuild and the cost of replacing household contents.
- For those who need emergency displacement (involuntary relocation), the program will cover the costs of property damage, the cost of replacing household contents and temporary housing costs for 6 months. The program also provides a discount to individuals who involuntarily relocate from a higher-risk region to a lower-risk region, covering 1% of the market value of their new property.

This should provide enough coverage to protect against the most substantial expenses associated with property damage and relocation.

There are, however, limitations to the coverage provided by our program.

- Claiming multiple times is possible but not within the same year, which will disadvantage households in riskier regions than experience property damage from multiple hazards.
- The program also does not cover aspects such as income protection, which may be an issue for households relocating from one region to another. This is an important consideration since not all workplaces or companies are flexible or established enough to accommodate inter-region movement and remote working.
- There are the less quantifiable costs such as psychological damage which are not covered by our program. To address this, a possible solution could be that future claimants are fully compensated for sessions with a therapist or counsellor for a year.

Incentives for voluntary relocation

A key feature of our proposed program is to incentivize voluntary relocation from higher risk regions to lower risk regions. This is a form of managed retreat, which refers to the "purposeful, coordinated movement of people and assets out of harm's way" (O'Donnell, 2021). The benefit of managed retreat is that it is a direct form of risk mitigation, removing properties and individuals from problem zones in the hopes of reducing economic costs and generating savings in future. To fuel this objective, our program will offer discounts for households that voluntarily relocate to lower risk regions, paying 3% of the market value of their new property, should they move within the first 5 years of the program. The discount following 5 years can be re-evaluated in 5 years time. The purpose of a discount is to encourage quicker migration to lower risk region while covering the potential losses of a quick sale on homes.

The discount is also used to overcome several obstacles to the successful implementation of managed retreat. Relocation out of one's region may be difficult to due to one's cultural values, attachment to their home and established microeconomic systems in their current locality. They may experience income loss while establishing financial supports in new regions, which the discount can compensate for, for some residents.

Other key features of requirements

Another feature of our program, which has not been modelled for the purposes of this project, but which is relevant for pricing considerations, is cross-subsidization. It is a feature adopted by the Cyclone Reinsurance Program, which was implemented by the Australian Commonwealth Government on 1 July 2022 (ACCC, 2022). Since this program is also for the government, which holds no need for economic profit, our program will take on a similar structure. This is where margins are removed and are replaced with cross-subsidies, where lower risk regions subsidize higher risk regions.

Cross-subsidization is aimed at addressing the issue of insurance affordability, where higher risk regions are charged significantly higher premiums, leading to underinsurance and non-insurance. Therefore, cross subsidization serves to make insurance more affordable to higher-risk households, especially those who are unable to relocate due to financial or personal reasons.

Justification of short- and long-term timeframes

The program will be evaluated in a timeframe of 5 years in the short term and 30 in the long-term in 2025 and 2050 respectfully. While this is an appropriate choice given Swift's analysis and ensures that there are enough years of projection to determine the effectiveness of the program, we recommend the program is monitored and reviewed on a regular yearly basis which aligns with reporting frequency of agencies in other countries as mentioned previously.

Pricing and Costs

Economic costs without program

To project the economic costs without the program, it was necessary to consider two different sets of costs, whose sum is the total economic costs without the program:

1. The costs of involuntary relocation
2. The cost of rebuilding for those who choose to remain in their property.

The provided sum of property damage data was split into its respective frequency and severity components. Furthermore, hazard events were grouped per region and per risk classification (minor, medium, major). These risks were classified based on the total sum of property damage incurred by event, but also other characteristics such as frequency of hazard event, average duration of event, total number of injuries and total number of fatalities. These components were all given various weightings from which a risk score and category was generated, as reflected in Appendix 7.

The frequency and severity components were fitted to various distributions to determine the best fit. It was discovered that a negative binomial distribution was most suitable for modelling frequency and a lognormal distribution was most suitable for modelling severity (Appendix 5). A GLM was then fitted to the frequency and severity distributions, using the historic data provided to produce central estimates and error estimates of both frequency and severity by region and risk classification. The purpose of this was to smooth out the volatility of the hazard experience and create a more reliable estimate for 2020 hazard costs as opposed to its current anomalous results.

After receiving the GLM outputs, the frequency outputs were fed into the provided Frequency Projection Model of Minor, Medium, and Major Hazard Events Per Year, as a Function of SSP Scenario. The severity outputs were projected out by region and by risk classification (minor, medium, major) and were inflated by inflation (assumed to be 2%). Finally, these projections were multiplied together to give the total sum of property damage, as per the following formula:

Total Sum of Property Damage = Severity of property damage x Inflation x Frequency of Property Damage

Of those affected, "n", a proportion of them migrate to another region, which we call "involuntary relocation". Their migration is spread evenly across the other regions. *People who choose not to migrate to another region "rebuild".*

$$Migration\ to\ other\ region\ after\ a\ hazard\ event\ =\ \left(5\% \cdot n_{general} +\ 20\% \cdot n_{major}\right) \cdot$$

To obtain the total economic costs without the program in both the short term (5 years) and long term (30 years), the following formulae was used:

Costs for Rebuilding = Percentage of Claimants Choosing to Rebuild * Total Sum of Property Damage + Material and Labour Costs + Costs of Replacing Household Goods

Costs for Involuntary Relocation = Percentage of Claimants Who Involuntary Relocate * Total Sum of Property Damage + Cost of Replacing Household Goods + Temporary Housing Costs + 1% Discount on New Property for Individuals that Relocate from a Higher to a Lower Risk Region

Total Economic Costs = Costs for Rebuilding + Costs for Involuntary Relocation

For the purposes of this project, it was assumed that 50% of damages are associated with rebuilding costs and the remaining 50% with involuntary relocation costs. Temporary housing costs were calculated by projecting the inflated costs per person per year and multiplying this by the volume of people involuntarily relocating to a given region.

Provided below are our projections for economic costs without the program, expressed as a percentage of Storslysia's GDP.

	Costs as a % of GDP that year			
	SSP1– 2.6	**SSP2–3.4**	**SSP3–6.0**	**SSP5–Baseline**
2020	0.117705%	0.117705%	0.117705%	0.117705%
2025	0.119453%	0.119453%	0.119453%	0.119453%
2050	0.554363%	1.024619%	2.653443%	7.995869%

Economic costs with program

To project the economic costs of the program, it was necessary to consider three different sets of costs, whose sum is the total economic costs of the program:

1. The costs of involuntary relocation
2. The costs of voluntary relocation
3. The cost of rebuilding for those who choose to remain in their property.

To model voluntary relocation costs, we assume an impact of the discount (3%) on people's migration to project gradual migration over time, from faster rates at short terms to slower rates long terms where the discount will be re-evaluated/is uncertain.

$$Short - term\, migration\ (5\ years) = (1 + discount)^{\frac{1}{(5 \cdot 4)}}$$

$$Short\ to\ long - term\, migration\ (25\ years) = (1 + discount)^{\frac{1}{(25 \cdot 2)}}$$

The change in population density over short and long terms across regions using these migration rates are assumed to impact average hazard severity. Each exiting or entering person reduces or increases the average hazard severity by a factor of the existing average hazard severity of the region. We also inflate the new average hazard severity over time.

The cost of voluntary relocation to the program each year is the product of voluntary relocation each year and average property costs in the new region.

To model additional involuntary relocation costs with discounts, above the 5% and 20% of the population affected by general and major hazard events, we first assume an impact of the discount (1%) on people's additional migration to less risky regions under the program.

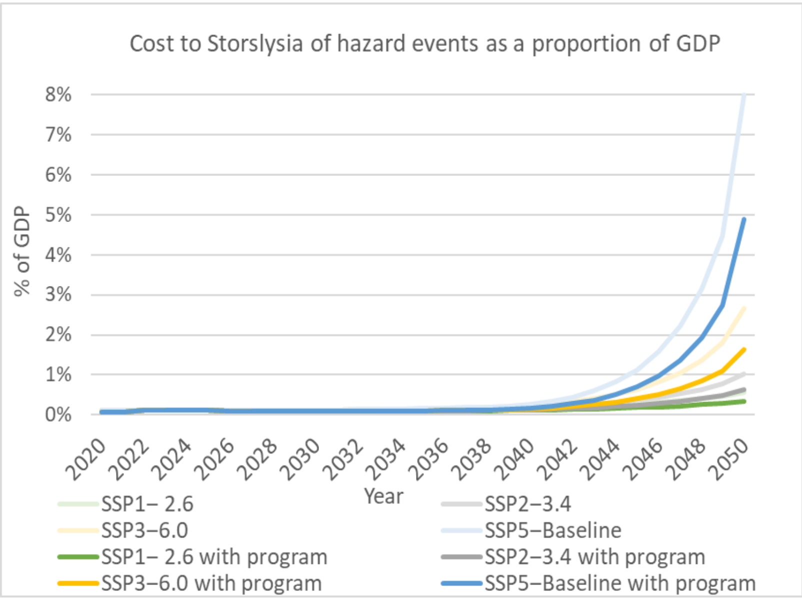
$$Migration\ after\ a\ hazard\ event = \left(5\% \cdot n_{general} + 20\% \cdot n_{major}\right) \cdot (1 + discount)^{\frac{1}{4}}$$

After executing this split, the same formulae as "without program" is used to model involuntary relocation costs.

Temporary housing costs are only provided for 6 months, instead of a year, to also encourage people to relocate earlier using the discount provided.

Provided below are our projections for the economic costs of the program, expressed as a percentage of Storslysia's GDP. Costs with the program are much lower in the long run than without the program in the long run, as reflected in the following graph (more graphs in Appendix 4).

Figure 1. Costs to Storslysia of hazard events from 2020 to 2050, as a proportion of GDP. Costs without the program in this period are below 10% of GDP. Our recommended program improves on costs to Storslysia, although our sensitivities show returns on greater upfront investment to relocation that may increase costs to Storslysia as a proportion of GDP in the short term but produce greater savings in the long term.



We assume that as people move out of their riskier regions, they are able to sell to people moving from even riskier regions or in the case of Region 2 – the reduction of the population in 2 will be driven by people choosing not to rebuild as they face hazard events over time.

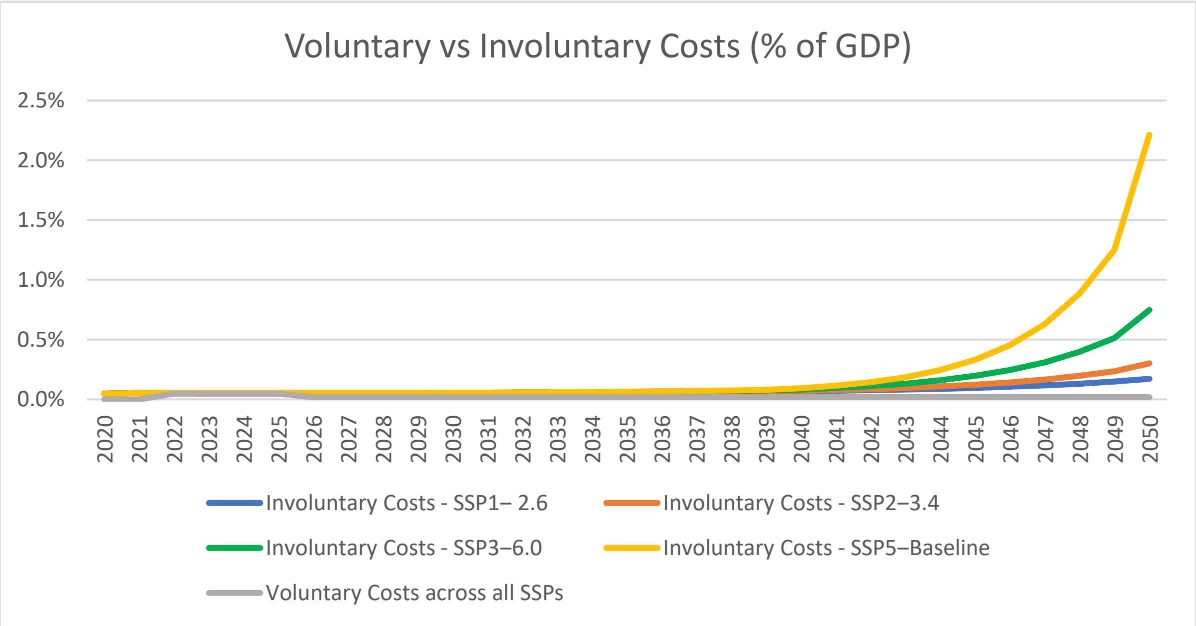
Solvency

As highlighted above, there is uncertainty in the costs of climate catastrophe damage and the assumptions made on people's additional migration between regions under the program. As a result, sufficient economic capital will need to be held to ensure that the program remains solvent. We use the minimum capital requirement (MCR) and solvency capital requirement (SCR) under the Solvency II legislation to evaluate solvency. Thus, enough economic capital should be held to ensure that the program remains solvent over the next 12 months with an 85% (MCR) and 99.5% (SCR) probability (European Commission, 2015).

We determine that the economic capital required to maintain the program in the first year at the 85% range to be **Ᵽ 10.9 million** and **Ᵽ 98.5 million** at the 99.5% range. For long term economic capital, this figure should be indexed to inflation and re-evaluated based on policy changes and migrations. For our solvency modelling approach see Appendix 8.

Contrast costs associated with voluntary and emergency displacement

Provided below are the voluntary versus involuntary costs of the program, expressed as a percentage of Storslysia's GDP. As can be seen, voluntary costs are consistently lower than involuntary costs across the short-term and long-term. Voluntary costs are also assumed to remain constant across all SSP scenarios, whereas involuntary costs are assumed to vary. For the voluntary versus involuntary costs as a percentage of GDP at time points 2020, 2025 (short-term) and 2050 (long-term), see Appendix 10.



Risks and Risk Mitigation

Provided below is a summary of potential risks and unforeseen events that may have a material impact on the program and mitigation strategies for each. A full table of risks as well as a risk matrix score is provided in Appendix 7.

Property prices in designated relocation regions
Mass relocation into low-risk regions will drive up demand for housing. If additional land development is not sufficient to cater for this surge in demand, unsustainable property price increases will result. Relocation into these regions will be less affordable, especially for vulnerable households (low income, high disaster risk), counteracting the key objectives of the proposed social insurance program. Strategies to prevent this include:

- Careful planning and implementation of measures to ensure adequate land development
- Incentives such as tax credits and subsidies to encourage developers to build affordable housing units in the affected areas.
- Implement rent control or other price control measures to limit the increase in rental prices.

The allowance to temporary housing costs (6 months) may also become insufficient for residents aiming to involuntarily relocate, as they are unable to find or afford a home within that time frame.
It is important to also consider that people may attempt to game the system moving to a higher risk region to then move back down to a lower risk region to become eligible for discount. This can be prevented by vigilant monitoring of behaviours, establishing limitations for people who moved into recently (less than a year) and exclude discounts for investment properties.

Low participation rates for voluntary relocation
There are cultural and socio-economic factors that may lead to low voluntary relocation rates such as attachment to jobs, schools, and home, heritage sites of cultural importance, family ties and financial feasibility. Strategies to prevent this include:

- Opt-in defaults into targeted informational campaigns to help raise awareness of relocation programs.
- Engage with community leaders and stakeholders to promote the program encourage community-wide participation, especially for high-risk locations.
- Identify causes for low participation rates through surveys and interviews.
- Monitor and re-evaluate discount provided to voluntary relocators, possibly increasing the discount to encourage greater voluntary relocation rates.

Projected costs deviate from actual experience
Due to the uncertainty surrounding climate risk, the SSP projections for frequency may deviate from actual experience. This affects the projected costs of the program, which may also be affected by policy decisions or initiatives surrounding climate change. Ongoing monitoring ensures that program projections are aligned with climate policies and targets adopted by the government.

Sensitivity Analysis

Assumption changed	**Result – cumulative costs of program with change relative to recommended program**
Material and labour costs decrease from 35% to 5%	Small cost saving impact in early years of program and costs decrease up to 7% in baseline scenario by 2050.
Material and labour costs increase from 35% to 50%	Small cost increase in early years of program and costs increase up to 4% in baseline scenario by 2050.

Migration rates decrease from 20% to 10% for major hazards, involuntary relocation	Costs decrease by 25% in years 2020-2025 but increase with lower long-term migration rates. By 2050, costs are similar to the recommended program.
Migration rates increase from 20% to 30% for major hazards, involuntary relocation	Costs increase by 25% in years 2020-2025 but decrease with lower long-term migration rates. By 2050, costs are similar to the recommended program.
Increasing discount for voluntary relocation from 3% to 5%	Costs to 2025 increase by 60%, then decrease to 2050 to 3% of the recommended program in baseline scenario.
Increasing discount for involuntary relocation from 1% to 3%	Costs increase to a small extent. Very minimal impact.
Property buy back i.e. 100% discount for voluntary relocation	Costs increase significantly (240 times the cost of the recommended program at 2025 and 15 times the cost of the recommended program at 2050 in the baseline scenario). Cumulative costs drop to under 10% of GDP by 2050 for SSPs 1, 2 and 3 only.

Data Limitations

All datasets were cleaned and exploratory data analysis was conducted to identify any anomalies. The program is modelled using data provided to Swift and thus relies on the accuracy of this historic data. The data has a small number of hazard events. Small sample sizes can bias a model, and although we cover all historically observed hazard events, it should be noted that there has only been 1 event for fogs and landslides, that fully drive our future expected experience for those events. While an effective program has been developed, as the design is limited to the current data provided for Storslysia, it is important to continue to monitor and review the program with new data and other relevant data that may be available, such as Storslysia's census.

The data sources used for this project include the provided hazard event data, demographic and economic data and emission scenarios model data. Swift also sourced reports to estimate voluntary and involuntary relocation rates. The data source is the journal article 'voluntary relocation as an adaptation strategy to extreme weather events' published by the International Journal of Disaster Risk Reduction (King et al., 2014).

Ethical Considerations

While there are benefits to the social insurance program designed by Swift (primarily reduced costs for government and enhanced human living), it is vital to consider other ethical impacts of the social insurance program across various facets of society which were not discussed in the Program Design. Ethical considerations will be analyzed with the assistance of Dobrin's 'The Right Way to Riches' ethical framework (Boyd, 2017), with particular emphasis on stakeholders including low socio-economic individuals, the wider and vulnerable communities.

A primary ethical issue to consider is the impact of the insurance program on those with low socio-economic status. Individuals in this category may find it difficult to relocate given that the properties they reside in are likely inexpensive and thus, the resale value may not be adequate to purchase a property in a safer region, even when including Swift's discount of

3%. Furthermore, there may be a shortage of jobs available to these individuals in safer areas, due to the limited education unfortunately found with low socio-economic people. Consequently, it may be harder for low socio-economic individuals to not only relocate, but also to assimilate into the new region. Under deontology, this social issue would warrant a significant number of issues considering that in NSW, as an example, 13.3% of people fall under the low socio-economic status (NSW Department of Justice, 2022), in turn making the current program unethical and biased against these stakeholders.

The cultural disruptions which can emerge from the social insurance program are another ethical issue to consider. While voluntary relocation enables individuals in risk-prone areas to move to a safer region at discounted costs, the culture in riskier areas may be negatively impacted. This is especially important when considering Indigenous culture and history on the land of Storslysia. Through relocation, heritage across the riskier areas will diminish across time as people will not have as much of a reason to visit the riskier areas if their new homes and jobs are in the safer regions. Thus, an ethical battle between promoting relocation verses maintaining cultural significance of the land needs to be balanced. While we could argue under teleology that it is ethically correct to promote relocation as it strengthens human living, one could also disagree under the deontology perspective as the program could be seen as a move for the government to just cut costs rather than strengthening communal connections and belonging (Emelda, 2011).

Discrimination against who can claim voluntary relocation cover is an ethical dilemma which needs to be accounted for. While it is ideal to allow the vulnerable community to relocate first (the elderly, young, and disabled) as they are more at risk of being injured or facing fatality from a hazard, a discrimination perspective towards ethics suggests this is unethical as the vulnerable only make up a minority 39.3% compared to the majority 60.7% (Australian Bureau of Statistics 2022). Even when discussing the vulnerable community, thorough analysis on ensuring a smooth transition from risky to safe regions for the vulnerable community needs to be taken as these individuals will need assistance in the form of nursing care as well as moving aid, which may be harder to find given the labor market.

All in all, it is of the essence to consider the nature of the ethical considerations in light of the social insurance program. While it isn’t possible to cater to every stakeholder, Swift has tried to find a balance across the needs of the people and government. Swift intends on reporting the effects of the program on a bi-annual basis in the first few years of the program to ensure that our expectations are consistent with the actual claims such that we can then focus on providing more aid to low socio-economic individuals and vulnerable people in their relocation. Cultural impacts will be discussed with other relevant bodies, such as UNESCO, to ensure that cultural and historical sites can maintain their significance despite relocation from risky regions.

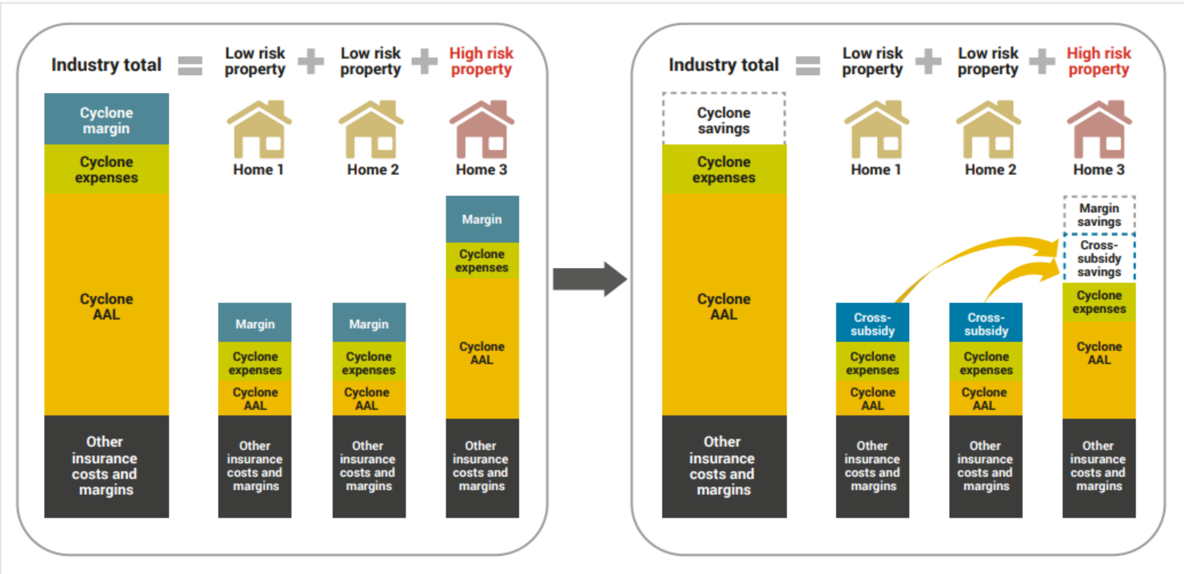
Conclusion and Recommendations

This report outlines Swift’s Social Insurance Program design to help Storslysia incentivise voluntary relocation to reduce costs due to climate-related events. Through careful analysis and modelling, we have produced results which satisfy requirements of the addition of a program reducing costs and cost of program being less than 10% of GDP. Risks, sensitivities and limitations of the program and process have been considered and Swift highly recommends further research and ongoing frequent monitoring of the proposed program.

Appendix

Appendix 1 – Cyclone Reinsurance Program Cross Subsidisation

The Cyclone reinsurance program has been able to deduct costs by removing the profit margin that insurers have in place. The savings from removing the margin are applied as cross-subsidies. High risk properties are able to be charged their expected cost – cross-subsidies; are charged less than their level of risk would demand.



(Guest Lecture slides, ACTL4100/5001 Week 4)

Appendix 2 – Hazard Events covered by policy

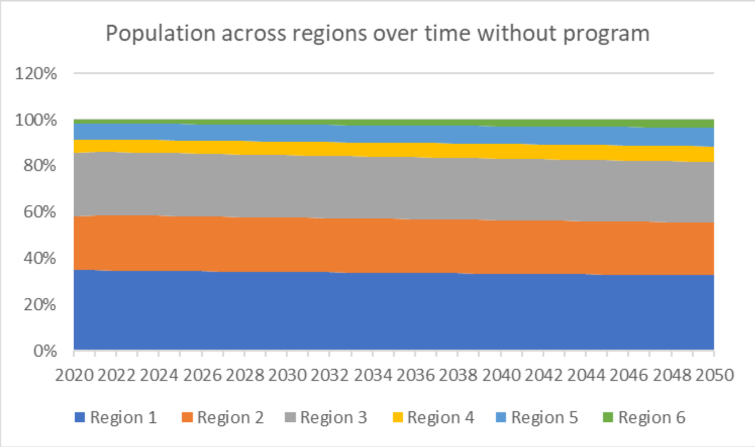
Coastal	Flooding
Severe Storm	Wind
Thunder Storm	Hurricane
Wildfire	Tropical Storm
Lightning	Hail
Fog	Winter Weather
Tornado	Landslide
Heat	Drought

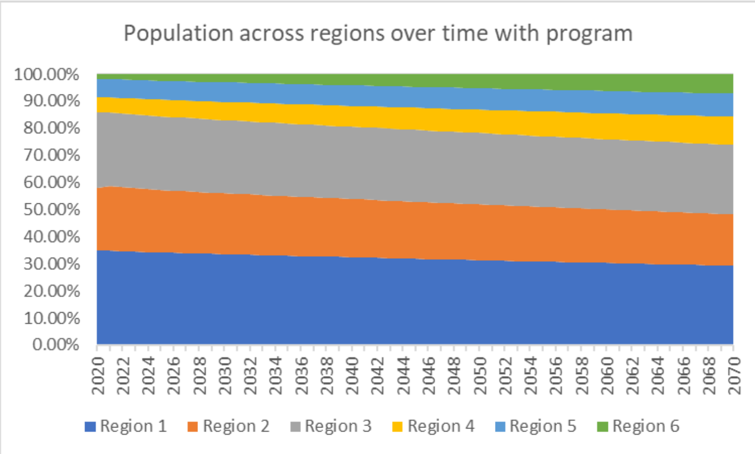
Appendix 3 – Past Inflation

Inflation has been consistently around 2% in the recent 10, 20 and 30 years.

Years	10	20	30
long-term inflation	1.61%	1.94%	2.26%

Appendix 4 – Population across regions over time charts for with and without program





Appendix 5 – Severity and Frequency Distribution Fitting

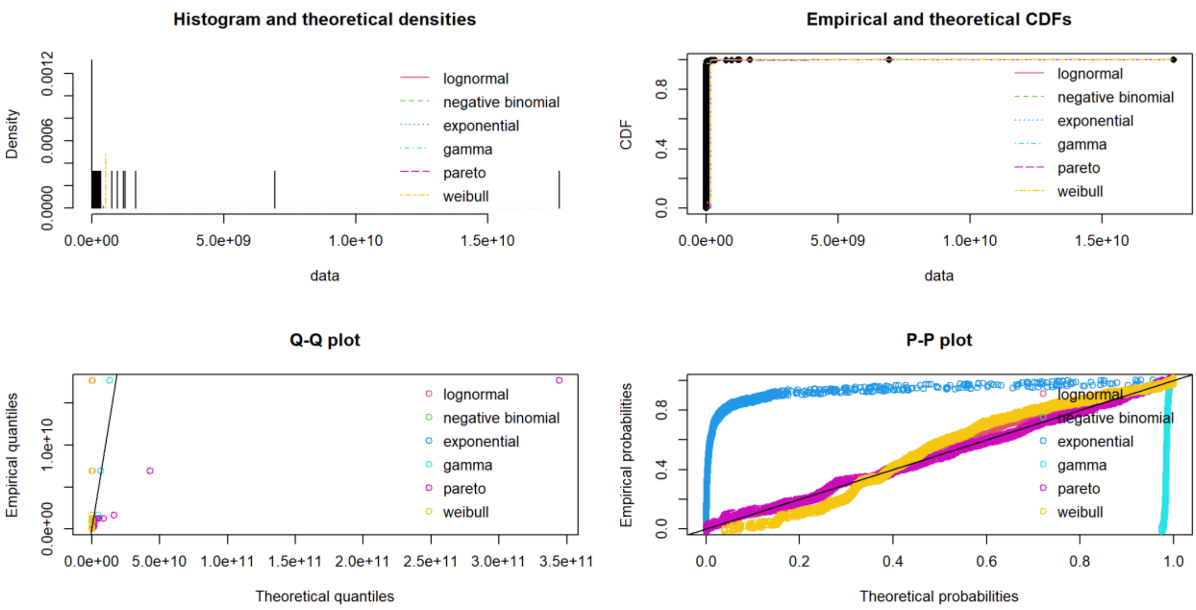
For the Severity Distribution modelling, Swift noticed that the data for the inflated property damages was positively skewed and leptokurtic. As such, Team Swift modelled the severity using the following distributions:

- Log Normal Distribution
- Negative Binomial Distribution
- Exponential Distribution
- Gamma Distribution
- Pareto Distribution
- Weibull Distribution

Based on the following graphical and statistical testing, both pareto and log-normal distributions fit the severity well, however due to the practicalities of implementing such a distribution into a Generalized Linear Model, Swift chose to use the Log Normal Distribution to model the severity data.

	Log-Normal	**Negative Binomial**	**Exponential**	**Gamma**	**Pareto**	**Weibull**
Kolmogorov-Smirnov Statistic	0.059	0.974	0.78	0.974	0.045	0.11

Cramer-von Mises Statistic	2.64	961.1	761.44	961.1	0.52	16.04
Anderson-Darling Statistic	13.99	9476.04	Inf	9476.05	6.44	Inf
AIC	82588.27	Inf	Inf	108603.5	82515.53	83552.94
BIC	82600.31	Inf	Inf	108614.5	82527.57	83564.97



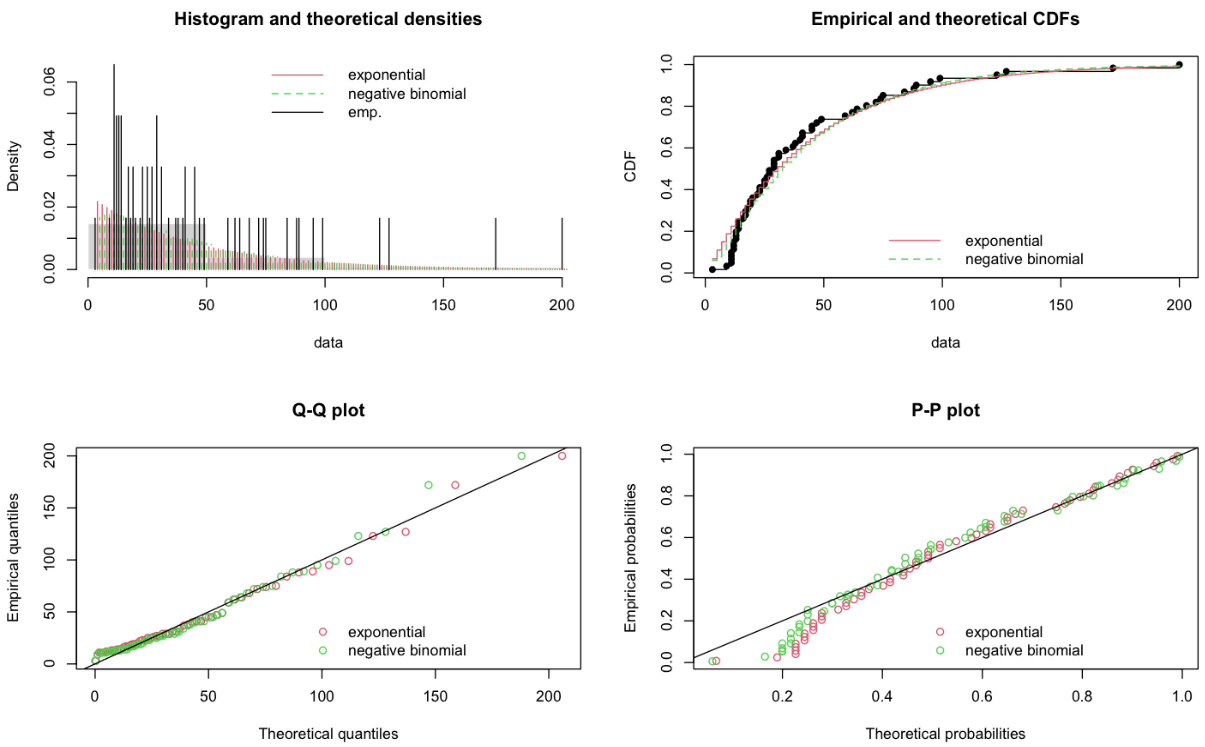
For the Frequency Distribution modelling, Team Swift used the following distributions to fit the frequency data against based on preliminary analysis pertaining to data plotting and summary statistics:

- Exponential Distribution
- Negative Binomial

For the “major” group of claims, we fit a distribution to and model on the most recent 15 years of experience only, after observing significantly different trends in frequency following 2005.

Based on the following graphical and statistical testing, Team Swift concluded that a Negative Binomial Distribution is most appropriate to fit the frequency data against. Results are provided below.

	Exponential	**Negative Binomial**
Kolmogorov-Smirnov Statistic	0.19	0.17
Cramer-von Mises Statistic	0.25	0.18
Anderson-Darling Statistic	1.80	1.35
AIC	582.45	581.15
BIC	584.56	585.37



Resulting parameters from GLM:

Frequency
~NB(Mu = estimate, Theta = 0.4823).

Table of estimates/sample means

	Group minor	Group medium	Group major
Region 1	-1.86	0.27	2.82
Region 2	-1.80	0.33	2.86
Region 3	-1.92	0.21	2.76
Region 4	-2.25	-0.12	2.43
Region 5	-2.22	-0.09	2.46
Region 6	-2.97	-0.84	1.71

Severity
~LN(Mu = mu coefficients, Sigma = 0.91737)

Table of mu coefficients,

	Group minor	Group medium	Group major
Region 1	12.55	11.41	11.63
Region 2	12.51	11.38	11.60
Region 3	11.92	10.78	11.00
Region 4	12.02	10.88	11.10
Region 5	12.01	10.88	11.10
Region 6	11.99	10.86	11.08

Resulting frequency and severity confidence intervals

Frequency – assumed normal distribution for confidence intervals

Region	Group	Central estimate	lower bound	upper bound
1	Major	16.80	9.60	24.00
1	Medium	1.32	0.86	1.77
1	Minor	0.16	0.09	0.22
2	Major	17.84	10.22	25.45
2	Medium	1.40	0.92	1.88
2	Minor	0.17	0.09	0.24
3	Major	15.84	9.02	22.65
3	Medium	1.24	0.81	1.67
3	Minor	0.15	0.15	0.15
4	Major	11.41	6.38	16.44
4	Medium	0.89	0.57	1.22
4	Minor	0.11	0.06	0.15
5	Major	11.75	6.58	16.91
5	Medium	0.92	0.58	1.26
5	Minor	0.11	0.06	0.16
6	Major	5.51	2.90	8.13
6	Medium	0.43	0.25	0.61
6	Minor	0.05	0.02	0.08

Severity – applying modified cox method for central estimate and confidence intervals

Modified cox adjustment for small sample sizes

$$Point\ estimate = estimate + \frac{sd^2}{2}$$

$$Lower/upper\ bound = estimate + \frac{sd^2}{2} \pm 2.02 * \sqrt{\frac{sd^2}{N} + \frac{sd^4}{2(N-1)}}$$

Region	Group	Central estimate	lower bound	upper bound
1	Major	1,627,950	1,064,765	2,031,554
1	Medium	300,101	187,618	411,597
1	Minor	590,509	206,873	1,288,469
2	Major	1,917,606	1,313,055	2,324,548
2	Medium	183,426	120,004	252,690
2	Minor	861,888	274,093	1,859,487
3	Major	1,060,404	729,052	1,282,609
3	Medium	110,839	72,050	152,153
3	Minor	216,660	84,508	475,176
4	Major	1,057,563	665,793	1,341,837
4	Medium	122,377	77,084	171,918
4	Minor	224,299	87,911	498,950
5	Major	949,386	573,479	1,234,873
5	Medium	132,255	81,261	187,751

5	Minor	260,782	97,207	579,162
6	Major	951,740	482,601	1,354,598
6	Medium	97,107	56,149	148,817
6	Minor	225,697	83,865	520,340

Appendix 6 – Key Metrics for Program

The performance of the program is measured and monitored through the following key metrics:

- Participation Rate: percentage of eligible individuals that opt into the program. Reflects accessibility and attractiveness
- Cost-effectiveness: Monitoring the cost per participant and per successful relocation – assess efficiency and effectiveness
- Success Rates: tracks number of successful relocations and the percentage of households that were able to relocate
- Impact on vulnerable populations: monitor whether the program is reaching and benefiting the most vulnerable populations.
- Feedback from beneficiaries: e.g., surveys to pinpoint pain points and potential improvements for the program

Appendix 6 – Key Assumptions Table

Key assumption	**Assumption made**	**Rationale/Analysis**
Inflation rate	Inflation for 2022 onwards sits at a constant 2% p.a.	Appendix 3. shows consistent inflation over the past 30 years around 2% p.a.
Cost of property damage of One Person per year	The reciprocal of the population of 2021 (5.4×10^{-6})	Each person contributes equally to average hazard property damage
Cost of replacing household goods (as a % of the sum of property damaged)	The cost of replacing household goods is 58% on average, assuming uniformity.	Cost of replacing goods ranges from 40% to 70%
Material and labour costs (as a % of the sum of property damaged)	Material and labour costs assumed to be 35% on average, assuming uniformity between 0 and 100%.	Material and labour costs ranges from 0% to 50% (50% government-enforced ceiling)
Hazard events	Each entry is independent	-
Affected population	0.1% of the population of a region will experience a single recorded hazard event, on average.	0.1% is a fraction of the average number of people affected by a hazard event worldwide in 2021 (1%), adjusted sensibly for the reduced average severity of hazards in Storslysia compared to worldwide in

		2021 ($770M). (CRED., 2021)
Migration rates – for involuntary relocation	5% of a region's affected population will relocate following minor and medium severity hazards. 20% of a region's population will relocate following major severity hazards. These rates are constant across the different SSP scenarios.	Surveys of Australian residents following catastrophe expressed readiness to move in line with 5% and 20% following "general" and "major" events (King et al., 2014)
Migration rates – for voluntary relocation	We assume there is no voluntary relocation without the program. With the program, people are relocate at a factor calculated based on the discount provided. $Short - term\ migration\ (5\ years) = (1 + discount)^{\frac{1}{(5 \cdot 4)}}$ These rates are constant across the different SSP scenarios.	See Pricing/Costs
Citizens act rationally	Assumes that the citizens of Storslysia, who either voluntarily or involuntarily relocate, move to regions with a lower risk profile than their current region	Based on the case brief, citizens of Storslysia are 'keenly aware of the threats', indicating sound risk education and thus decision making.

Appendix 7 – Risk Mitigation Strategy Table

Risk	**Explanation**	**Risk Matrix Score**	**Risk mitigation strategy**
Property prices in designated relocation regions increasing proportional to demand	Mass relocation into low-risk regions will drive up demand for housing. If additional land development is not sufficient to cater for this surge in demand, unsustainable property price increases will result. Relocation into these regions will be less affordable, especially for vulnerable households (low	Moderate-possible 9	Careful planning and implementation of measures to ensure adequate land development Incentives such as tax credits and subsidies to encourage developers to build affordable housing units in the affected areas.

	income, high disaster risk), counteracting the key objectives of the proposed social insurance program.		Implement rent control or other price control measures to limit the increase in rental prices.
Low participation rates for voluntary relocation	There are cultural and socio-economic factors that may lead to low voluntary relocation rates. Examples include: Attachment to jobs, schools, and homes Attachment to heritage sites of cultural importance Family ties	Moderate-likely 12	Opt-in defaults into targeted informational campaigns to help raise awareness of relocation programs. Engage with community leaders and stakeholders to promote the program encourage community-wide participation, especially for high-risk locations. Identify causes for low participation rates through surveys and interviews.
Projected costs deviate from actual experience	Due to the uncertainty surrounding climate risk, the SSP projections for frequency may deviate from actual experience. This affects the projected costs of the program, which may also be affected by policy decisions or initiatives surrounding climate change.	Minor - moderate 6	Ongoing monitoring to ensure that program projections are aligned with climate policies and targets adopted by the government.
Relocation resulting in economic and service contraction for rural communities	Incentives to relocate will probably have a stronger impact on younger members of the community. "This may be devastating to marginally viable small and rural settlements, where outmigration of young families exacerbates an already present economic decline." (King et al., 2014)	Minor - moderate 7	Encourage and incentivize community wide voluntary relocation wherever possible.

Flexibility of program is insufficient to adapt to socio-economic changes arising from relocation	Relocation will result in socio-economic changes across regions which may result in distortion of program design intentions if these changes are not accounted for.	Minor - moderate 6	Review and adjust program design annually to ensure that objectives are achievable under current and re-projected socio-economic conditions

Risk scores are based on the following matrix:

Risk score	Risk level category
1 to 4	Low
5 to 10	Moderate
11 to 18	High
19 to 25	Critical

		Likelihood				
		Rare (1)	Unlikely (2)	Possible (3)	Likely (4)	Almost certain (5)
Severity	Catstrophic (5)	Moderate	Moderate	High	Critical	Critical
	Major (4)	Low	Moderate	High	High	Critical
	Moderate (3)	Low	Moderate	Moderate	High	High
	Minor (2)	Low	Low	Moderate	Moderate	Moderate
	Insignificant (1)	Low	Low	Low	Low	Moderate

The following risk score formula was used to categorize hazards into Minor, Medium, and Major hazards:

$$Risk\ Score = 0.35 * Sum\ of\ Property\ Damage + 0.075 * Sum\ of\ Injuries + 0.075 * Sum\ of\ Fatalities + 0.1 * Average\ Duration + 0.4 * Frequency$$

The classification score was provided as following:

Classification	**Risk Score**
Major	>0.01
Medium	(0.0015, 0.01]
Minor	≤0.0015

Major Hazards:

Hurricane/Tropical Storm (0.3265)	Wind (0.031)
Severe Storm/Thunderstorm/Wind (0.126)	Drought/Heat (0.03)
Flooding (0.078)	Drought (0.025)
Winter Weather (0.068)	Wildfire (0.023)
Tornado (0.049)	Heat (0.02)
Lightning (0.044)	Severe Storm/Thunderstorm (0.02)
Hail (0.036)	Coastal (0.018)

Medium Hazards:

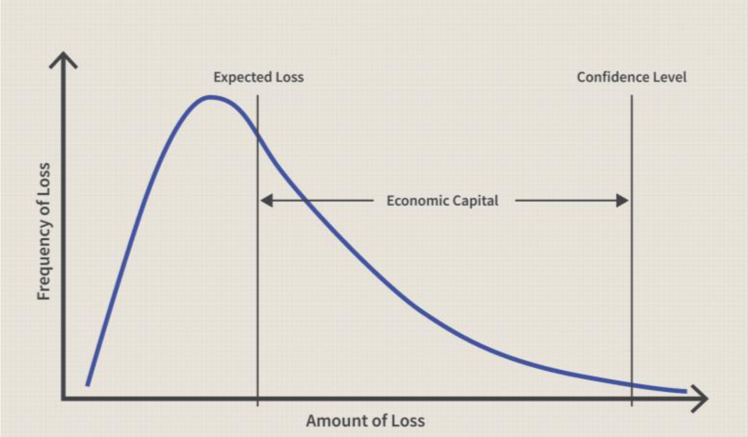
Hail/Severe Storm/Thunderstorm/Wind (0.009)	Landslide (0.0039)
Flooding/Severe Storm/Thunderstorm (0.008)	Lightning/Severe Storm/Thunderstorm (0.0038)
Hail/Lightning/Wind (0.008)	Severe Storm/Thunderstorm/Winter Weather (0.0036)
Lightning/Wind (0.0077)	Flooding/Wind (0.0035)
Hail/Lightning/Severe Storm/Thunderstorm/ Wind (0.0059)	Coastal/Flooding (0.0025)
Wind/Winter Weather (0.0056)	Flooding/Severe Storm/Thunderstorm/ Wind (0.0023)
Hail/Wind (0.0047)	Hail/Severe Storm/Thunderstorm (0.0021)
Lightning/Severe Storm/Thunderstorm/ Wind (0.0046)	Flooding/Lightning/Severe storm/ Thunderstorm (0.002)
Coastal/Wind (0.0045)	

Minor Hazards:

Hail/Severe Storm/Wind/Winter Weather (0.0019)	Coastal/Hurricane/Tropical Storm/Wind (0.000978)
Fog (0.0018)	Hail/Tornado/Wind (0.00097)
Coastal/Severe Storm/Thunderstorm/Wind (0.0017)	Tornado/Wind (0.0009)
Coastal/Hurricane/Tropical Storm/Severe Storm/Thunderstorm/Wind (0.0015)	Flooding/Lightning/Wind (0.0008958)
Severe Storm/Thunderstorm/Wind/Winter Weather (0.0014)	Hail/Tornado (0.00086)
Coastal/Flooding/Severe Storm/ Thunderstorm/Wind (0.001329)	Hurricane/Tropical Storm/Severe Storm/ Thunderstorm (0.0007786)
Coastal/Severe Storm/Thunderstorm (0.001328)	Flooding/Hail/Wind (0.00071)
Flooding/Lightning (0.0013)	Lightning/Tornado/Wind (0.000708235)
Hail/Lightning/Severe Storm/Thunderstorm (0.0011)	Flooding/Hail (0.000708203)
Hail/Lightning (0.001)	

Appendix 8 – Economic Capital and Solvency

Due to the removal of funding considerations, solvency was be considered primarily from a cost perspective. To model solvency, 10,000 simulations of the total costs associated with both voluntary and involuntary relocation under the program were conducted and critical values at the 85% and 99.5% confidence level determined. We deem the program to be ‘solvent’ if these values are below the 10% GDP cap imposed. The expected costs under the program were then subtracted from the critical values to determine the economic capital required for the program to remain solvent. The economic capital required was: Ᵽ10,889,231 at the 85% level and Ᵽ98,486,060 at the 99.5% level.



The relationship between the frequency of loss, amount of loss, expected loss, financial strength or confidence level, and economic capital (Bang 2019)

Appendix 9 – Regions ranked by risk

To classify the regions from least risky to most risky, a variety of factors were considered:

- Injuries
- Fatalities
- Average Property Damage
- Population Density
- Land Area
- Unemployment
- The temporary cost of living in the case of emergency displacement

A score was developed for each of these categories, which was then summed and weighted to yield a risk rating, where the highest risk rating corresponds to the riskiest region.

Please see below for how we determined the scores of the individual risk categories:

Injuries	- An injury is defined as the physical damage a person experiences due to a natural hazard. - For our risk rating methodology, we standardised injuries per region by dividing by the population of each region. - The lower the score for this section, the less likely it is for an injury to occur.
Fatalities	- A fatality refers to the occurrence of a death due to a natural hazard. - Again, for our risk rating methodology, we standardised fatalities per region by dividing by the population of each region.

<table>
<tr><td></td><td>- The lower the score for this section, the less likely it is for a fatality to occur.</td></tr>
<tr><td>Average Property Damage</td><td>- Formula: average(PropertyDamageRegion)/average(AllPropertyDamage)
- Taking the average of property damage in the region across the average of all property damages allows us to compare the average property damage across regions according to a baseline.
o Lowest value means it has less property damage on average compared to other regions.
o Highest value means it has highest property damage on average compared to other regions.</td></tr>
<tr><td>Population Density</td><td>- Calculated as population per hectare
- The lower the population density of a region, the more capacity there is for migration into this area.</td></tr>
<tr><td>Land Area</td><td>- The score for Land Area is determined by: 1/(Landarea/totallandarea)
o Land area of each region is first standardised by dividing by the total land area across the 6 regions (i.e. area/ total land area). The lowest value means it has the least land area across all the regions whereas the highest value means it has the most land area across all the regions
- We then take the reciprocal, so that the region with the highest land area has the lowest value, and the region with the lowest land area has the highest value. This aligns it with the rest of the risk ratings/scores, where</td></tr>
</table>

	a lower number corresponds to lower risk, and a higher number corresponds to higher risk
Unemployment	- Formula: o Employment + Unemployment = Labour Force ▪ Unemployment Rate = (labour force rate * population 2020 – Employment)/labour force rate * population 2020 - Lowest value means lowest unemployment rates - Highest value means highest unemployment rates
Cost of Living	- The cost of living is determined by dividing the temporary housing cost per household per month in a particular region by the corresponding median household income of that region (i.e. Cost of Living = Temporary housing cost (per household per month) / Median Household Income (monthly)) - The lower the value, the lower the cost of living in this region, which is advantageous from the program's perspective (we will bear lower costs).

The scores for each risk category were determined for each region and are seen in the table below. Finally, each individual risk category was weighted according to the following formula, to yield the overall risk ratings of each region.

Risk Rating = 0.025 * Injuries + 0.025 * Fatalities + 0.4 * Average Property Damage + 0.15 * Population Density + 0.1 * Land Area + 0.05 * Unemployment + 0.25 * Cost of Living in the case of Involuntary Relocation

Region	Injuries	Fatalities	Average Property Damage	Population Density	Land Area	Unemployment	Cost of Living (Involuntary Relocation)	Risk Rating	Rank (1 equals least risky, 6 equals most risky)
1	0.000139	0.000059	0.205	2.58	6.297	26.82%	0.059	1.127	4
2	0.000536	0.000151	2.762	1.19	4.367	39.38%	0.067	1.756	6
3	0.000413	0.000097	0.279	2.12	6.535	37.99%	0.066	1.119	3
4	0.000914	0.000239	0.344	0.29	4.473	48.65%	0.084	0.674	1
5	0.003291	0.000105	1.513	0.61	7.441	44.95%	0.065	1.480	5
6	0.001380	0.000214	0.126	0.19	9.883	58.17%	0.063	1.112	2

Appendix 10 – Voluntary and Involuntary Costs as a % of GDP

	Voluntary Costs as a % of GDP			
	SSP1– 2.6	**SSP2–3.4**	**SSP3–6.0**	**SSP5–Baseline**
2020	0.00000%	0.00000%	0.00000%	0.00000%
2025	0.04749%	0.04749%	0.04749%	0.04749%
2050	0.01792%	0.01792%	0.01792%	0.01792%

	Involuntary Costs as a % of GDP			
	SSP1– 2.6	**SSP2–3.4**	**SSP3–6.0**	**SSP5–Baseline**
2020	0.04797%	0.04797%	0.04797%	0.04797%
2025	0.05444%	0.05444%	0.05444%	0.05444%
2050	0.17215%	0.30114%	0.74790%	2.21327%

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