# ECONOMIC ANALYSIS

1. Tonga is one of the most isolated countries in the Pacific Region. Its population of 103,036 inhabits 48 of its 176 islands.[1] Approximately 73% of the population lives on the main island of Tongatapu, where the capital city Nuku'alofa is located. The services sector accounts for approximately 60% of total gross domestic product (GDP), while agriculture and industry each account for approximately 20%.

2. Tonga is located within the "Ring of Fire" in the Pacific Ocean. Most of its atoll islands, including Tongatapu, are flat with an average altitude of 2–5 meters. The country is very vulnerable to storm surges accompanying tropical cyclones, tsunami inundation, and flooding resulting from heavy rainfall. A 1999 study, which examined the vulnerability of 111 countries to the effects of natural disasters, ranked Tonga as being "very vulnerable." In the 25 years prior to 1999, Tonga was the second most affected country (as percentage of population) by natural disasters of all the countries in the study.[2] Since the 1960s, four cyclones (in statistical terms, approximately one per decade) have very severely affected Tonga, causing extensive damage to crops and food supply, buildings (residential and commercial), tourist resorts, and infrastructure (electricity supply and roads); and disrupted essential services.[3] Tropical cyclones Isaac (1982) and Waka (2001) resulted in seven fatalities. Estimates of damage caused range from approximately $20 million (1982) to $48 million (2001), representing in excess of 20% of GDP in those 2 years.[4] Over the last 100 years, 21 tsunamis have impacted Tonga.[5] The 2009 Niuatoputapu Tsunami caused approximately $10 million of damage, in addition to nine fatalities and six serious injuries. According to the Pacific Catastrophe Risk Assessment and Financing Initiative, Tonga is expected to incur, on average, $18.7 million in annual losses (direct and emergency losses) due to earthquakes, tsunamis, and cyclones, in addition to 34 casualties (fatalities and injuries).[6]

## A. Economic Analysis

3. An economic analysis was conducted on two subprojects: (i) Hahake Coastal Protection and Evacuation Roads, (ii) Mangrove Improvement and Rehabilitation, and (iii) Early Warning System Enhancement (EWS). It should be noted that, while the capital and operational costs of the EWS sub-project were included in the computation of the total project cost, no benefit estimate was derived for the EWS due to limited information available, and as a result is likely to underestimate the total benefits of the project presented under this analysis. For each subproject, costs and benefits are estimated by comparing the with-project and without–project scenarios during 2013–2037 in constant 2013 prices. The without-project scenario represents a continuation of the existing situation taking into account population growth, while the with-project scenario represents the project investment scenario. Both scenarios include estimates of losses (in probabilistic terms) from potential cyclones and tsunamis, which may affect the country as

[1] Statistics Department Tonga. 2011. *Tonga National Population and Housing Census 2011*. Nuku'alofa.
[2] J. P. Atkins et al. 1999. Small States: A Composite Vulnerability Index. Advisory Board to the Joint Commonwealth Secretariat and World Bank Task Force Conference on Small States, St. Lucia, West Indies.
[3] Cyclone Flora (1961), Cyclone Isaac (1982), Cyclone Waka (2001), and Cyclone Renee (2010).
[4] Ministry of Environment and Climate Change, Government of Tonga. 2010. *Joint National Action Plan on Climate Change Adaptation and Disaster Risk Management 2010–2015*. Nuku'alofa.
[5] Jayavanth et al. 2009. Disaster and Emergency Preparedness in Tonga. *Southeast Asian Journal of Tropical Medicine and Public Health*. 40. pp. 31–40.
[6] Pacific Catastrophe Risk Assessment and Financing Initiative, Secretariat of the Pacific Community http://pacrisk.sopac.org.

presented in *Tonga's Catastrophe Risk Profile* (refer footnote 6). Avoided losses and casualties represent the bulk of the estimated benefits of the subprojects.

## B. Economic Costs and Benefits

4. The economic cost of the project is divided into capital and operating costs. The financial capital costs of each subproject are converted into economic terms by applying the general conversion factor (GCF) to actual cost. This ratio is applied to the constant price financial values in project analysis to derive the corresponding economic values. The GCF removes taxes, subsidies, and other distortions. Equipment and machinery required for the subprojects are assumed to be exempt from taxes and duties. Taking into account indirect taxes, the GCF is considered to be 0.9.[7] Labor market statistics are noted to be weak: employment statistics were last compiled in 2003.[8] Unofficial sources have presented estimates of unemployment reaching approximately 13%[9] with an additional large share of underemployment.[10] For the purpose of this economic analysis, a shadow wage rate of 0.9 is used to convert domestic financial labor costs into economic costs. The residual value of all equipment and infrastructure at the end of the analysis time horizon is assumed to be zero.

## C. The Subprojects

### 1. Hahake Coastal Protection and Evacuation Roads

5. Much of the northern coastline of Hahake in Tongatapu is eroding. Roads in the villages of Kolonga, Manuka, and Nukuleka are especially exposed to coastal erosion. Low-lying coastal villages with topographic elevations of less than 2 meters above sea level are currently inundated by tidal flooding.

6. The Hahake coastal protection investment entails the construction of a mix of infrastructure along the coastline from Manuka to Nukuleka to protect communities from storm surges and tsunamis. Five villages,[11] comprising a total population of 2,169 and 372 households in 2011, will benefit from this investment (refer footnote 1). The evacuation roads investment entails the construction of two new roads, which will facilitate the evacuation of coastal populations prior to the landfall of tropical cyclones and tsunamis. Four villages,[12] comprising a total population of 3,342 and 557 households in 2011 (refer footnote 1), will benefit from this investment. Two villages (Navutoka and Talafo'ou) will benefit from both investments. Thus, seven villages with a total population of 4,336 and 725 households will benefit from this subproject.

7. For the cost–benefit analysis, the coastal protection and evacuation road investments are combined into one subproject. The rationale is that while an important benefit of these two investments is the saving of lives, existing data and information prevents attributing saved lives to any single one of these investments.

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7 This same conversion factor was recently used in the economic analyses of two recent projects approved in Tonga (ADB. 2013. Report and Recommendation of the President to the Board of Directors: *Proposed Grant to Tonga for Outer Island Renewable Energy Project*. Manila; ADB. 2011. Report and Recommendation of the President to the Board of Directors: *Proposed Grant to Tonga for Nuku'alofa Urban Development Sector Project*. Manila).
8 International Monetary Fund. 2013. *Tonga Article IV Consultation*. Washington, DC.
9 http://www.indexmundi.com/tonga/unemployment_rate.html.
10 Index mundi. Tonga Unemployment Rate. http://www.indexmundi.com/tonga/unemployment_rate.html.
11 Makaunga, Manuka, Navutoka, Nukuleka and Talafo'ou.
12 Navutoka, Popua, Talafo'ou, and Tufuvai.

8. The following five types of benefits are accounted for: (i) avoided damage to residential buildings, (ii) avoided damage to roads, (iii) avoided damage to crops, (iv) reduced public expenditure on emergency and relief operations, and (v) saved statistical lives. The national expected average annual losses (AAL) are presented in the Tonga Catastrophe Risk Profile based on population and socioeconomic characteristics prevailing in 2010. These estimated AAL were scaled down for the seven villages in proportion to their population, number of households, and crop areas. They were then adjusted to 2013 prices using inflation rates,[13] and then kept constant in real terms for 2013–2037. To estimate benefits, an annual population growth rate of 0.6%[14] is assumed from 2011 to 2013, and the same growth rate is then assumed for 2013–2037. Finally, the evacuation roads will reduce travelling time for village residents to the capital city, Nuku'alofa. However, because of the lack of appropriate information, this timesaving is not included in the analysis.

9. The following unit values are estimated: (i) the expected AAL per residential building of $280 is applied to the 372 households of the five villages benefiting from coastal protection; (ii) the Tonga Ministry of Infrastructure estimates the road repair and replacement cost at $174/meter; this is applied to the 6.3 km of coastal road at risk and then multiplied by the annual probability of such repair and replacement being needed, estimated to be 10% (corresponding to a 1–in–10 year event);[15] (iii) expected AAL to crops is $14,505 per hectare (ha); this value is then applied to the number of hectares of agricultural land exposed to storm surges; (iv) expected average annual emergency expenditures (in support of relief operations following a natural disaster) are $23.77 per capita; and (v) cyclones and tsunamis are expected to result in 11 fatalities per year nationwide; this number is adjusted in proportion to the population of the seven villages to the overall population, thus representing 0.463 lives per year. For the purpose of this analysis, a value per statistical life (VSL) of $735,000 is used (Box 1).

**Box 1: Estimating Value of Statistical Life in Tonga: A Benefit–Transfer Approach**

Kochi et al. (2006) conducted a meta-analysis of value per statistical life (VSL) studies from high-income countries drawing on 18 contingent valuation studies and 42 hedonic wage studies.[a] The authors report a VSL of $5.4 million (base year equals 2000) with a standard deviation of $2.4 million. Cropper and Sahin then used this value to perform a benefits transfer exercise to estimate VSL in developing countries.[b] As noted by the authors, if risk preferences, discount rates, and survival probabilities were the same in all countries, then the VSL should simply be proportional to income. Under these assumptions, one could assess the VSL in Tonga as a proportion of the VSL in high-income countries ($5.4 million), where the proportion is estimated by the ratio of GDP per capita in Tonga and the United States (US) (selected as a representative of high-income countries):

$$VSL_{Tonga} = VSL_{USA} * (\frac{Y_{Tonga}}{Y_{USA}})^{\varepsilon}$$

Where $Y_{Tonga}$ and $Y_{USA}$ stands for gross domestic product (GDP) per capita measured in purchasing power parity terms in Tonga and the US respectively, and $\varepsilon$ stands for income elasticity. While noting that it is common practice to assume an income elasticity of 1, income elasticity could be greater than 1 as a result of differences in attitudes toward risk, discount rates, and survival probabilities that may be correlated with income.

To estimate a VSL in Tonga, a number of steps are required. First, the reported $5.4 million is measured in dollars (base year equals 2000). Using the US GDP deflator available in the *World Development Indicators Database*, this

[13] ADB. 2012. *Tonga Economic Update and Outlook 2012*. Manila.

[14] The ADB Economic Outlook 2013 reports a population growth rate of 0.4% (footnote 1), while the Tonga Statistics Office reports growth of 0.8%. A midpoint estimate was used in the economic analysis.

[15] On a decadal basis, trend in the occurrence of tropical cyclones in Tonga has been increasing, from 7 during 1960–1969 to 15 during 2000–2009 (refer footnote 6) Hence, the assumed 10% probability may be an underestimate of the existing and future true probability of occurrence.

figure amounts to approximately $7.02 million in 2013. Second, GDP per capita must be measured in PPP. The International Monetary Fund's *World Economic Outlook Database 2012* reports a GDP per capita of $49,922 for the US and $7,548 for Tonga. This provides a GDP per capita ratio of 0.151. Finally is the issue of income elasticity. Following the recommendations and example presented in Cropper and Sahin (2009), income elasticities of 1.0 and of 1.5 are used. With an income elasticity of 1.0, VSL Tonga is estimated to be $1.06 million, and to be $410,000 with an income elasticity of 1.5. As there is no indication as to which of these values may be more appropriate, a simple arithmetic mean provides a VSL of $737,000. For purpose of this analysis, a VSL of $735,000 is used in Tonga.[c]

[a] I. Kochi et al. 2006. An empirical Bayes approach to combining and comparing estimates of the value of a statistical life for environmental policy analysis. *Environmental and Resource Economics*. 34. pp. 385–406.

[b] M. Cropper and S. Sahin. 2009. *Valuing Mortality and Morbidity in the Context of Disaster Risks*, Working Paper 4832, Development Research Group, World Bank. The point estimates from the studies were adjusted weighting the VSL estimates in inverse proportion to their precision.

[c] As a result of high remittances, income per capita in Tonga is considerably higher than GDP per capita. In FY2012, remittances amounted to 15% of GDP (ADB. 2013. *Asian Development Outlook 2013*. Manila). As a result, the VSL used in this analysis may be an underestimate of the true VSL in Tonga (which only an original analysis conducted in Tonga could reveal).

Source: Asian Development Bank

### 2. Early Warning System

10. Early warning systems (EWSs) have been subjected to several economic analyses around the world and in Asia in particular. The benefits include direct tangible benefits (in the form of damage avoided by households and various sectors due to appropriate responses by utilizing the lead time provided by the early warning) as well as indirect tangible benefits such as avoidance of production losses, relief and rehabilitation costs, and costs involved in providing such services. All show high economic returns, with the benefit–cost ratio ranging from 7.33 (Fiji) to 558 (Bangladesh). A key factor explaining these results is that EWSs are cost–effective ways of saving lives, preventing injuries, and reducing damage to assets and infrastructure associated with extreme events.

11. The cost of an EWS includes two broad components: (i) scientific*:* input costs for technical institutions required to generate forecast information; and (ii) institutional: costs of training and other capacity development required for institutions to be able to use forecast information, especially to facilitate its use at lower levels.

12. For the purpose of economic analysis, no estimate benefits were imputed to this sub-project as it was not possible to provide reliable estimates of avoided casualties (injuries and fatalities) which may result from the EWS. Hence, it is believed that the estimated net present value and economic rate of return reported below may be significant under-estimates of the true impacts of the project. It should also be mentioned that the EWS to be implemented in Tonga is expected to provide data to all countries of the region – these regional benefits were also not included in the analysis.

### 3. Mangrove Rehabilitation

13. Coastal zones are already under considerable pressure. An increasing population, together with rapid urbanization are creating a demand for access to coastal zones for a range of uses—notably land reclamation, coastal stabilization, clearing of mangroves, mining of construction materials (including sand), and waste disposal—all of which threaten to destabilize beaches and coasts.

14. The subproject is expected to support improvements and rehabilitation of at least 40% of the 318.7 ha of mangrove wetlands on the island of Tongatapu. Estimates of the economic

value of mangroves are not available in Tonga. However, two published papers have reported such values based on meta–analysis. Both papers report median values ranging from $500 to $15,000/ha per year. Salem and Mercer (2012) report median values of $627/ha per year for fisheries and $576/ha per year for forestry. The economic value of the coastal protection provided by mangroves is estimated to be $3,604/ha per year. For this economic analysis, a conservative estimate of approximately $1,500/ha per year is used to estimate the benefits of the subproject.

15. The total cost of the subproject includes (i) international technical assistance to develop the framework of a national mangrove inventory; (ii) domestic experts to implement the survey; (iii) education and awareness activities in support of local communities to effectively manage mangrove plantations; and (iv) development and implementation of a mangrove planting, monitoring, and evaluation system.

## D. Results

16. Table 1 presents estimated costs and benefits of the project as a whole. The net present value (NPV) of the three subprojects is approximately $(0.106) million, with an internal rate of return of approximately 11.7%, and a benefit–cost ratio of 0.98. It should again be noted that the cost of the EWS are included due to difficulties in reliably estimating the same. Taken separately, the estimated NPV of the coastal protection and evacuation road is $1.315 million and of the mangrove rehabilitation is $0.386 million.

17. Two sensitivity test cases were examined: (i) total costs increased by 20%; and (ii) total benefits reduced by 20%. In both cases, the project becomes economically unfeasible, but it is again noted that the benefits of the EWS have been excluded from the analysis. The EWS is estimated to need to save at least 0.39 statistical lives annually (out of the estimated 5.33 estimated annual statistical lives lost in the absence of the project) for the entire project to realize a positive NPV (and a rate of return of 12%).

**Table 1. Economic Costs and Benefits of Three Subprojects of the Climate Resilience Sector Project** ($'000)

| | Benefits | | | Costs | | | Net benefits |
|---|---|---|---|---|---|---|---|
| | Coastal and road | Mangrove | Total benefits | Capex | Opex | Total costs | |
| 2013 | 0 | 0 | 0 | 1,745.2 | 0 | 1,745.2 | (1,745.2) |
| 2014 | 0 | 0 | 0 | 3,974.9 | 0 | 3,974.9 | (3,974.9) |
| 2015 | 706.3 | 0 | 706.3 | 0 | 199.7 | 199.7 | 0.506 |
| 2016 | 709.8 | 0 | 709.8 | 0 | 93.5 | 93.5 | 0.616 |
| 2017 | 713.3 | 0 | 713.3 | 0 | 62.8 | 62.8 | 0.650 |
| 2018 | 716.8 | 137.0 | 853.8 | 0 | 50.1 | 50.1 | 0.803 |
| 2019 | 720.3 | 137.0 | 857.3 | 0 | 50.1 | 50.1 | 0.807 |
| 2020 | 723.9 | 137.0 | 860.9 | 0 | 50.1 | 50.1 | 0.810 |
| 2021 | 727.5 | 137.0 | 864.5 | 0 | 50.1 | 50.1 | 0.814 |
| 2022 | 731.1 | 137.0 | 868.1 | 0 | 50.1 | 50.1 | 0.818 |
| 2023 | 734.7 | 137.0 | 871.7 | 0 | 50.1 | 50.1 | 0.821 |
| 2024 | 738.4 | 137.0 | 875.4 | 0 | 50.1 | 50.1 | 0.825 |
| 2025 | 742.1 | 137.0 | 879.1 | 0 | 50.1 | 50.1 | 0.829 |
| 2026 | 745.7 | 137.0 | 882.7 | 0 | 50.1 | 50.1 | 0.833 |
| 2027 | 749.5 | 137.0 | 886.5 | 0 | 50.1 | 50.1 | 0.836 |
| 2028 | 753.2 | 137.0 | 890.2 | 0 | 50.1 | 50.1 | 0.840 |
| 2029 | 756.9 | 137.0 | 893.9 | 0 | 50.1 | 50.1 | 0.844 |
| 2030 | 760.7 | 137.0 | 897.7 | 0 | 50.1 | 50.1 | 0.847 |
| 2031 | 764.5 | 137.0 | 901.5 | 0 | 50.1 | 50.1 | 0.851 |
| 2032 | 768.4 | 137.0 | 905.4 | 0 | 50.1 | 50.1 | 0.855 |
| 2033 | 772.2 | 137.0 | 909.2 | 0 | 50.1 | 50.1 | 0.859 |
| 2034 | 776.1 | 137.0 | 913.1 | 0 | 50.1 | 50.1 | 0.863 |
| 2035 | 780.0 | 137.0 | 917.0 | 0 | 50.1 | 50.1 | 0.867 |
| 2036 | 783.9 | 137.0 | 920.9 | 0 | 50.1 | 50.1 | 0.871 |
| 2037 | 787.9 | 137.0 | 924.9 | 0 | 50.1 | 50.1 | 0.875 |
| **PV** | 4,489.7 | 580.6 | 5,070.3 | 4,726.9 | 449.5 | 5,176.5 | |
| **NPV** | | | | | | | **(0.106)** |
| **IRR** | | | | | | | **11.7%** |
| **B/C** | | | | | | | **0.98** |

( ) = negative value; B/C = benefit cost ratio; EWS = early warning system; IRR = internal rate of return; NPV = net present value; PV = present value
Source: Asian Development Bank

**Table 2. Sensitivity Analysis**

| | NPV ($ million) | EIRR (%) | B/C |
|---|---|---|---|
| Base case | -0.106 | 11.7 | 0.98 |
| 20% increase in costs | -1.141 | 9.23 | 0.82 |
| 20% decrease in benefits | -1.12 | 8.71 | 0.78 |

B/C = benefit cost ratio; EIRR = economic internal rate of return; NPV = net present value
Source: Asian Development Bank